HIGH DENSITY ORCHARD SYSTEMS FOR EUROPEAN PEAR: 2013 NC-140 REGIONAL ROOTSTOCK PROJECT (2019 Progress Report) I. Overall training systems, spacing, and rootstocks

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ABSTRACT

The California pear industry has shrunk considerably in the past two decades, both in number of growers and total acreage (USDA-NASS 2020 and 2014; Elkins, Bell and Einhorn 2012). Remaining growers are considering replanting options or have already replanted small acreages. In coordination with Oregon State University (OSU) and Cornell University, three replicated trials were established in Spring 2013 in Mendocino County, California (CA), Hood River, Oregon (OR), and Geneva, New York (NY) to evaluate multiple training system, spacing, and rootstock combinations for the European pear cultivars 'Bartlett' (California), 'D'Anjou' (Oregon), and 'Bosc' (New York). California treatments consisted of Tall Spindle (TS), "V" Trellis (V-T), parallel 2-leader (2-L), and nursery-formed Bi-axis (B-A) x 3', 4.5' and 6' spacings x OHxF 69, OHxF 87, and Pyro 2-33 rootstocks (36 total combinations) in a split-split plot design.

Cumulatively from 2013-2019, survival rate is 98.8%. 2019 harvested overall yield increased 14% over 2018, excluding the 29% of fruit removed pre-harvest after finalizing restructuring trees from a 3- to 2-dimensional canopy (6-52% removed previously). TS had the most (30 fruit/tree) but smallest (206 gm) fruit and highest yield (6.0 kg/tree), while B-A had the least (17.3) fruit and lowest yield (3.7 kg). Spacing significantly influenced fruit number and size, but unlike 2018, not yield. 3' had the most (24.9) but smallest (210 gm) fruit, and 6' the least (21.1) and largest fruit (221 gm) fruit. Rootstock fruit number, fruit size, and yield differences were insignificant. B-A trees were largest based on cultivar TCSA (both single and combined scaffolds) and 2-L trees smallest. V-T and TS, 3', and Pyro-233 trees were tallest. TS, 3' and 4.5', and Pyro 2-33 and OHxF 87 trees were most efficient and B-A, 6', and OHxF 69 least. There were few root suckers, with no training system differences. There were fewer root suckers in 3' than 4.5' or 6' spacing (0.22 vs 0.50 and 0.51, respectively). Pyro 2-33, the most vigorous rootstock had the most (0.59), followed by OHxF 69 (0.44) and OHxF 87 (0.22), the least vigorous. Fruit maturity was much lower in 2019 than in previous years (average 6.8 vs. average 8.6 kg force 2015-2018), however sugars were higher (14.0 vs. 13.2 °B 2015-2018), suggesting trial fruit was harvested at higher maturity in 2019, and trees more vigorous with better water status. There were interactions for fruit number, fruit

size, yield, scion TCSA, scion yield efficiency, rootstock TCSA, rootstock yield efficiency, tree height, and root suckers. Completely unpruned trees in an adjacent row to treatment trees yielded 36% less than 2018 (14.7 vs. 22.9 kg), but 207% more than pruned trees at harvest, with total fruit number approximately 159% more combining removed and harvested fruit. Unpruned OHxF 69 fruit size was trended larger than OHxF 87 (196 vs.184 gm, p = 0.10). For spread versus unspread B-A trees on OHxF 87 and 69 unspread fruit size (178 vs. 126 gm, $p = 0.02$) and rootstock TCSA (74 vs. 48.5 cm^2, p = 0.03) were greater. There were no significant differences in fruit number, yield, scion TCSA, scion or rootstock yield efficiency, tree height or root suckers. Overall mid-day stem water potential (MSWP) measurements from the main treatment area were equal between rootstocks, however all Pyro 2-33 6' trees but only TS 6' and 2-L 3' OHxF 87 trees approached baseline (8 to 10 bars), suggesting more canopy variability among OHx87 trees. Pyro 2-33 average seasonal MSWP (14.3 bars) was slightly higher than OHxF 87 (13.8 bars), similar to 2018 and likely reflected a more uniform larger canopy. Data collection will continue in 2021.

INTRODUCTION

The California pear industry has shrunk considerably in the past several decades, both in number of growers and total acreage (USDA-NASS 2020 and 2014). There are many reasons for this, which have been described (Elkins, Bell and Einhorn, 2012). Remaining growers are considering replanting older low-density orchards with high density "wall type" orchards amenable to mechanization. Formal economic evaluation and the example of one small planting in the Ukiah Valley of Mendocino County that completed its 14th year in 2019 have shown that higher density plantings can be successful (Elkins et al 2011; Elkins and DeJong, 2011; Elkins et al 2008; Elkins and DeJong, 2002; Chris Ruddick, pers. communication).

The NC140 Regional Rootstock Research Project (*www.nc140.org*) is a USDA NIFA multi-state project for perennial fruit (and nut) crops. Regional projects are resubmitted for authorization every five years; the 2017-2022 NC140 Regional Research Project Proposal may be downloaded from NC140 web site. The goal of NC- 140 is to develop and disseminate information generated from trials throughout the U.S. Each participating state establishes and evaluates similar ("uniform") trials using the same rootstocks and similar plot design so that regional differences can be determined. Progress and results are shared at an annual two-day meeting (California hosted in 2015, 2016 Pennsylvania, 2017 Washington, 2018 North Carolina, 2019 New York, 2020 planned for Colorado) and via the NC140 website. Each state submits an annual report which is distributed and discussed at the meeting. State reports are then compiled into a national report for USDA. California began participating in NC140 in 1995 (apples, Scott Johnson) and peaches (Johnson and Ted DeJong) were added in 1999. The first pear trial was initiated in 1987 by the late Dr. Eugene Mielke of OSU (Azarenko et al 2002), followed by the 2002, 2004, 2005, 2006, and 2013 trials. Rachel Elkins is the California voting representative for all crops (currently pear and organic apple) and leads the current trials in California, summarizing and reporting California information at the annual meeting. She also co-organizes pear data for the national trials for reporting and publications with Associate Professor Todd Einhorn (formerly of Oregon State University (OSU), now at Michigan State University (MSU), East Lansing). Her expenses to the meetings were covered through 2016 by Hatch funds through the UC Davis Department of Plant Sciences and in 2017 by industry research funds (no travel funds were expended in 2018-2019).

In coordination with OSU and Cornell University, an NC-140 project to study high density systems and management techniques was initiated in Spring 2013. Three replicated trials were established in Mendocino County, California (CA), Hood River, Oregon (OR) (removed in early 2018 due to extensive damage from winter injury and fire blight) and Geneva, New York (NY) to evaluate multiple combinations of training systems, spacings, and promising commercially-available rootstocks for the European pear cultivars 'Bartlett' (CA), 'D'Anjou' (OR), and 'Bosc' (NY). The 2013 trial succeeds the 10-year 2005 multi-state rootstock trial that was formally completed in 2014 (Elkins 2016; Elkins et al 2008).

The 2013 NC-140 trial compares 27 (OR, NY) or 36 (CA) combinations of training systems, spacings, and rootstocks. The California trial was planted May 1 - 2, 2013 in Hopland, Mendocino County, California and has completed seven growing seasons (7th leaf). Treatments consist of four (versus three in OR and NY) training systems and three spacings that have shown promise in high density plantings, particularly apple and pear, and three commercially available rootstocks which have shown promise in previous NC- 140 trials. Similar to the 2005 NC-140 trial, the 2013 trial is the only formal, replicated pear systems trial in California to benefit future planting decisions.

OBJECTIVES

This multi-state, multi-factor trial will evaluate alternative rootstocks, planting systems, and cultivars relative to:

- Cultivar compatibility ('Bartlett; CA, 'Bosc' NY, 'D'Anjou' OR);
- Early and consistent production;
- Improved labor efficiency/increased attractiveness for picking crews and amenability to future mechanization;
- Ability to apply a systems approach to canopy management; and
- Improved fruit quality (higher percentage of "target" fruit, which may or may not be accompanied by increased production per acre).

While not a specific objective of the orchard systems project, improved pesticide application efficacy (cost, coverage) will be observed and documented once trees are fully trained out.

PROCEDURES (Figure 1**)**

Trial locations:

1) OSU Mid-Columbia Agricultural Research and Extension Center, Hood River, OR (‘D’Anjou’, Todd Einhorn, PI); (REMOVED IN WINTER 2018)

2) Cornell Geneva Experiment Station, NY (‘Golden Russet®’ Bosc’, Terence Robinson, PI);

3) Shadowbrook Farms (Kurt Ashurst), Hopland, Mendocino County, CA (‘Bartlett’, Rachel Elkins, PI; collaborators Bruce Lampinen, Ted DeJong, and Chuck Ingels (through 2017). Soil type is a very deep Russian loam adjacent to the east bank of the Russian River.

Training systems:

1) *Tall spindle* (TS) (developed by Terence Robinson for apple) (unheaded at planting);

2) *Tatura “V” trellis* (V-T) (22° at the base, planted in-line with every other tree pulled to the opposite side of the trellis);

3) *Bi-axis* (B-A) planted parallel to the row. Developed by Dr. Stefano Musacchi, formerly of University of Bologna, Italy, now with Washington State University. B-A trees are pre-formed in the nursery; the California B-A trees were headed high to a “knip” at planting so are one year behind those left unheaded. Trees were spread into a parallel “V” after the 2013 growing season in order to more quickly fill the growing space, reduce main scaffold vigor, and hasten fruiting;

4) *2-leader* (2-L) planted parallel to the row, created by choosing two appropriately placed “feathers” just above or below the first wire (left unheaded), or if nonavailable, heading the leader and choosing two new scaffolds.

In all cases where tree vigor was adequate, “feathers”, i.e. branches grown in the nursery, were left on unless broken and utilized to begin cropping.

In addition to the main trial block, an adjacent row of extra B-A and single leader trees was left completely unheaded and unpruned. A replicated sub-trial was initiated on one set of these extra B-A trees on OHxF 87 to compare the effect of spreading vs. not spreading on vigor and precocity. The remaining trees in the extra row were left completely unpruned as an unreplicated control. These trees were divided into two sets on either OHxF 69 or OHxF 87 to be analyzed separately.

