# COMPARISON OF HORNER 4, OHXF 87 AND OHXF 97 ROOTSTOCKS UNDER VARYING GROWING CONDITIONS AND CULTURAL PRACTICES IN LAKE COUNTY, CALIFORNIA

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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). 2014 was the tenth season of the 10-year trial and the final year of formal data collection. After ten years (2005 – 2014) Bartlett on the open pollinated OHxF[1] selection Horner 4 consistently had the largest fruit (197 grams average), yielded 41% or more than the next highest yielding rootstocks were nearly twice as large as others, with similar yield efficiencies despite being the largest trees. For 'Golden Russet' Bosc, Horner 4 trees were largest and had the largest fruit in the final year of the trial, but lower yield efficiency than other rootstocks, suggesting it may be better suited to less vigorous Bartlett. There were very few, if any, root suckers. Horner 4 was also the least water stressed rootstock, most likely to attain baseline values of -6 - -8 bars mid-day stem water potential (MSWP), the suggested baseline for fully-watered trees (Shackel 2007). Increasing (positive) MSWP was significantly and positively correlated with fruit size, TCSA, and yield efficiency. Based on positive results, a series of four replicated trials was planted in 2016 in the Kelseyville (Big Valley) growing area of Lake County, California to compare Horner 4 versus OHxF 87 and OHxF 97 rootstocks on a range of soil types and cultural practices. After four growing seasons (2016 - 2019), Horner 4 were significantly largest trees based on both TCSA and height (15.0 $cm^2$ TCSA ,244 cm tall). followed by OHxF 97 (12.4 $cm^2$, 222 cm tall), then OHxF 87 (9.5 $cm^2$,203 cm tall). OHXF 97 had the most fruit and highest yield and yield efficiency in the first orchard evaluated for productivity (11.1 fruit, 196 gm per fruit, 2.2 kg/tree, 0.19 yield efficiency). Tree growth, (potential) flowering and fruiting, and MSWP data will continue in 2020.

## 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®)[1] series offers several potential options that are now becoming more widely planted. 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 smaller 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; Reed 2011; Elkins, Bell and Einhorn 2012).

The North Central Regional Research Project NC-140 (*www.NC140.org*) is a federally (NIFA)-supported, multi-state rootstock project focused on perennial tree fruit crops. The goal of NC-140 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 growers and nurseries who can then select rootstocks suitable to their location and customer base. All Regional projects must be re-authorized every five years; the NC-140 2017-2022 continuing 5-year proposal accepted by the North Central Regional Association (NCRA) of State Agricultural Experiment Station Directors is available on the NC-140 website. 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 2005 NC-140 trials were the only **bearing *replicated*** rootstock trials in California. The ultimate objective of these, as with all NC-140 and other rootstock trials, was to select the best potential available candidates for future increased propagation and industry use. The information they have provided has already contributed to future nursery and grower planting decisions, particularly for new, high density planting systems.

After ten years (2005 – 2014) Bartlett on the open pollinated OHxF[1] selection Horner 4 consistently had the largest fruit (197 grams average), yielded 41% or more than the next highest yielding rootstocks were nearly twice as large as others, with similar yield

efficiencies despite being the largest trees. For 'Golden Russet' Bosc, Horner 4 trees were largest and had the largest fruit in the final year of the trial, but lower yield efficiency than other rootstocks, suggesting it may be better suited to less vigorous Bartlett. There were very few, if any, root suckers. Horner 4 was also the least water stressed rootstock, most likely to attain baseline values of -6 - -8 bars mid-day stem water potential (MSWP), the suggested baseline for fully-watered trees (Shackel 2007). Increasing (positive) MSWP was significantly and positively correlated with fruit size, TCSA, and yield efficiency.

[1]The male parent of this series has now been shown to be Bartlett (Postman et al. 2013).

Based on positive results from 2005-2014, efforts were made to propagate a greater number of Horner 4 trees to test Horner 4 under varying grower conditions (soil type, nutritional challenges, microclimates), culminating in planting four replicated trials (all Bartlett scion) in the Big Valley (Finley-Kelseyville) growing area of Lake County in spring 2016. Comparison rootstocks were OHxF 97 and OHxF 87.