Cultivar and Rootstocks: 'Bartlett' on OHxF 69, OHxF 87, Pyro 2-33. Rootstocks were chosen based on best available data in comparison with standard size rootstocks. Micro propagated rootstock plants (North American Plant, Lafayette, Oregon) were delivered to Willow Drive Nursery (Ephrata, WA), acclimated, fall budded, grown and planted May 1-2, 2013. A total of (about) 700 trees were planted, of which 540 are part of the main systems trial.

Spacing: 3' (1m), 4-5' (1.5m), and 6' (2m) in-row x 12' (4m) between rows. Fina height is 10-12' (3.3-4m) (TBD). The unreplicated "fifth" row in-row spacing is 6' (2m).

Design: Split-split plot: main plot = training system, sub-plot = spacing, sub-sub-plot = rootstock. 5 replicated blocks, each plot consisting of 27 trees (27/training system; 9/spacing; 3/rootstock) (4 treatment rows per block)[1]. Blocking is across the field with trees oriented north to south (east-west sun exposure). Approximately 2 acres of land in a high-producing orchard along the Russian River was cleared and prepared in 2012 in preparation for fumigation, however, the fumigation was unable to occur due to weather and regulatory delays[2].

[1] Data analysis is on four replicates as one replicate required re-training and is one year behind. Analysis will include all five replicates once trees are bearing equally.

[2] While *Armillaria mellea* has infected trees in the orchard, average tonnage of existing trees approached 40 tons per acre; oak root fungus has yet to affect trial results.

Data Collection

Tree training and crop load management: From 2013 through 2019 training continued to emphasize and refine leader development, proper shaping, and thinning to optimize fruiting wood distribution. 2019 completed the process started in 2017 of more intensive pruning to transform tree shape from a 3- to 2-dimentional (flat canopy) to accommodate mechanization. Nearly all training was performed between the start of terminal bud growth and terminal bud set in October. Emphasis was on 1) encouraging leaders to reach the top wire by reducing the influence of competing scaffolds, 2) filling intra-row and inter-tree space along the supporting wire, and 3) ensuring ideally spaced and optimally vigorous fruiting wood development. Clothes pins and rubber tubing tie were the main training aides, and nearly all wood removal was done by hand or pruners using thinning rather than heading cuts. Fruit was removed on weak trees but left if vigor appeared adequate. 33% of fruit was removed across all treatments in 2019. This reflects the need to remove fewer fruiting branches in contrast with 2018 when just over 50% of total fruit was removed along with the large number of branches removed to create a “flat” canopy and prevent upper limb breakage.

Tree survival, growth and vigor (2013-2019): Percent surviving trees was determined. Tree height and trunk cross-sectional area (TCSA) of both cultivar (10 cm. above graft union) and rootstock (5 cm. below graft union) were measured. Measuring above and below the union allowed comparing single-leader trees with the bi-axis trees which were nursery budded very low at the base. Root suckers were counted. Baseline canopy light interception was initially measured on October 19, 2013 using a Kawasaki Mule- mounted lightbar, then annually through 2016 to eventually develop a predictive model to inform future plantings. (In 2016 the new smartphone iPAR “app” was utilized instead of the large lightbar system, however measurement data was corrupted; these were resumed in 2017). From 2013-2015 four plant cameras, each focused on one training system, recorded the daily and weekly progress of tree growth (e.g. terminal height growth, number of leaves, flowers, fruit) and biotic and abiotic interactions. One photo per day at 10:00 a.m. served as a continuous recording of seasonal growth pattern.

Productivity and harvest maturity: Flower clusters (2013-2015), fruit number and size, and yield (2014-2019) per tree were measured and both cultivar and rootstock yield efficiency (YE) calculated (see above for why rootstock TCSA was recorded). 2015- 2019 data also included number of fruits removed prior to harvest (an indicator of overall vigor and result of severity of canopy modification) and firmness (kg) and soluble solids (°Brix). In 2014-2019, weekly mid-day stem water potential (MSWP) was measured from May through early October using a pressure chamber (PMS Model 610 Pressure Chamber, PMS Instrument Company, Albany, OR) to assess whether and how much water stress might affect vigor and yield (crop load and fruit size), and vice versa. Measurements were taken from trees representing all training systems but only Pyro 2- 33 and OHxF 87 rootstocks.

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). Due to unequal tree age of one of the replicates, only four replicates were utilized for most analyses, with data from the fifth replicate used as appropriate. From 2013-2019, the main significant interactions were among training x rootstock (fruit number, yield, scion yield efficiency, rootstock TCSA) and training x spacing (fruit number, scion TCSA, scion yield efficiency, rootstock yield efficiency). There were no significant training x spacing interactions, nor any related to fruit size.

2019 AND CUMULATIVE 2013-2019 RESULTS (Tables 1-19); (2013-2019 results summarized in Elkins and Lampinen 2018, 2017, 2016, and 2015, Elkins 2014)).

Tree survival, growth, and vigor (Tables 1-3): Five trees have died (1.2%) and not been replace and nine (2.1%) replanted since 2014. (data not shown): 2 x 2-L/Pyro 2-33, 2 x 2-L/OHxF 87, 5 x B-A/OHxF 87, 2 x B-A OHxF 69, 1 x B-A/Pyro 2-33, 1 x TS/OHxF 69, and 1 x V-T/OHxF 69, for a total of 3 x Pyro 2-33, 4 x OHxF 69, and 7 x OHxF 87.

2019 scion (above graft union) TCSA increase averaged 13% from 2018, with most training systems, spacings and rootstocks increasing similarly. As in 2018, 2-L, 6’, and Pyro 2-33 scion size increased the most and Bi-axis, 3’, and OHxF 87 scions the least. 2-L trees had the smallest scion single leader TCSA while B-A had the largest (averaging both B-A leaders). Rootstock (below graft union) TCSA increase averaged 16%. B-A and V-T, 4.5’ spacing, and Pyro-33 trees had the greatest rootstock growth, while TS, 3’, and OHxF 87 trees had the least. There were training x spacing (scion) and training x rootstock (rootstock) TCSA interactions. V-T and T-S, 3’, and Pyro 2-33 trees were tallest, and B-A, 4.5’, and OHxF 87 shortest. All treatments averaged <1 sucker per tree, though 3’ spacing had significantly fewer and Pyro 2-33 had significantly more than the OHxF rootstocks. There were training x spacing interactions for both tree height and suckers.

Productivity (fruit number, fruit size, yield, yield efficiency) (Tables 1-4): Average harvested fruit number increased 11% from 2018 across all treatments (percent change not shown). Training system fruit number increased 13% and spacing and rootstock 10%. There was great variability within main treatments: 2-L fruit number increased most (41%), followed by TS (23%), and B-A (15%). V-T fruit number actually decreased 10%. Spacing fruit number increased 10%, with 3’ increasing 33% and 4.5’ 7%. 6’ number actually decreased 6%. Rootstock fruit number also varied greatly: Pyro 2-33 increased 24%, while the OHxF rootstocks showed the least change (10% for 69 and 2% for 87). Overall, 2019 fruit number averaged 23.5 per tree, with a similar average for all three main treatments. TS (30.1/tree), 3’ and 4.5’ (24.9 and 23.9) trees had significantly more fruit. B-A and 2-L (17.3 and 22.1) and 6’ (21.1) had the least. Rootstocks averaged 23.3 fruit per tree with no difference among treatments. There were training x spacing interactions.

Overall average fruit size increased 8% from 2018 (199 gm in 2018 to 215 gm in 2019), with similar 8% increase across the main treatments. Fruit averaged >200 gm for all treatments, despite increase in both fruit number and yield.

Among training systems, 2-L, B-A, and V-T had equal size (range 216-220 gm), with TS significantly smaller (205 gm). 6' fruit were significantly larger (221 gm), followed by 4.5' (214 gm) and 3' (210 gm). Versus 2018, there were no rootstock differences in fruit size, and no significant differences among them (range 213 -218 gm). There were significant training x rootstock interactions.

Overall yield increased 9%. 2-L increased most (48%), followed by B-A 19%, VT 15.5% and TS (0%). 3' spacing increased 35%, 4.5' 14%, and 6' least (0%). Pyro 2-33 yield increased the most 26%, OHxF 69 15%, and OHxF 87 6%. TS yielded significantly most (6.0 kg/tree), followed by V-T (4.9 kg), 2-L (4.6 kg). B-A yielded significantly least (3.7 kg). There were no significant differences among spacings (range 4.5 – 5.0 kg/tree), and for the first time, no differences among rootstocks (range 4.7 – 4.9 kg/tree). There were significant training x spacing interactions.

Overall, 2019 scion YE decreased about 13% from 2018, with variability among individual treatments. Training system scion YE decreased 17%; B-A system increased most (20%), followed by 2-L and TS (8% and 6%), and VT actually decreased 35%. Among spacings (-8%), 3' scion YE increased 8%, while 4.5' (-8%) and 6' (-21%) decreased. Rootstock scion YE decrease averaged 14%, ranging from 0% (no change) for Pyro-233, -8% for OHxF 69, and -19% for OHxF 87, the latter reflecting more limited bearing capacity on smaller trees at this site. Overall rootstock YE decreased about 9%. While most training system rootstock YE increased modestly or not at all, V-T trellis YE decreased 31%, similarly to scion YE (-35%), reflecting the 10% yield decrease. Spacing rootstock YE varied greatly: 3' pacing rootstock YE increased 10%, 4.5 stayed the same and 6' decreased 10%. Rootstock YE also varied greatly, with Pyro 2-33 increasing 11%, OHxF69 staying the same, and OHxF 87 decreasing 9%. 2013-2019 cumulative results solidified those of 2018. V-T and TS trees had numerically and statistically equal fruit numbers (91/tree), however V-T had larger fruit (200 vs.190 gm) and corresponding numerically, but not statistically, higher total yield (18.4 vs. 17.5 kg). On both a two and single leader basis, B-A trees were largest (combined leaders 69.4 cm^2, average 35 cm^2), followed by TS (33.4 cm^2), V-T (31.8 cm^2) and 2-L (28.2 cm^2). V-T and TS trees were equally efficient (.56 and .52 kg/cm^2), followed by 2-L (.40 kg/cm^2) and lastly, B-A (.15 kg/cm^2). The only spacing differences were in scion and rootstock TCSA. 6' scions were largest (43.5 $cm^{2)}$, followed by 4.5' (40.9 cm^2), and 3' (37.9 cm^2). Rootstock TCSAs were numerically larger than scion TCSAs and followed the same pattern: 6' = 4.5' > 3'. 2019 rootstock productivity results were similar to 2018. OHxF 87 had the most fruit (87/tree) and highest yield (17.1 kg), and highest scion YE (0.50 kg/, cm^2), but numerically smallest fruit (195 gm). OHxF 69 trees were largest (44.0 cm^2), had fruit size statistically equal to OHxF 87 (199 gm), and intermediate fruit number (71), yield (14.3 kg), and scion YE (.40 kg/cm^2). Pyro 2-33 had the least fruit (56), largest fruit (206 gm), lowest yield (11.5 kg), and despite being relatively small trees, lowest YE (0.35 kg/cm^2). Interactions were training x rootstock (fruit number, yield, scion and rootstock TCSA and YE), training x spacing (fruit number, scion TCSA and YE, rootstock YE), and training x spacing x rootstock (fruit number, yield).

Pre-harvest fruit removal (Tables 5-8): An average of 9 fruit per tree was removed prior to harvest (about 29% of the total number per tree) versus about 23 harvested, with the same overall average number and percent across training, spacing, and rootstock. In contrast to earlier years (11.8% removed in 2015, 6.2 in 2016, 15.0% in 2017, 52% in 2018) when it was accomplished mainly to avoid overcropping, foster vigor and facilitate leader development, the number and percent of fruit removed in 2018 and 2019 reflected the pruning severity needed to complete restructuring tree architecture from 3- to 2-dimensional initiated in 2017, which required removing all east and west protruding branches and associated fruit. There were no differences in number removed among training systems, however percent removed differed significantly, with the most removed from B-A (33%) and least from TS (24%). There were no spacing or rootstock differences There were training x spacing interactions (preharvest removal, number harvested, total) and training x spacing x rootstock (preharvest, total removed).

Firmness and soluble solids (Table 9-): Fruit was more mature at harvest than previously, averaging 6.8 kg. force, or about 15 lbs. vs. averaging 8.6 kg or 17.6 lbs. in 2015-2018Soluble solids were also higher (14.0 vs. average 13.25 °Brix). Similar to previous years, only training systems significantly differed. B-A fruit was firmest (7.0 kg force) and TS softest (6.7). There were no significant interactions.

Completely unpruned OHxF 69 and 87 trees (Tables 10 -13) averaged 62 more fruit at harvest (88 vs. 23) and 56 more fruit including fruit removed pre- and at harvest, 55% less fruit than in 2018. There were no significant differences in fruit number or total yield between the two rootstocks in 2019, however, as in 2018 OHxF 69 fruit trended (p= 0.10) larger than OHxF 87 (195 vs.184 gm). While OHxF 69 trees were significantly larger than OHxF 87 (43.3 vs. 35.5 cm^2 TCSA, 264 vs. 233 cm tall), yield efficiencies were similar. OHxF 69 rootstock TCSA was significantly larger, suggesting greater vigor. Both firmness (6.8 vs. 6.5 kg. force) and soluble solids (14.8 vs. 13.6 ^{o}Brix) were significantly higher for OHxF 87 fruit.

Cumulative 2013-2019 results resembled 2019, however the trend toward larger fruit for OHxF 69 became significant (183 vs. 169 gm), despite equal fruit number and total yield. OHxF 69 trees were also larger above (scion) and below (rootstock) the graft union, suggesting the weaker OHxF 87 trees are less able to carry an increasing crop load as trees mature (Tables 8-11).

Spread versus unspread Bi-Axis/OHxF 87 (Tables 14 - 186): Fruit was significantly larger on unspread trees (178 vs.126 gm) in 2019. There were no statistical differences in fruit number, yield, or yield efficiency. Scion TCSA and YE were the same for both treatments, however rootstock TCSA was significantly larger on unspread trees (73.7 vs. 48.5 cm^2), suggesting greater vigor. There were no differences in firmness and soluble solids. Cumulatively from 2013-2019, fruit size trended higher for unspread trees (181 vs. 162 gm., p = 0.10), with no differences in fruit number or total yield. Scion TCSA (104.5 vs. 86.1, p = .26 cm^2) and YE (0.81 vs. 0.68 kg/cm^2) trended higher on unspread trees; rootstock TCSA and YE (were significantly higher (1.12 vs 0.84).

Mid-day Stem Water Potential (MSWP) (Table 19, Figures 2-7): 2019 measurements ceased from August 21 to October 14 due to harvest. There were no overall significant differences between treatments or between Pyro 2-33 and OHxF 87 rootstocks, however differences occurred on discrete dates. While values remained consistently below baseline in all years, they approached it after each irrigation in 2019, suggesting irrigations more closely aligned with canopy development and size, as well as deeper rooting capacity. Despite initially lower MSWP (more stress) on June 12 compared to 2018, MSWP improved until reaching close to baseline (between 8 to 9 bars) at harvest (August 26-28). For both rootstocks, TS at 3' was most stressed at harvest and 2-L 3' the least. For Pyro 2-33, all 3' treatments were more stressed than the 6' by harvest, while the pattern was less clear for OH x F 87, suggesting more tree to tree variability. Higher stress for the 3' spacing suggests higher water demand due to a more continuous canopy footprint.

2013-2019 DISCUSSION AND 2020 PLANS

After seven growing seasons, training system continues to be the most consistent factor determining tree growth and productivity. TS fruit number, total yield, and yield efficiency surpassed V-T, however as yield has increased, relative fruit size has decreased. B-A productivity continued to lag, largely due to extensive retraining needed to achieve a 2-dimensional canopy. Thus, to date, T-S and V-A have shown the greatest overall productivity. Spacing has increasingly influenced productivity; 3' spaced trees were smaller and bore more but smaller fruit, and thus had higher YE. They were also taller and had fewer root suckers. While spacing influence increased, differences among rootstocks have narrowed. Rootstock had no effect on productivity in 2019, though Pyro 2-33 box size was significantly larger (90 vs. 100 for both OHxF rootstocks). Pyro-233 fruit number, total yield, and scion YE equaled OHxF rootstocks in 2019, though trees were taller. It also exhibited the most root suckers; OHxF 69 was intermediate. OHxF 87 productivity (fruit number, fruit size, yield, and YE) has trended lower due to smaller tree size and a trend toward significantly smaller fruit versus OHxF 69 and Pyro 2-33. Tree water status appeared better in 2019, with MSWP suggesting applied water is meeting tree needs during the hottest part of the year. Comparing spreading versus allowing natural upright scaffold growth (unspread), from 2013-2019, larger fruit size has been the most consistent trend favoring unspread trees. While spreading favors rootstock YE, larger rootstock TCSA suggests greater vigor of unspread trees, favoring larger fruit without sacrificing fruit number or total yield. Spreading (in this case on unpruned trees) thus appears to diminish fruit size over time.

Completely forgoing pruning in early years encourages early fruiting, however compromises fruit size as trees mature. The more vigorous OHxF 69 trees resulted in significantly larger fruit than OHxF 87, with equal yield efficiency.

Tree training and data collection will continue in 2020 (Year 8).

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↑ SOUTH
Reps II - V

Training	Spacing/Rootstock	
Row 1	6	2-33
	6	2-33
	6	2-33
	6	87
BI-AXIS	6	87
	6	87
	6	69
	6	69
	6	69
Buffer	PYRO 2-33	
Row 1	4.5	69
	4.5	69
	4.5	69
	4.5	2-33
BI-AXIS	4.5	2-33
	4.5	2-33
	4.5	87
	4.5	87
	4.5	87
Buffer	PYRO 2-33	
Row 1	3	2-33
	3	2-33
	3	2-33
	3	87
BI-AXIS	3	87
	3	87
	3	69
	3	69
	3	69
Buffer	PYRO 2-33	

Training	Spacing/Rootsto	
Row 2	3	69
	3	69
	3	69
	3	2-33
"V" TRELLIS	3	2-33
	3	2-33
	3	87
	3	87
	3	87
Buffer	PYRO 2-33	
Row 2	6	69
	6	69
	6	69
	6	2-33
"V" TRELLIS	6	2-33
	6	2-33
	6	87
	6	87
	6	87
Buffer	PYRO 2-33	
Row 2	4.5	2-33
	4.5	2-33
	4.5	2-33
	4.5	87
"V" TRELLIS	4.5	87
	4.5	87
	4.5	69
	4.5	69
	4.5	69
Buffer	PYRO 2-33	

Training	Spacing/Rootstock	
Row 3	4.5	2-33
	4.5	2-33
	4.5	2-33
	4.5	87
2-LEADER	4.5	87
	4.5	87
	4.5	69
	4.5	69
	4.5	69
Buffer	PYRO 2-33	
Row 3	6	87
	6	87
	6	87
	6	69
2-LEADER	6	69
	6	69
	6	2-33
	6	2-33
	6	2-33
Buffer	PYRO 2-33	
Row 3	3	2-33
	3	2-33
	3	2-33
	3	87
2-LEADER	3	87
	3	87
	3	69
	3	69
	3	69
Buffer	PYRO 2-33	

Training	Spacing/Rootstock	
Row 4	6	2-33
	6	2-33
	6	2-33
	6	69
TALL SPINDLE	6	69
	6	69
	6	87
	6	87
	6	87
Buffer	PYRO 2-33	
Row 4	4.5	87
	4.5	87
	4.5	87
	4.5	2-33
TALL SPINDLE	4.5	2-33
	4.5	2-33
	4.5	69
	4.5	69
	4.5	69
Buffer	PYRO 2-33	
Row 4	3	87
	3	87
	3	87
	3	69
TALL SPINDLE	3	69
	3	69
	3	2-33
	3	2-33
	3	2-33
Buffer	PYRO 2-33	

BARTLETT TREES

Row 5 - UNPRUNED BARTLETT TREES AND NEW USDA CULTIVAR SELECTION

BOSC TREES/RUSSIAN RIVER

NORTH END

Figure 1: 2013 NC-140 PEAR SYSTEMS TRIAL - REP I (Rows 1-4), Shadowbrook Farms, Hopland, Mendocino, CA. Planted May 1-2, 2013.

Table 1: Effect of training system, spacing, and rootstock on number and size of fruit, yield, box size and number, tree growth, yield efficiency and root suckers of 7th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2019.