## OBJECTIVES

- Early and consistent production;
- Vigor and production on a range of (heavier) soil types;
- Compatibility with organic production (two orchards)
- Usefulness as an interplant to replace the vigorous but non-precocious *P. betulaefolia* (being phased out by nurseries).

## PROCEDURES

*Trial locations and descriptions:* all Bartlett, sprinkler irrigated

1) D&S (conventional; omit 87); 12.5' x 12.5', interplanted; Cole clay loam, Still loam (stratified);
2) Henderson (organic); 12' x 6', interplanted; Cole clay loam;
3) Lone Pine (organic); 12' x 12', open ground, replanted; Cole clay loam;
4) Neck (conventional); 12.5' x 6', interplanted; Still loam, stratified; Landlow Variant silty clay loam.

Budded trees from hardwood cuttings were obtained from Sierra Gold Nursery (Yuba City, California) and planted April 4-27, 2016.

*Design:* Randomized complete block, each plot consisting of 15 trees (10 in one case) (5 each of 3 (2 in one case) rootstocks) Blocking varies with location.

## Data Collection

*Tree survival, growth and vigor (2016-2019):* Percent surviving trees was determined. Tree height and cultivar trunk cross-sectional area (TCSA) 10 cm. above the graft union were measured. Root suckers were counted. Mid-day stem water potential (MSWP) measurements were omitted in 2019 due to lack of staffing.

## Data summarization and analysis

Data was analyzed using ANOVA and means separated using Tukey HSD test, $p \leq 0.05$ (root suckers by Duncans MRT, $p \leq 0.10$) (Statgraphics Centurion XVII, StatPoint Technologies, Warrenton, VA).

## 2017-2019 RESULTS

***Tree survival, growth, and vigor*** (Tables 2-11)*:* There were no differences in cumulative % survival; Horner 4 lost no trees, OHxF 97 one, and OHxF 87 three. Across all four orchards, there was a slight trend ($p$ = 0.14) in TCSA, with Horner 4 increasing most (47.4%), followed by OHxF 97 (44.1%), and OHxF 87 least (39.7%). Horner 4 trees were significantly largest (15.0 $cm^2$ TCSA, 244 cm tall), followed by OHxF 97 (44.1 $cm^2$, 222 cm tall), then OHxF 87 (9.5 $cm^2$, 203 cm tall). Horner 4 was significantly taller than the two OHxF rootstocks, which were equal.

Results for each location were:

*D&S (Horner 4 and OHxF 97 only)*: No additional trees died in 2019; cumulative survival rate was 91% for Horner 4 and 100% for OHxF 97. OHxF 97 trees outgrew Horner 4 in 2019 at this site. While TCSAs were statistically equal, OHxF 97 growth rate increased 53%, versus 39% for Horner 4, and OHxF 97 trees were larger at the end of the season (OHxF 97 12.9 $cm^2$, 220 cm tall vs Horner 4 11.4 $cm^2$, 178.5 cm tall). There were no root suckers.

*Henderson*: While there were no statistical differences in survival rate, no Horner 4 trees died, while four OHxF 97 and eight OHxF 97 trees died. Horner 4 trees were significantly largest (9.0 $cm^2$ TCSA, 218.4 cm tall). OHxF 97 and OHxF 87 tree size was statistically equal, but OHxF 97 trees were larger (6.2 $cm^2$, 172.6 cm tall) than OHxF 87 (5.1 $cm^2$, 155.3 cm tall). There was a trend ($p$ =.12) toward more OHxF 97 root suckers.

*Lone Pine*: There were no survival differences (averaging one tree lost per treatment) and no additional trees died in 2019*.* Horner 4 and OHxF 97 trees were significantly larger than OHxF 87 (22.8 and 19.1 $cm^2$ TCSA and 279.7 and 260.4 cm tall vs 14.0 $cm^2$ TCSA/231.9 cm tall). There were no significant differences in root suckers.