	Fruit No. (no./tree) 8/26-28/2019	Fruit Size (g) 8/26-28/2019	Yield (kg/tree) 8/26-28/2019	Nearest Box Size (44 lb.box) 8/26-28/2019	Average Box Number (per tree) 8/26-28/2019	Scion TCSA[4] (cm^2) 10&12/2019	Scion Yield Efficiency (kg/cm^2)	Rootstock TCSA[5] (cm^2) 10&12/2019	Rootstock Yield Efficiency (kg/cm^2)	Tree Heights[6] (cm) 10/9-16/2019	Root Suckers[7] (no./tree) 10/9-16/2019
Training[1]											
2-Leader	22.1 bc	216 a	4.6 bc	90 b	0.24 b	28.2 c	0.14 b	41.7 b	0.10 ab	273 ab	0.53
Bi-axis[3]	17.3 c	220 a	3.7 c	90 b	0.19 c	69.4 a	0.06 c	46.0 ab	0.08 c	263 b	0.41
Tall Spindle	30.1 a	205 b	6.0 a	100 a	0.30 a	33.4 b	0.17 a	49.8 a	0.12 a	276 a	0.30
V-Trellis	26.7 b	220 a	4.9 b	90 b	0.25 ab	31.8 bc	0.13 b	50.5 a	0.09 bc	278 a	0.40
Spacing[1]											
3 feet	24.9 a	210 b	5.0	100 a	0.26	37.9 b	0.14 a	43.6 b	0.11 a	278 a	0.22 b
4.5 feet	23.9 ab	214 ab	4.9	100 ab	0.25	40.9 ab	0.13 a	47.9 a	0.10 ab	268 b	0.50 ab
6 feet	21.1 b	221 a	4.5	90 b	0.23	43.5 a	0.11 b	49.5 a	0.09 b	271 ab	0.51 ab
Rootstock[1]											
Pyro 2-33	23.4	218	4.8	90 b	0.25	40.0 b	0.13 a	46.9 b	0.10 a	281 a	0.59 a
OHxF 69	22.7	214	4.7	100 ab	0.24	44.0 a	0.11 b	51.1 a	0.09 b	272 ab	0.44 ab
OHxF 87	23.8	213	4.9	100 a	0.25	38.3 b	0.13 a	43.0 c	0.11 a	265 b	0.20 b
ANOVA (*P* -values)[2]											
Training	***(<0.001)	***(<0.001	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	**(0.002)	NS (0.26)
Spacing	* (0.04)	***(0.001)	NS (0.28)	** (0.002)	NS (0.24)	***(<0.001)	***(0.001)	***(0.001)	**(0.002)	*(0.05)	NS (0.04)
Rootstock	NS (0.84)	NS (0.15)	NS (0.86)	* (0.04)	NS (0.98)	***(<0.001)	**(0.004)	***(<0.001)	**(0.002)	*** (0.001)	* (0.02)
Block	***(<0.000)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.000)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)
Interaction (*P* -values)[2]											
Training x Rootstock	NS (0.41)	** (0.01)	NS (0.38)	** (0.003)	NS (0.46)	NS (0.21)	NS (0.14)	* (0.05)	NS (0.20)	NS (0.32)	NS (0.35)
Spacing x Rootstock	NS (0.90)	NS (0.23)	NS (0.91)	NS (0.17)	NS (0.84)	NS (0.27)	NS (0.69)	NS (0.52)	NS (0.76)	NS (0.49)	NS (0.58)
Training x Spacing	** (0.01)	NS (0.61)	** (0.004)	NS (0.43)	** (0.01)	* (0.04)	** (0.003)	NS (0.48)	**(0.004)	**(0.01)	* (0.02)
Training x Spacing x Rootstock	NS (0.06)	* (0.04)	NS (0.08)	* (0.04)	NS (0.12)	NS (0.39)	NS (0.45)	NS (0.28)	NS (0.39)	NS (0.19)	NS (0.44)

[1] Within columns, treatment means significantly different (Tukey HSD test, $P \leq 0.05$, $P < 0.10$ No. Fruit and Box No. by spacing).

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

[3] Total of two scaffolds.

[4] Measured 10 cm above union.

[5] Measured 5 cm below union.

[6] Tallest scaffold.

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

Harvest date, 8/26-8/28/2019

Table 2: Effect of training system, spacing, and rootstock on number and size of fruit, yield, box size and number, tree growth, yield efficiency and root suckers of 6th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2018.

	Fruit No. (no./tree) 8/31-9/1/2018	Fruit Size (g) 8/31-9/1/2018	Yield (kg/tree) 8/31-9/1/2018	Mean Box Size (44 lb box) 8/31-9/1/2018	Average Box Number (per tree) 8/31-9/1/2018	Cultivar TCSA[4] (cm^2) 11/20-12/3/2018	Cultivar Yield Efficiency (kg/cm^2)	Rootstock TCSA[5] (cm^2) 11/20-12/3/2018	Rootstock Yield Efficiency (kg/cm^2)	Tree Heights[6] (cm) 10/18-24/2018	Root Suckers[7] (no./tree) 10/18-24/2018
Training[1]											
2-Leader	15.7 c	199 ab	3.1 c	102 ab	0.16 c	24.5 c	0.13 c	36.0 b	0.09 c	286 b	0.12
Bi-axis[3]	15.0 c	206 a	3.1 c	99 b	0.15 c	61.7 a	0.05 d	38.6 b	0.08 c	272 b	0.12
Tall Spindle	24.4 b	194 b	4.7 b	105 a	0.23 b	29.8 b	0.16 b	44.7 a	0.11 b	310 a	0.17
V-Trellis	29.8 a	197 b	5.8 a	105 a	0.29 a	28.3 b	0.20 a	43.4 a	0.13 a	282 b	0.04
Spacing[1]											
3 feet	18.8 b	198	3.7 b	103	0.19 b	34.2 b	0.13	38.2 b	0.10	301 a	0.06
4.5 feet	22.4 a	198	4.3 a	103	0.22 a	36.0 ab	0.14	40.8 ab	0.10	284 b	0.15
6 feet	22.4 a	202	4.5 a	101	0.22 a	38.1 a	0.14	43.1 a	0.10	278 b	0.13
Rootstock[1]											
Pyro 2-33	18.8 b	202 a	3.8 b	101 b	0.19 b	34.9 b	0.13 b	39.8 b	0.09 b	298 a	0.14
OHxF 69	20.7 b	202 a	4.1 ab	101 b	0.21 ab	39.4 a	0.12 b	44.2 a	0.09 b	288 ab	0.13
OHxF 87	24.2 a	194 b	4.6 a	106 a	0.23 a	33.9 b	0.16 a	38.1 b	0.12 a	277 b	0.06
ANOVA (*P* -values)[2]											
Training	***(<0.001)	***(<0.001)	***(<0.001)	**(0.003)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.22)
Spacing	* (0.02)	NS (0.11)	**(0.01)	NS (0.44)	** (0.01)	***(<0.001)	NS (0.51)	***(<0.001)	NS (0.51)	***(<0.001)	NS (0.18)
Rootstock	***(0.001)	**(0.002)	**(0.01)	***(<0.001)	** (0.01)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.26)
Block	**(0.003)	***(<0.001)	**(0.002)	***(<0.001)	**(0.003)	***(<0.001)	***(<0.001)	***(<0.001)	**(0.002)	***(<0.001)	NS (0.31)
Interaction (*P* -values)[2]											
Training x Rootstock	NS (0.47)	NS (0.47)	NS (0.55)	NS (0.82)	NS (0.57)	NS (0.33)	NS (0.84)	NS (0.06)	NS (0.67)	NS (0.36)	NS (0.56)
Spacing x Rootstock	NS (0.27)	NS (0.18)	NS (0.56)	NS (0.44)	NS (0.55)	NS (0.33)	NS (0.36)	NS (0.27)	NS (0.34)	NS (0.14)	NS (0.17)
Training x Spacing	NS (0.22)	* (0.04)	NS (0.19)	NS (0.06)	NS (0.19)	NS (0.36)	NS (0.81)	NS (0.69)	NS (0.36)	***(<0.001)	NS (0.79)
Training x Spacing x Rootstock	NS (0.19)	* (0.05)	NS (0.33)	* (0.05)	NS (0.33)	NS (0.19)	NS (0.21)	NS (0.10)	NS (0.56)	NS (0.23)	NS (0.71)

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

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

[3] Total of two scaffolds.

[4] Measured 10 cm above union.

[5] Measured 5 cm below union.

[6] Tallest scaffold.

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

Harvest date, 8/31-9/1/2018

Table 3: Cumulative effect of training system, spacing, and rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of 7th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2013-2019.

	Average Fruit No. (per tree)	Average Fruit Size[3] (g)	Average Yield (kg/tree)	2019 Scion TCSA (cm^2)	Average Cumulative Scion Yield Efficiency[4] (kg/cm^2)	2019 Rootstock TCSA (cm^2)	Average Cumulative Rootstock Yield Efficiency[4] (kg/cm^2)	Root Suckers[5] (no/tree)
Training[1]								
2-Leader	56 b	203 ab	11.4 b	28.2 c	0.40 b	41.7 b	0.27 b	1.12
Bi-axis[3]	47 b	207 a	9.8 b	69.4 a	0.15 c	46.0 ab	0.22 c	0.80
Tall Spindle	91 a	190 c	17.5 a	33.4 b	0.52 a	49.8 a	0.35 a	0.70
V-Trellis	91 a	200 b	18.4 a	31.8 bc	0.56 a	50.5 a	0.36 a	0.67
Spacing[1]								
3 feet	70	201	13.9	37.9 b	0.42	43.6 b	0.31	0.62
4.5 feet	72	198	14.2	40.9 ab	0.40	47.9 a	0.29	0.88
6 feet	73	201	14.8	43.5 a	0.40	49.5 a	0.30	0.96
Rootstock[1]								
Pyro 2-33	56 c	206 a	11.5 c	40.0 b	0.35 b	46.9 b	0.25 b	1.05 a
OHxF 69	71 b	199 b	14.3 b	44.0 a	0.40 b	51.1 a	0.27 b	0.80 ab
OHxF 87	87 a	195 b	17.1 a	38.3 b	0.50 a	43.0 c	0.39 a	0.61 b
ANOVA (*P* -values)[2]								
Training	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.20)
Spacing	NS (0.88)	NS (0.18)	NS (0.47)	***(<0.001)	NS (0.56)	***(0.001)	NS (0.06)	NS (0.09)
Rootstock	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	*(0.03)
Block	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)
Interaction (*P* -values)[2]								
Training x Rootstock	*(0.02)	NS (0.53)	*(0.04)	NS (0.21)	*(0.02)	*(0.05)	NS (0.26)	NS (0.70)
Spacing x Rootstock	NS (0.14)	NS (0.10)	NS (0.26)	NS (0.27)	NS (0.83)	NS (0.52)	NS (0.92)	NS (0.38)
Training x Spacing	*(0.04)	NS (0.58)	NS (0.20)	*(0.04)	*(0.05)	NS (0.48)	**(0.01)	NS (0.24)
Training x Spacing x Rootstock	*(0.03)	NS (0.13)	*(0.05)	NS (0.39)	NS (0.25)	NS (0.28)	NS (0.50)	NS (0.73)

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

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

[3] Average fruit size 2014 to 2019.

[4] Based on cumulative yield (2014-19) and final TCSA (2019).

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

Table 4: Cumulative effect of training system, spacing, and rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of 6th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2013-2018.

	Average Fruit No. (per tree)	Average Fruit Size[3] (g)	Average Yield (kg/tree)	2018 Cultivar TCSA (cm^2)	Average Cumulative Cultivar Yield Efficiency[4] (kg/cm^2)	2018 Rootstock TCSA (cm^2)	Average Cumulative Rootstock Yield Efficiency[4] (kg/cm^2)	Root Suckers[5] (no/tree)	Average Box Size (44 lb.)	Average Box No. (per tree)
Training[1]										
2-Leader	34 b	200 ab	6.8 c	24.5 c	0.28 c	36.0 b	0.19 c	0.59	100 b	0.34 c
Bi-axis[3]	31 b	206 a	6.3 c	61.7 a	0.11 d	38.6 b	0.17 c	0.39	101 b	0.31 c
Tall Spindle	61 a	186 c	11.5 b	29.8 b	0.39 b	44.7 a	0.26 b	0.40	110 a	0.58 b
V-Trellis	68 a	196 b	13.5 a	28.3 b	0.46 a	43.4 a	0.30 a	0.27	104 b	0.67 a
Spacing[1]										
3 feet	45	200 a	8.9 b	34.2 b	0.31	38.2 b	0.23	0.40	103	0.45 b
4.5 feet	48	194 b	9.3 ab	36.0 ab	0.30	40.8 ab	0.22	0.38	105	0.47 ab
6 feet	52	196 ab	10.3 a	38.1 a	0.32	43.1 a	0.24	0.45	104	0.52 a
Rootstock[1]										
Pyrod 2-33	33 c	203 a	6.7 c	34.9 b	0.23 c	39.8 b	0.17 c	0.45	101 b	0.33 c
OHxF 69	49 b	196 b	9.6 b	39.4 a	0.28 b	44.2 a	0.21 b	0.37	105 a	0.48 b
OHxF 87	64 a	192 b	12.3 a	33.9 b	0.42 a	38.1 b	0.31 a	0.41	106 a	0.61 a
ANOVA (*P* -values)[2]										
Training	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.29)	***(<0.001)	***(<0.001)
Spacing	NS (0.10)	*(0.05)	*(0.03)	***(<0.001)	NS (0.46)	***(0.001)	NS (0.31)	NS (0.60)	NS (0.16)	* (0.03)
Rootstock	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.63)	***(<0.001)	***(<0.001)
Block	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	* (0.04)	***(<0.001)	***(<0.001)
Interaction (*P* -values)[2]										
Training x Rootstock	** (0.004)	NS (0.79)	* (0.02)	NS (0.33)	***(<0.001)	NS (0.06)	* (0.04)	NS (0.46)	NS (0.40)	** (0.02)
Spacing x Rootstock	NS (0.06)	NS (0.10)	NS (0.16)	NS (0.33)	NS (0.59)	NS (0.27)	NS (0.77)	NS (0.36)	NS (0.47)	NS (0.16)
Training x Spacing	NS (0.30)	NS (0.51)	NS (0.20)	NS (0.36)	NS (0.94)	NS (0.69)	NS (0.26)	NS (0.70)	NS (0.46)	NS (0.20)
Training x Spacing x Rootstock	** (0.01)	* (0.05)	* (0.03)	NS (0.19)	NS (0.73)	NS (0.10)	NS (0.27)	NS (0.74)	NS (0.23)	* (0.03)

[1] Within columns, treatment means significantly different (Tukey HSD test, P <0.05).

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

[3] Average fruit size 2014 to 2018.

[4] Based on cumulative yield (2014-18) and final TCSA (2018).

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

Table 5: Effect of training system, spacing, and rootstock on number of dropped fruit and % dropped or removed fruit as compared to total fruit of 7th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2019.

	Fruit Dropped, Removed, or Harvested from Tree (no./tree)			
	Preharvest 6/11-8/26/2019	Harvested Fruit 8/26-28/2019	Total Dropped, Removed and Harvest Fruit (per tree)	Percent Removed Preharvest 6/11-8/28/2019
Training[1]				
2-Leader	10	22 bc	32 bc	31.4 ab
Bi-axis[#]	8	17 c	25 c	33.1 a
Tall Spindle	10	30 a	40 a	24.3 b
V-Trellis	9	24 b	33 b	25.6 ab
Average	9	23	33	28.6
Spacing[1]				
3 feet	11	25	36 a	30.8
4.5 feet	9	24	33 ab	26.7
6 feet	8	21	29 b	28.3
Average	9	23	33	28.6
Rootstock[1]				
Pyro 2-33	9	23	33	28.4
OHxF 69	9	23	31	29.7
OHxF 87	10	24	34	27.6
Average	9	23	33	28.6
ANOVA (*P* -values)[2]				
Training	NS (0.28)	***(<0.001)	***(<0.001)	**(<0.004)
Spacing	NS (0.11)	NS (0.08)	* (0.02)	NS (0.28)
Rootstock	NS (0.64)	NS (0.88)	NS (0.74)	NS (0.70)
Block	***(<0.001)	***(<0.001)	***(<0.001)	**(0.01)
Interaction (*P* -values)[2]				
Training x Rootstock	NS (0.86)	NS (0.41)	NS (0.41)	NS (0.57)
Spacing x Rootstock	NS (0.33)	NS (0.90)	NS (0.67)	NS (0.41)
Training x Spacing	* (0.02)	** (0.01)	** (0.003)	NS (0.12)
Training x Spacing x Rootstock	* (0.02)	NS (0.06)	* (0.04)	NS (0.42)

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

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

[#] Total of two scaffolds

Harvest date, 8/26-28/2019

Table 6: Effect of training system, spacing, and rootstock on dropped or removed fruit number and % dropped or removed fruit as compared to total harvested fruit number of 6th leaf 'Bartlett' pear trees Hopland, Mendocino County, California, 2018.

	Dropped or Removed Fruit No. (per tree) 5/25-8/24/2018	Harvested Fruit 8/26-28/2019	Total Dropped, Removed and Harvest Fruit (per tree)	% Dropped or Removed Fruit No. (per tree) 5/25-8/24/2018
Training[1]				
2-Leader	26 b	16 c	41 bc	58.8 a
Bi-axis[#]	19 b	15 c	34 c	50.9 b
Tall Spindle	21 b	24 b	46 b	44.2 c
V-Trellis	42 a	30 a	72 a	53.4 ab
Average	**27**	**21**	**48**	**51.8**
Spacing[1]				
3 feet	25	19 b	44 b	53.3
4.5 feet	27	22 a	50 ab	50.3
6 feet	29	22 a	51 a	52.0
Average	**27**	**21**	**48**	**51.8**
Rootstock[1]				
Pyro 2-33	22 b	19 b	40 b	49.0 b
OHxF 69	31 a	21 b	51 a	56.4 a
OHxF 87	29 a	24 a	53 a	50.1 b
Average	**27**	**21**	**48**	**51.8**
ANOVA (***P* -values**)[2]				
Training	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)
Spacing	NS (0.20)	* (0.02)	** (0.01)	NS (0.21)
Rootstock	***(<0.001)	***(0.001)	***(<0.001)	**(0.003)
Block	***(<0.001)	**(0.003)	***(<0.001)	**(0.002)
Interaction (***P* -values**)[2]				
Training x Rootstock	NS (0.35)	NS (0.47)	NS (0.19)	NS (0.84)
Spacing x Rootstock	NS (0.10)	NS (0.27)	NS (0.06)	NS (0.10)
Training x Spacing	NS (0.46)	NS (0.22)	NS (0.66)	NS (0.50)
Training x Spacing x Rootstock	NS (0.33)	NS (0.19)	NS (0.22)	NS (0.31)

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

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

[#] Total of two scaffolds

Harvest date: 8/31-9/1/2018

Table 7: Effect of training system, spacing, and rootstock on the amount of fruit dropped, removed, or harvested from 'Bartlett' pear 3rd, 4th, 5th, 6th, and 7th leaf trees, Hopland, Mendocino County, California, 2015-2019.

	Total Fruit Dropped, Removed, or Harvested (per tree)					
	6/10-11/2015	6/6 & 17/2016	6/26 & 7/6/2017	5/25-8/24/2018	6/11-8/26/2019	Average 2015-2019
Training[1]						
2-Leader	9 b	2 bc	11 b	41 bc	32 bc	
Bi-axis	7 b	1 c	9 b	34 c	25 c	
Tall Spindle	18 a	2 ab	20 a	46 b	40 a	
V-Trellis	15 a	3 a	19 a	72 a	33 b	
Average	**12**	**2**	**15**	**48**	**33**	**22**
Spacing[1]						
3 feet	12	2	14 ab	44 b	36 a	
4.5 feet	12	2	14 b	50 ab	33 ab	
6 feet	13	3	17 a	51 a	29 b	
Average	**12**	**2**	**15**	**48**	**33**	**22**
Rootstock[1]						
Pyro 2-33	5 c	1 c	9 c	40 b	33	
OHxF 69	14 b	2 b	14 b	51 a	31	
OHxF 87	18 a	3 a	21 a	53 a	34	
Average	**12**	**2**	**15**	**48**	**33**	22
ANOVA[2] **(*P* -values)**						
Training	***(<0.0001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	
Spacing	NS (0.40)	*(0.04)	**(0.002)	** (0.01)	* (0.02)	
Rootstock	***(<0.0001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.74)	
Block	***(<0.0001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	
Interaction[2] ***P* -values**						
Training x Rootstock	***(<0.0001)	*(0.02)	**(0.01)	NS (0.19)	NS (0.41)	
Spacing x Rootstock	*(0.04)	NS (0.38)	NS (0.15)	NS (0.06)	NS (0.67)	
Training x Spacing	NS (0.50)	NS (0.22)	**(0.01)	NS (0.66)	** (0.003)	
Training x Spacing x Rootstock	NS (0.23)	NS (0.29)	**(0.002)	NS (0.22)	* (0.04)	

[1] Within columns, 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.