*Neck*: Survival was 100%. Horner 4 trees were largest (16.4 $cm^2$ TCSA, 285 cm tall),

with both OHxF rootstocks statistically equal in size. There were no rootstock differences in root suckers.

***Tree productivity***: Only Neck orchard trees had sufficient fruit to statistically analyze. OHxF 97 trees had slightly more than double the fruit number of Horner 4 and OHxF 87, which had equal numbers (11.1 vs. 5.4 and 5.2, respectively). There was also a trend toward larger OHxF 97 fruit size (196 gm), followed by Horner 4 (187 gm), and OHxF 87 (171 gm), translating into a trend toward higher OHxF 97 yields vs Horner 4, significantly higher yields versus OHxF 87, and significantly higher yield efficiency than either of the other rootstocks.

## 2018-2019 DISCUSSION AND 2020 PLANS

After four growing seasons, Horner 4 trees are the largest (TCSA and/or height) in three of four orchards, with OHxF 87 consistently smallest. Some fruit was observed in variable numbers across all rootstocks in most orchards in 2019 but was sufficient to analyze in only one orchard in 2019, in which OHxF 97 had the most fruit, and highest yield and yield efficiency.

Tree growth, productivity, and MSWP measurements will continue in 2020 (Year 5).

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

| Rootstock | Origin | CA1[2] | CA2[3] | CH (MX) | NY | WA |
|---|---|---|---|---|---|---|
| 708-36 | United Kingdom | Bart, Bosc | Bart | - | Bart, Bos | - |
| BM 2000 | France | Bart, Bosc | Bart | Bart | Bart | Bosc |
| Fox 11 | France | Bart, Bosc | Bart | - | Bart | - |
| Horner 4 | Oregon | Bart, Bosc | Bart | - | Bart, Bos | Bosc |
| OHxF 69 | Australia | Bart | - | - | - | - |
| OHxF 87 | Germany | Bart, Bosc | Bart | Bart | Bart | Bosc |
| OHxF 97 | Germany | - | - | - | - | - |
| Pyrodwarf | Italy | Bart, Bosc | Bart | Bart | Bart, Bos | 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]CA1 is in Talmage, Mendocino County.
[3]CA2 was disbanded in 2009 and was in Courtland, Sacramento County.

Table 2: Average effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, and survival of 4-year-old (5th leaf), average of four orchards, 'Bartlett' pear trees, Kelseyville, California, 2019.

| Treatment[1] | Dormant TCSA ($cm^2$) 12/19-1/20 | TCSA Increase (%) 12/2019-1/2020 | Tree Height (cm) 12/19-1/20 | Survival[3] (%) 12/2019-1/2020 |
|---|---|---|---|---|
| Horner 4[4] | 15.0 a | 47.4 | 244 a | 94 |
| OHxF 87[5] | 9.5 c | 39.7 | 203 b | 89 |
| OHxF 97[4] | 12.4 b | 44.1 | 222 b | 94 |
| ANOVA (*P* -value) [2] | | | | |
| Treatment | * (<0.001) | NS (0.14) | *** (0.001) | NS (0.41) |
| Block | NS (0.18) | NS (0.51) | NS (0.65) | NS (0.65) |
| Treatment x Block | NS (0.14) | NS (0.10) | NS (0.20) | NS (0.72) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$).
[2] *, **, *** Indicates significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant.
[3] Survival data normalized using SQRT (survival+1).
[4] Average of 4 plots.
[5] Average of 3 plots.