Table 8: Effect of training system, spacing, and rootstock on the amount of fruit dropped or removed from 'Bartlett' pear 3rd, 4th, 5th, 6th, and 7th leaf trees, Hopland, Mendocino County, California, 2015-2019.

	Percent Dropped or Removed Fruit (%/per tree)					
	6/10-11/2015	6/6 & 17/2016	6/26 & 7/6/2017	5/25-8/24/2018	6/11-8/26/2019	Average % 2015-2019
Training[1]						
2-Leader	18.9 a	3.3 b	14.7 b	58.8 a	31.4 ab	
Bi-axis	18.5 a	0.1 b	15.5 b	50.9 b	33.1 a	
Tall Spindle	4.3 b	18.5 a	23.1 a	44.2 c	24.3 b	
V-Trellis	5.4 b	3.0 b	6.6 c	53.4 ab	25.6 ab	
Average	**11.8**	**6.2**	**15.0**	**51.8**	**28.6**	**22.7**
Spacing[1]						
3 feet	14.4	7.2	14.4	53.3	30.8	
4.5 feet	10.0	7.0	13.6	50.3	26.7	
6 feet	11.1	4.4	17.0	52.0	28.3	
Average	**11.8**	**6.2**	**15.0**	**51.9**	**28.6**	**22.7**
Rootstock[1]						
Pyro 2-33	13.0	4.6	12.4 b	49.0 b	28.4	
OHxF 69	13.1	6.9	18.4 a	56.4 a	29.7	
OHxF 87	9.3	7.1	14.2 ab	50.1 b	27.6	
Average	**11.8**	**6.2**	**15.0**	**51.8**	**28.6**	**22.7**
ANOVA[2] **(*P* -values)**						
Training	***(<0.0001)	*** (<0.001)	*** (<0.001)	***(<0.001)	**(<0.004)	
Spacing	NS (0.08)	NS (0.67)	NS (0.28)	NS (0.21)	NS (0.28)	
Rootstock	NS (0.13)	NS (0.83)	* (0.02)	**(0.003)	NS (0.70)	
Block	NS (0.11)	NS (0.06)	NS (0.34)	**(0.002)	**(0.01)	
Interaction[2] ***P* -values**						
Training x Rootstock	NS (0.33)	NS (0.49)	* (0.05)	NS (0.84)	NS (0.57)	
Spacing x Rootstock	* (0.02)	NS (0.30)	NS (0.32)	NS (0.10)	NS (0.41)	
Training x Spacing	NS (0.19)	NS (0.67)	** (0.01)	NS (0.50)	NS (0.12)	
Training x Spacing x Rootstock	NS (0.84)	~[3]	NS (0.38)	NS (0.31)	NS (0.42)	

[1] Within columns, 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] Insufficient replicated data.

Table 9: Effect of training system, spacing, and rootstock on firmness and soluble solids of 3rd-7th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2015-2019.

	Firmness (kg. force)					Soluble Solids (°Brix)				
	8/12-13/2015	8/8/2016	8/26-27/2017	8/31-9/1/2018	8/26-28/2019	8/12-13/2015	8/8/2016	8/26-27/2017	8/31-9/1/2018	8/26-28/2019
Training[1]										
2-Leader	9.4 ab	8.8	8.6 a	7.9 bc	6.7 ab	14.1	12.9 a	13.1 ab	13.3	14.0
Bi-axis	9.5 a	8.7	8.5 a	8.4 a	7.0 a	13.9	12.2 b	12.7 b	13.3	14.1
Tall Spindle	9.4 ab	8.5	8.4 a	8.3 ab	6.7 b	14.0	12.5 ab	12.8 b	13.4	13.8
V-Trellis	9.1 b	8.6	7.9 b	7.6 c	6.8 ab	14.1	12.8 a	13.2 a	13.5	14.1
Average	**9.4**	**8.7**	**8.4**	**8.1**	**6.8**	**14.0**	**12.6**	**13.0**	**13.4**	**14.0**
Spacing[1]										
3 feet	9.4	8.6	8.3	8.0	6.7	13.9	12.6 ab	13.0	13.4	14.1
4.5 feet	9.3	8.6	8.3	8.0	6.8	14.1	12.4 b	12.9	13.4	13.9
6 feet	9.4	8.7	8.5	8.0	6.9	14.1	12.9 a	13.0	13.3	13.9
Average	**9.4**	**8.6**	**8.4**	**8.0**	**6.8**	**14.0**	**12.6**	**13.0**	**13.4**	**14.0**
Rootstock[1]										
Pyro 2-33	9.5	8.7	8.5	8.1	6.8	13.7 b	12.3 b	12.8 b	13.3	14.1
OHxF 69	9.3	8.6	8.4	8.1	6.8	14.0 ab	12.6 ab	13.0 ab	13.2	13.8
OHxF 87	9.2	8.7	8.3	7.9	6.7	14.4 a	12.9 a	13.2 a	13.5	14.0
Average	**9.3**	**8.7**	**8.4**	**8.0**	**6.8**	**14.0**	**12.6**	**13.0**	**13.3**	**14.0**
ANOVA[2] (*P* -values)										
Training	*(0.02)	NS (0.24)	*** (<0.001)	*** (<0.001)	* (0.04)	NS (0.53)	** (0.002)	** (0.01)	NS (0.61)	NS (0.32)
Spacing	NS (0.82)	NS (0.44)	NS (0.56)	NS (0.96)	NS (0.12)	NS (0.64)	** (0.01)	NS (0.91)	NS (0.24)	NS (0.20)
Rootstock	NS (0.19)	NS (0.85)	NS (0.15)	NS (0.09)	NS (0.36)	**(0.01)	*** (0.001)	** (0.01)	NS (0.06)	NS (0.15)
Block	*(0.03)	*(0.04)	NS (0.40)	NS (0.10)	** (0.01)	*(0.03)	NS (0.36)	* (0.02)	** (0.002)	*** (0.001)
Interaction[2] *P* -values										
Training x Rootstock	NS (0.54)	NS (0.07)	NS (0.47)	NS (0.61)	NS (0.27)	**(0.01)	NS (0.39)	NS (0.90)	NS (0.61)	NS (0.54)
Spacing x Rootstock	NS (0.56)	NS (0.15)	NS (0.82)	NS (0.40)	NS (0.90)	NS (0.18)	NS (0.91)	NS (0.18)	NS (0.15)	NS (0.35)
Training x Spacing	NS (0.28)	NS (0.92)	*** (<0.001)	NS (0.07)	NS (0.55)	NS (0.13)	NS (0.23)	NS (0.97)	NS (0.51)	NS (0.94)
Training x Spacing x Rootstock	NS (0.43)	~[3]	NS (0.51)	NS (0.12)	NS (1.00)	NS (0.18)	~[3]	NS (0.67)	NS (0.83)	NS (0.16)

[1] Within columns, 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] Insufficient data for interaction.

Table 10: Effect of rootstock on fruit number and size, tree vigor, yield efficiency and root suckers of completely unpruned 7th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2019.

Treatment[1]	Fruit No. (no./tree) 8/28/2019	Fruit Size (g) 8/28/2019	Yield (kg/tree) 8/28/2019	Scion TCSA[3] (cm^2) 10 & 12/2019	Scion Yield Efficiency (kg/cm^2)	Rootstock TCSA[4] (cm^2) 10 & 12/2019	Rootstock Yield Efficiency (kg/cm^2)	Tree Heights (cm) 10/9-16/2019	Root Suckers (no./tree) 10/9-16/2019
OHxF 69	88	196	15.3	43.3 a	0.35	73.7 a	0.20	264 a	0.0
OHxF87	83	184	14.2	35.5 b	0.40	60.1 b	0.24	233 b	0.0
ANOVA (*P* -values)[2]									
Treatment	NS (0.77)	NS (0.10)	NS (0.59)	* (0.02)	NS (0.24)	* (0.03)	NS (0.18)	** (0.004)	~
Block	*** (<0.001)	*** (<0.001)	*** (<0.001)	NS (0.17)	*** (<0.001)	NS (0.21)	*** (0.001)	** (0.01)	~

[1] Within columns, 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] Measured 10 cm above union.

[4] Measured 5 cm below union.

Harvest date: 8/28/19

Table 11: Effect of rootstock on fruit number and size, tree vigor, yield efficiency and root suckers of completely unpruned 6th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2018.

Treatment[1]	Fruit No. (no./tree) 8/31-9/1/18	Fruit Size (g) 8/31-9/1/18	Yield (kg/tree) 8/31-9/1/18	Scion TCSA[3] (cm^2) 12/3/18	Scion Yield Efficiency (kg/cm^2)	Rootstock TCSA[4] (cm^2) 12/3/18	Rootstock Yield Efficiency (kg/cm^2)	Tree Heights (cm) 10/23/18	Root Suckers (no./tree) 10/23/18
OHxF 69	145	174	25.7	39.0 a	0.63	60.0 a	0.41	278 a	0.0
OHxF87	126	162	20.1	31.3 b	0.66	50.4 b	0.40	241 b	0.0
ANOVA (*P* -values)[2]									
Treatment	NS (0.33)	NS (0.13)	NS (0.15)	** (0.01)	NS (0.66)	* (0.02)	NS (0.89)	** (0.01)	~
Block	NS (0.43)	NS (0.09)	NS (0.31)	* (0.04)	*** (0.001)	* (0.02)	** (0.002)	** (0.01)	~

[1] Within columns, 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] Measured 10 cm above union.

[4] Measured 5 cm below union.

Harvest date: 9/1-4/18

Table 12: Cumulative effect of rootstock on fruit number and size, tree vigor, yield efficiency and root suckers of completely unpruned 3rd to 7th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2013-2019.