Table 3: Average effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, and survival of 3-year-old (4th leaf), average of four orchards, 'Bartlett' pear trees, Kelseyville, California, 2018.

| Treatment[1] | Dormant TCSA ($cm^2$) 12/13/2018 | TCSA Increase (%) 12/13/2018 | Tree Height (cm) 12/13/2018 | Survival[3] (%) 12/13/2018 |
|---|---|---|---|---|
| Horner 4[4] | 10.0 a | 52.4 a | 232 a | 94 |
| OHxF 87[5] | 6.6 c | 38.4 b | 179 c | 92 |
| OHxF 97[4] | 8.4 b | 44.5 ab | 204 b | 95 |
| ANOVA (*P* -value) [2] | | | | |
| Treatment | * (<0.001) | ** (0.01) | *** (<0.001) | NS (0.71) |
| Block | NS (0.17) | NS (0.85) | NS (0.74) | NS (0.62) |
| Treatment x Block | NS (0.20) | ** (0.01) | ** (0.01) | NS (0.65) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$).
[2] **, *** Indicates significance at $P \leq 0.01$, and 0.001 respectively. NS indicates not significant.
[3] Survival data normalized using SQRT (survival+1).
[4] Average of 4 plots.
[5] Average of 3 plots.

Table 4: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, root suckers, and survival of 4-year-old (5th leaf) 'Bartlett' pear trees, D & S Orchard, Kelseyville, California, 2019.

| Treatment[1] | Dormant TCSA ($cm^2$) 12/27/2019 | TCSA Increase[3] (%) 12/27/2019 | Tree Height (cm) 12/27/2019 | Root Suckers (no./tree) 12/27/2019 | Survival (%) 12/27/2019 |
|---|---|---|---|---|---|
| Horner 4 | 11.4 | 39.0 | 178.5 b | 0.0 | 91 |
| OHxF 97 | 12.9 | 53.0 | 219.7 a | 0.0 | 100 |
| ANOVA (*P* -value) [2] | | | | | |
| Treatment | NS (0.19) | ** (0.01) | *** (<0.001) | ~ | NS (0.16) |
| Block | NS (0.24) | NS (0.11) | *** (<0.001) | ~ | NS (0.64) |
| Treatment x Block | NS (0.86) | NS (0.51) | *** (<0.001) | ~ | NS (0.63) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$).
[2] * Indicates significance at $P \leq 0.05$. NS indicates not significant.
[3] 2018 to 2019 increase. Tree heights over 10' were analyzed as 10' 0 '.

Table 5: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, root suckers, and survival of 3-year-old (4th leaf) 'Bartlett' pear trees, D&S Orchard, Kelseyville, California, 2018.

| Treatment[1] | Dormant TCSA ($cm^2$) 12/13/2018 | TCSA Increase[3] (%) 12/13/2018 | Tree Height (cm) 12/13/2018 | Root Suckers (no./tree) 12/13/2018 | Survival (%) 12/13/2018 |
|---|---|---|---|---|---|
| Horner 4 | 8.4 | 56.1 | 202.7 | 0.1 | 91 |
| OHxF 97 | 8.4 | 56.0 | 214.7 | 0.0 | 100 |
| ANOVA (*P* -value) [2] | | | | | |
| Treatment | NS (0.92) | NS (0.98) | NS (0.41) | NS (0.06) | NS (0.16) |
| Block | NS (0.08) | NS (0.69) | * (0.05) | NS (0.31) | NS (0.64) |
| Treatment x Block | NS (0.17) | NS (0.12) | * (0.05) | NS (0.07) | NS (0.63) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$).
[2] * Indicates significance at $P \leq 0.05$. NS indicates not significant.
[3] 2017 to 2018 increase.

Table 6: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, and survival of 4-year-old (5th leaf) 'Bartlett' pear trees, Kelseyville, California, 2019.

| Treatment[1] | Dormant TCSA ($cm^2$) 12/27/2019 | TCSA Increase[3] (%) 12/27/2019 | Tree Height (cm) 12/27/2019 | Root Suckers[4] (no./tree) 12/27/2019 | Survival (%) 12/27/2019 |
|---|---|---|---|---|---|
| Horner 4 | 9.0 a | 24.7 | 218.4 a | 0.08 | 92 |
| OHxF 87 | 5.1 b | 19.7 | 155.3 b | 0.01 | 80 |
| OHxF 97 | 6.2 b | 22.1 | 172.6 b | 0.19 | 84 |
| ANOVA (*P* -value) [2] | | | | | |
| Treatment | (<0.001) | NS (0.61) | *** (<0.001) | NS (0.12) | NS (0.48) |
| Block | NS (0.59) | NS (0.85) | NS (0.38) | NS (0.18) | NS (0.34) |
| Treatment x Block | * (0.02) | NS (0.67) | ** (0.01) | NS (0.27) | NS (0.79) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$, TCSA % increase $P \leq 0.10$).