Treatment[1]	Average Fruit No. (per tree)	Average Fruit Size (g)	Average Cumulative Yield (kg)	2019 Scion TCSA (cm^2)	Scion Yield Efficiency[4] (kg/cm2)	2019 Rootstock TCSA (cm^2)	Rootstock Yield Efficiency[4] (kg/cm2)	Rootsuckers (no/tree)
OHxF 69	356	183 a	63.4	43.3 a	1.45	73.7 a	0.86	0.0
OHxF87	333	169 b	56.0	35.5 b	1.61	60.1 b	0.94	0.0
ANOVA (*P* -values)[2]								
Treatment	NS (0.47)	* (0.04)	NS (0.23)	* (0.02)	NS (0.18)	* (0.03)	NS (0.23)	~
Block	NS (0.23)	* (0.04)	NS (0.78)	NS (0.17)	NS (0.42)	NS (0.21)	NS (0.58)	~

[1] Within columns, treatment means significantly different (Duncan Multiple Range test, *P* ≤0.05).

[2] * Indicates significance at *P* ≤0.05. NS indicates not significant.

[3] Based on fruiting years 2014-2019.

[4] Based on cumulative yield (2014-2019) and final TCSA (2019).

Table 13: Cumulative effect of rootstock on fruit number and size, tree vigor, yield efficiency and root suckers of completely unpruned 3rd to 6th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2013-2018.

Treatment[1]	Average Fruit No. (per tree)	Average Fruit Size (g)	Average Cumulative Yield (kg)	2018 Cultivar TCSA (cm^2)	Cultivar Yield Efficiency[4] (kg/cm^2)	Rootstock TCSA (cm^2)	Rootstock Yield Efficiency[4] (kg/cm^2)	Root Suckers (no./tree)
OHxF 69	268	181	48.0	39.0 a	1.62	60.0 a	0.81	0.0
OHxF87	249	166	41.8	31.3 b	1.18	50.4 b	0.84	0.0
ANOVA (*P* -values)[2]								
Treatment	NS (0.47)	NS (0.08)	NS (0.20)	** (0.01)	NS (0.16)	* (0.02)	NS (0.54)	~
Block	NS (0.56)	NS (0.41)	NS (0.38)	* (0.04)	*** (<0.001)	* (0.02)	*** (<0.001)	~

[1] Within columns, treatment means significantly different (Duncan Multiple Range test, *P* ≤0.05).

[2] *, **, *** Indicate significance at *P* ≤0.05, 0.01, and 0.001 respectively. NS indicates not significant.

[3] Based on fruiting years 2014-2018.

[4] Based on cumulative yield (2014-2018) and final TCSA (2018).

Table 14: Effect of rootstock on firmness and soluble solids of completely unpruned 3rd to 6th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2015-2019.

	Firmness (kg force)					Soluble Solids (° Brix)				
Treatment[1]	2015[3]	2016[4]	2017[5]	2018[6]	2019[7]	2015[3]	2016[4]	2017[5]	2018[6]	2019[7]
OHxF 69	9.2	8.1	7.7	6.3	6.5 b	14.1	14.1	13.6 b	14.0	13.6 b
OHxF87	9.4	8.3	7.9	6.7	6.8 a	14.5	14.5	14.2 a	14.2	14.8 a
ANOVA (*P* -values)[2]										
Treatment	NS (0.52)	NS (0.53)	NS (0.12)	NS (0.16)	* (0.05)	NS (0.07)	NS (0.07)	** (0.01)	NS (0.36)	** (0.003)
Block	NS (0.20)	NS (0.24)	NS (0.51)	NS (0.21)	NS (0.18)	** (0.01)	* (0.03)	** (0.01)	* (0.02)	** (0.002)

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

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

[3] Samples collected at harvest : 8/12/15, measured 8/26, 28, 31/15.

[4] Samples collected at harvest : 8/8/16, measured 8/9, 10, 12/16.

[5] Samples collected at harvest : 8/26/17, measured 8/28, 30, 31/17.

[6] Samples collected at harvest : 9/1/18, measured 9/5, 13/18.

[7] Samples collected at harvest : 8/28/19, measured 8/31/19.

Table 15: Effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 7th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2019.

Treatment[1]	Fruit No. (per tree)	Fruit Size (g)	Yield (kg/tree)	Cultivar TCSA[3] (cm^2)	Cultivar Yield Efficiency (kg/cm^2)	Rootstock TCSA (cm^2)	Rootstock Yield Efficiency	Tree Heights (cm)	Root Suckers (per tree)
Spreading	141.4	126.2	17.7	86.1	0.20	48.5	0.36	243	0.0
No Spreading	108.8	178.2	19.0	104.5	0.18	73.7	0.26	242	0.0
***P* -value**[2]	NS (0.27)	* (0.02)	NS (0.76)	NS (0.26)	NS (0.62)	* (0.03)	NS (0.11)	NS (0.99)	~

Table 16: Cumulative effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 2nd-7th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2013-2019.

Treatment[1]	Average Fruit No. (per tree)	Average Fruit Size (g)	Average Yield (kg)	2019 Scion TCSA[3] (cm2)	Scion Yield Efficiency (kg/cm2)	2018 Rootstock TCSA (cm2)	Rootstock Yield Efficiency (kg/cm2)	Root Suckers (per tree)
Spreading	457	162	69.3	86.1	0.81	48.5	1.43	0.0
No Spreading	398	181	71.1	104.5	0.68	73.7	0.96	0.0
***P* -value**[2]	NS (0.48)	NS (0.10)	NS (0.89)	NS (0.26)	NS (0.15)	* (0.03)	** (0.003)	~

[1] Means analyzed by T-test, $P \leq 0.05$).
[2] *, ** Indicates significance at P<0.05 and 0.01 respectively. NS indicates not significant.
[3] Total of two scaffolds.
Harvest Date - 8/28/2019

Table 17: Effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 6th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2018.

Treatment[1]	Fruit No. (per tree)	Fruit Size (g)	Yield (kg/tree)	Cultivar TCSA[3] (cm^2)	Cultivar Yield Efficiency (kg/cm^2)	Rootstock TCSA (cm^2)	Rootstock Yield Efficiency	Tree Heights (cm)	Root Suckers (per tree)
Spreading	141.4	163.2	22.8	74.6	0.30	46.4	0.49	267	0.0
No Spreading	160.2	175.4	27.6	91.1	0.30	61.2	0.45	269	0.0
***P* -value**[2]	NS (0.60)	NS (0.35)	NS (0.36)	NS (0.26)	NS (0.85)	NS (0.09)	NS (0.44)	NS (0.96)	~

Table 18: Cumulative effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 6th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2013-2018.

Treatment[1]	Average Fruit No. (per tree)	Average Fruit Size (g)	Average Yield (kg)	2018 Cultivar TCSA[3] (cm2)	Cultivar Yield Efficiency (kg/cm2)	2018 Rootstock TCSA (cm2)	Rootstock Yield Efficiency (kg/cm2)	Root Suckers (per tree)
Spreading	316	169	51.6	74.6	0.70	46.4	1.12	0.0
No Spreading	289	182	52.1	91.1	0.57	61.2	0.84	0.0
***P* -value**[2]	NS (0.68)	NS (0.23)	NS (0.96)	NS (0.26)	NS (0.06)	NS (0.09)	** (0.01)	~

[1] Means analyzed by T-test, $P \leq 0.05$).
[2] ** Indicates significance at P<0.05. NS indicates not significant.
[3] Total of two scaffolds.

Table 19: Effect of scaffold spreading on firmness and soluble solids on Bi-axis trained 3rd to 6th leaf 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2015-2019.

	Firmness (kg force)					Soluble Solids (° Brix)				
Treatment[1]	2015[3]	2016[4]	2017[5]	2018[6]	2019[7]	2015[3]	2016[4]	2017[5]	2018[6]	2019[7]
Spreading	8.7	8.2	6.9	6.3	6.4	14.4	31.1	13.6	14.1	13.9
No Spreading	8.7	8.3	7.1	6.2	6.4	14.3	13.1	14.2	13.9	14.1
P -value[2]	NS (1.00)	NS (0.84)	NS (0.76)	NS (0.70)	NS (0.68)	NS (0.73)	NS (0.86)	NS (0.22)	NS (0.50)	NS (0.63)

[1] Means analyzed by T-test, $P \leq 0.05$).
[2] NS indicates not significant.
[3] Samples collected at harvest : 8/12/15, measured 8/26, 28, 31/15.
[4] Samples collected at harvest : 8/8/16, measured 8/9, 10, 12/16.
[5] Samples collected at harvest : 8/26/17, measured 8/28, 30, 31/17.
[6] Samples collected at harvest : 9/1/18, measured 9/5, 13/18.
[7] Samples collected at harvest : 8/28/19, measured 10/31/19.

Table 20: Comparison of average mid-day stem water potential (negative bars) for OHxF 87 and Pyro 2-33 rootstocks by training and spacing for 'Bartlett' pear trees, Hopland, Mendocino County, Californis, 2014-2019.

	2014[4] (n=5)			2015[4] (n=10)			2016[4] (n=14)		
Treatment[1]	OHxF 87	Pyro 2-33	*P* -value[2]	OHxF 87	Pyro 2-33	*P* -value[2]	OHxF 87	Pyro 2-33	*P* -value[2]
Bi-axis x 3 ft.	14.4	14.2	NS (0.84)	18.2	17.4	NS (0.61)	16.3	16.8	NS (0.80)
Bi-axis x 6 ft.	14.9	15.0	NS (0.94)	18.2	17.7	NS (0.72)	16.9	15.7	NS (0.52)
V-Trellis x 3ft.	14.4	15.5	NS (0.53)	17.9	18.7	NS (0.60)	16.2	17.0	NS (0.67)
V-Trellis x 6ft.	14.5	14.7	NS (0.93)	18.9	18.8	NS (0.95)	17.2	16.7	NS (0.82)
2-Leader x 3 ft.	12.2	13.7	NS (0.20)	17.0	17.3	NS (0.87)	15.8	16.4	NS (0.75)
2-Leader x 6 ft.	14.8	14.5	NS (0.88)	17.9	17.9	NS (0.98)	17.9	16.9	NS (0.62)
Tall Spindle x 3 ft.	13.5	14.4	NS (0.42)	18.7	17.8	NS (0.62)	16.8	16.6	NS (0.92)
Tall Spindle x 6 ft.	15.0	15.2	NS (0.88)	19.1	18.4	NS (0.66)	16.9	16.4	NS (0.80)
Baseline[3]	7.7			7.7			7.6		

	2017[4] (n=9)			2018[4] (n=8)			2019[4] (n=8)		
Treatment[1]	OHxF 87	Pyro 2-33	*P* -value[2]	OHxF 87	Pyro 2-33	*P* -value[2]	OHxF 87	Pyro 2-33	*P* -value[2]
Bi-axis x 3 ft.	17.7	15.9	* (0.03)	14.2	13.8	NS (0.52)	14.1	13.9	NS (0.92)
Bi-axis x 6 ft.	16.6	15.2	NS (0.18)	13.8	13.4	NS (0.68)	13.3	13.4	NS (0.92)
V-Trellis x 3ft.	18.6	17.7	NS (0.51)	12.9	14.6	NS (0.13)	13.2	14.7	NS (0.44)
V-Trellis x 6ft.	18.6	17.6	NS (0.41)	14.2	14.1	NS (0.89)	13.8	13.6	NS (0.91)
2-Leader x 3 ft.	16.6	18.4	NS (0.12)	12.9	14.2	NS (0.21)	12.9	15.0	NS (0.25)
2-Leader x 6 ft.	19.0	17.7	NS (0.30)	14.9	13.9	NS (0.40)	13.8	14.4	NS (0.79)
Tall Spindle x 3 ft.	17.9	18.2	NS (0.85)	15.1	15.3	NS (0.84)	15.8	14.7	NS (0.51)
Tall Spindle x 6 ft.	18.3	18.9	NS (0.73)	13.5	14.6	NS (0.20)	13.2	14.4	NS (0.55)
Baseline[3]	8.1			7.7			7.6		

[1] Means analyzed by T-test, *P* ≤0.05).