[2] *' **, *** Indicates significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant.

[3] 2018 to 2019 increase.

[4] Root sucker data normalized, SQRT (root suckers+1.0) for *P* -values.

Table 7: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, and survival of 3-year-old (4th leaf) 'Bartlett' pear trees, Henderson Orchard, Kelseyville, California, 2018.

| Treatment[1] | Dormant TCSA ($cm^2$) 12/13/2018 | TCSA Increase[3] (%) 12/13/2018 | Tree Height (cm) 12/13/2018 | Survival (%) 12/13/2018 |
|---|---|---|---|---|
| Horner 4 | 7.1 a | 24.3 | 187.0 a | 92 |
| OHxF 87 | 4.0 c | 20.0 | 139.2 b | 88 |
| OHxF 97 | 5.1 b | 25.9 | 153.0 ab | 88 |
| ANOVA (*P* -value) [2] | | | | |
| Treatment | (<0.001) | NS (0.64) | ** (0.004) | NS (0.87) |
| Block | NS (0.24) | NS (1.00) | NS (0.59) | NS (0.18) |
| Treatment x Block | ** (0.01) | NS (0.07) | * (0.04) | NS (0.31) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$, TCSA % increase $P \leq 0.10$).

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

[3] 2017 to 2018 increase.

Table 8: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, root suckers, and survival in 4-year-old (5th leaf) "Bartlett" pear trees, Lone Pine Orchard, Kelseyville, California, 2019.

| Treatment[1] | TCSA ($cm^2$) 1/8-9/2019 | TCSA Increase[3] (%) 1/8-9/2019 | Tree Height (cm) 1/8-9/2019 | Root Suckers (no./tree) 1/8-9/2019 | Survival (%) 1/8-9/2019 |
|---|---|---|---|---|---|
| Horner 4 | 22.8 a | 52.5 | 279.7 a | 3.0 | 92 |
| OHxF 87 | 14.0 b | 43.0 | 231.9 b | 2.6 | 88 |
| OHxF 97 | 19.1 a | 46.9 | 260.4 ab | 2.3 | 92 |
| ANOVA (*P* -value) [2] | | | | | |
| Treatment | *** (<0.001) | NS (0.44) | ** (0.01) | NS (0.73) | NS (0.85) |
| Block | NS (0.09) | NS (0.29) | NS (0.30) | NS (0.74) | NS (0.47) |
| Treatment x Block | NS (0.08) | NS (0.17) | NS (0.14) | NS (0.51) | NS (0.11) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$).
[2] **, *** Indicate significance at $P \leq 0.01$ and 0.001 respectively. NS indicates not significant.
[3] 2018 to 2019 increase. Tree heights over 10' were analyzed as 10' 0 '.

Table 9: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, root suckers, and survival of 3-year-old (4th leaf) 'Bartlett' pear trees, Lone Pine Orchard, Kelseyville, California, 2018.

| Treatment[1] | TCSA ($cm^2$) 12/13/18 | TCSA Increase[3] (%) 12/13/18 | Tree Height (cm) 12/13/18 | Root Suckers (no./tree) 12/13/18 | Survival (%) 12/13/18 |
|---|---|---|---|---|---|
| Horner 4 | 15.0 a | 61.1 | 272.3 a | 1.0 | 92 |
| OHxF 87 | 9.8 b | 57.9 | 209.6 b | 1.3 | 88 |
| OHxF 97 | 12.9 a | 55.5 | 232.5 b | 0.5 | 92 |
| ANOVA (*P* -value) [2] | | | | | |
| Treatment | *** (<0.001) | NS (0.86) | *** (0.001) | NS (0.09) | NS (0.85) |
| Block | NS (0.29) | NS (0.25) | NS (0.46) | NS (0.53) | NS (0.47) |
| Treatment x Block | NS (0.13) | NS (0.08) | NS (0.07) | NS (0.33) | NS (0.11) |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$).
[2] *, *** Indicate significance at $P \leq 0.05$ and 0.001 respectively. NS indicates not significant.
[3] 2017 to 2018 increase.

Table 10: Effect of 2016 pear rootstock planting on fruit number and size, yield, yield efficiency, trunk cross-sectional area (TCSA), tree height, number of root suckers, and survival in 4-year-old (5th leaf) "Bartlett" pear trees, Neck Orchard, Kelseyville, California, 2019.

| Treatment[1] | Fruit No. per tree 9/2/2019 | Size (g.) 9/2/2019 | Yield (kg/tree) 9/2/2019 | Yield Efficiency ($kg/cm^2$) | TCSA ($cm^2$) 12/27/2019 | TCSA Increase[3] (%) 12/27/2019 | Tree Height (cm) 12/27/2019 | Root Suckers[4] (no./tree) 12/27/2019 | Survival (%) 12/27/2019 |
|---|---|---|---|---|---|---|---|---|---|
| Horner 4 | 5.4 b | 187 | 1.2 ab | 0.07 b | 16.4 a | 70.1 a | 285 a | 0.12 | 100 |
| OHxF 87 | 5.2 b | 171 | 0.9 b | 0.09 b | 9.6 b | 53.3 b | 219 b | 0.04 | 100 |
| OHxF 97 | 11.1 a | 196 | 2.2 a | 0.19 a | 11.1 b | 50.4 b | 233 b | 0.00 | 100 |
| ANOVA (*P* -value)[2] | | | | | | | | | |
| Treatment | ** (0.01) | NS (0.09) | ** (0.01) | *** (0.001) | *** (<0.001) | * (<0.001) | * (<0.001) | NS (0.32) | ~ |
| Block | NS (0.34) | NS (0.54) | NS (0.40) | NS (0.29) | *** (<0.001) | * (0.03) | ** (0.01) | NS (0.69) | ~ |
| Treatment x Block | NS (0.88) | ***(<0.001) | NS (0.71) | NS (0.43) | *** (<0.001) | ** (0.002) | ** (0.001) | NS (0.47) | ~ |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$), n=25.
[2] *, **, *** Indicates significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant.
[3] Root sucker data normalized, SQRT (root suckers+1.0) for *P* -values.
[4] 2018 to 2019 increase. Tree heights over 10' were analyzed as 10' 0 '.

Table 11: Effect of 2016 pear rootstock planting on trunk cross-sectional area (TCSA), tree height, and survival in 3-year-old (4th leaf) "Bartlett" pear trees, Neck Orchard, Kelseyville, California, 2018.

| Treatment[1] | TCSA ($cm^2$) 12/13/2018 | TCSA Increase[3] (%) 12/13/2018 | Tree Height (cm) 12/13/2018 | Root Suckers (no./tree) 12/13/2018 | Survival (%) 12/13/2018 |
|---|---|---|---|---|---|
| Horner 4 | 9.7 a | 68.9 ab | 259.1 a | 0.1 | 100 |
| OHxF 87 | 6.2 b | 39.7 b | 189.2 b | 0.0 | 100 |
| OHxF 97 | 7.4 b | 39.2 b | 211.8 b | 0.0 | 100 |
| ANOVA (*P* -value)[2] | | | | | |
| Treatment | * (<0.001) | ** (<0.001) | *** (<0.001) | NS (0.37) | ~ |
| Block | * (<0.001) | *** (0.001) | *** (<0.001) | NS (0.41) | ~ |
| Treatment x Block | ** (0.01) | * (0.02) | * (0.04) | NS (0.45) | ~ |

[1] Within columns, treatment means significantly different (Tukey HSD, $P \leq 0.05$), n=25.
[2] *, **, *** Indicates significance at $P \leq 0.05$, 0.01, and 0.001 respectively. NS indicates not significant.
[3] 2017 to 2018 increase.