[2] * Indicates significance at *P* ≤0.05. NS indicates not significant.

[4] Monitor period: 2014: 6/3-10/6, 2015: 6/4-10/1, 2016: 6/23-9/26, 2017: 6/2-9/27, 2018: 6/14-10/18, 2019: 6/12-10/14.

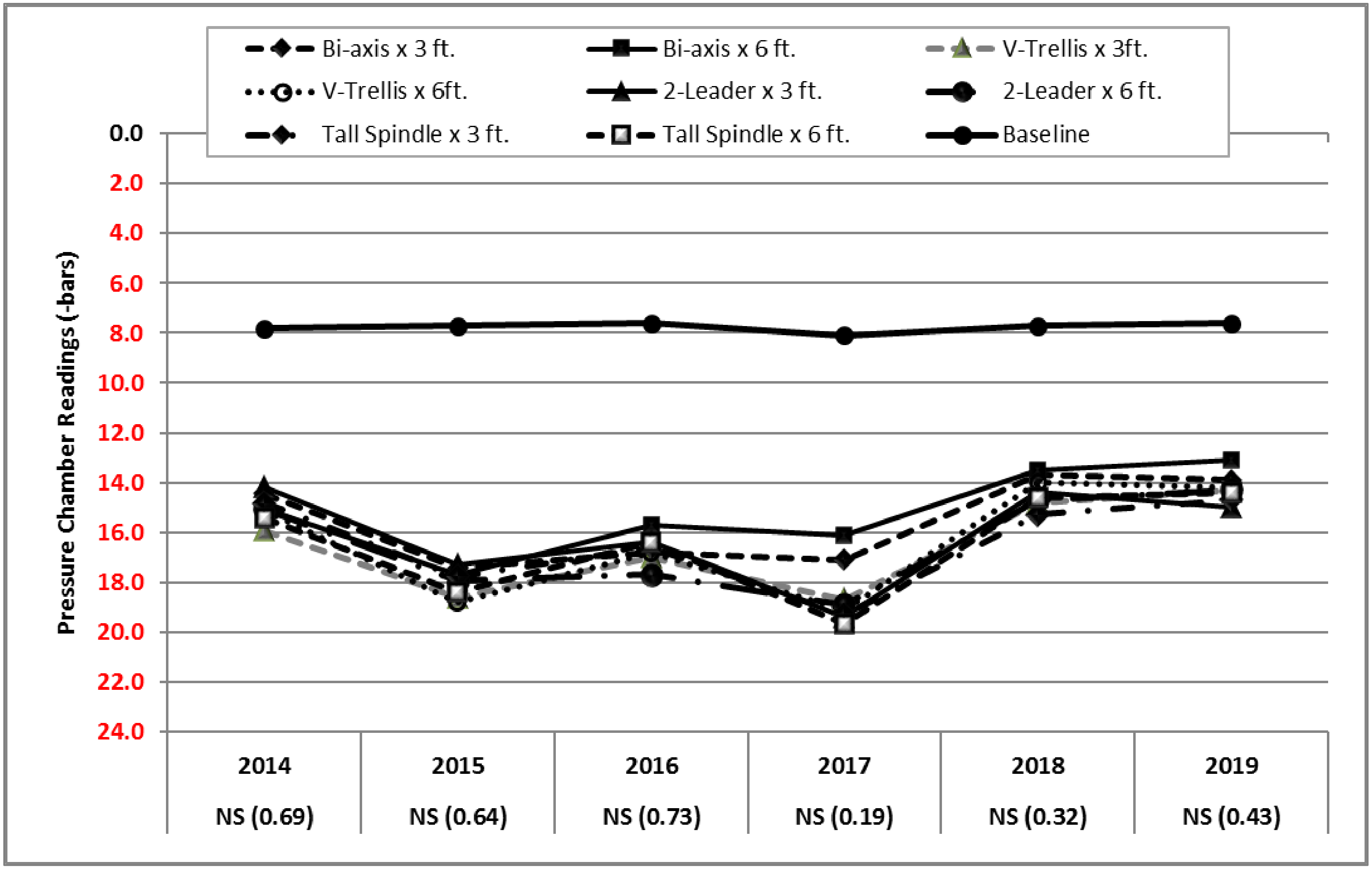
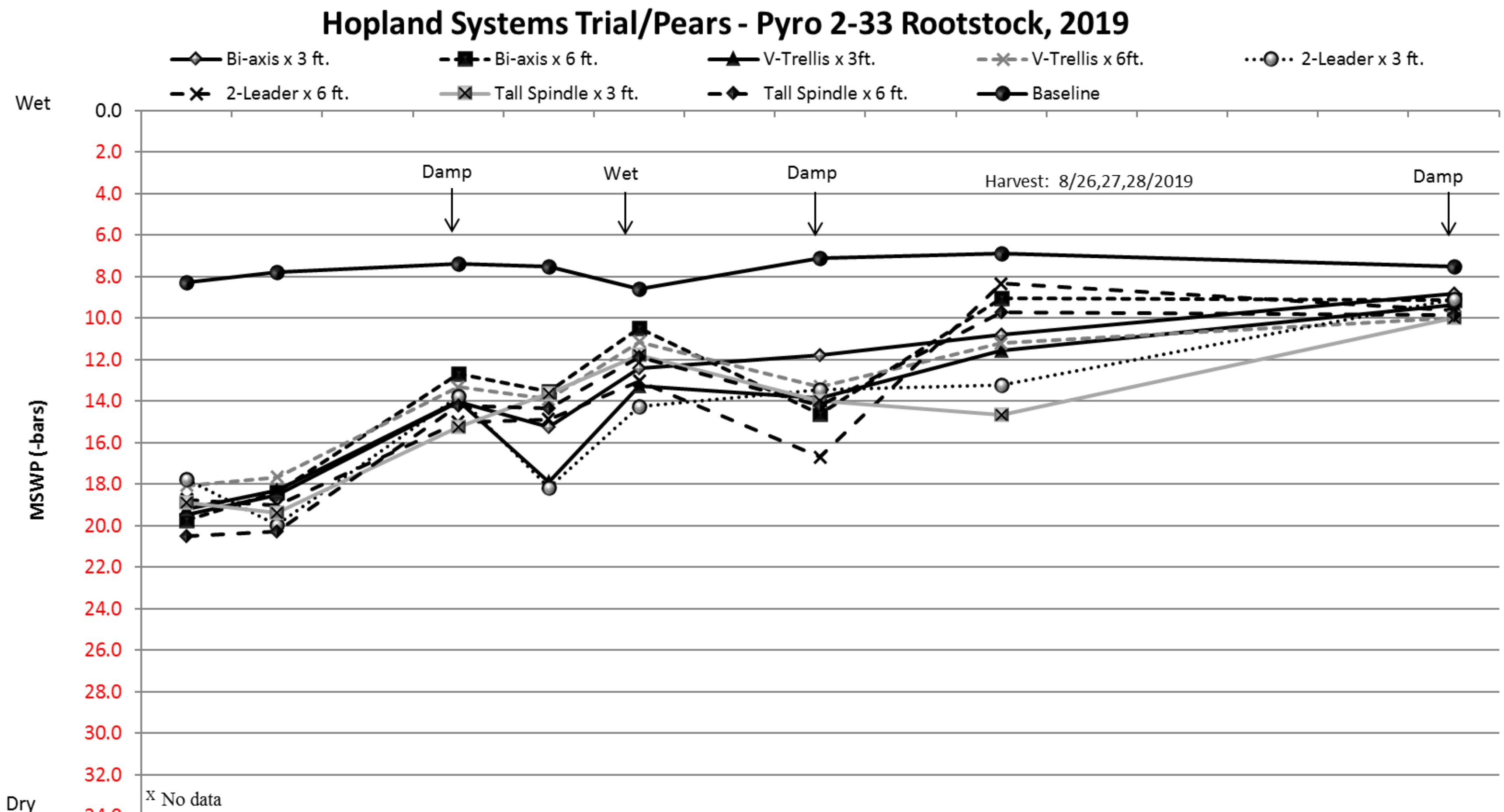


Figure 2: Effect of training system and spacing on seasonal average mid-day stem water potential (MSWP) of 2nd-7th leaf "Bartlett" pear trees on Pyro 2-33 rootstock, Hopland, Mendocino County, California, 2014-2019.



	6/12	6/18	6/29 X	7/9	7/18	7/23	7/31 X	8/6	8/16 X	8/20	9/1 X	9/9 X	9/17 X	9/25 X	10/14
ETo:	1.69	1.70	1.57	1.63	1.63	1.75	1.73	1.72	1.52	1.57	1.50	1.40	1.29	1.21	0.87
Predicted ETo:	1.55	1.75	1.80	1.69	1.79	1.72	1.66	1.67	1.57	1.57	1.40	1.37	1.15	1.15	0.89

Figure 3: Comparison of mid-day stem water potential (MSWP) and baseline (-7 to-9 bars) among Pyro 2-33 rootstock, 7th-leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2019.

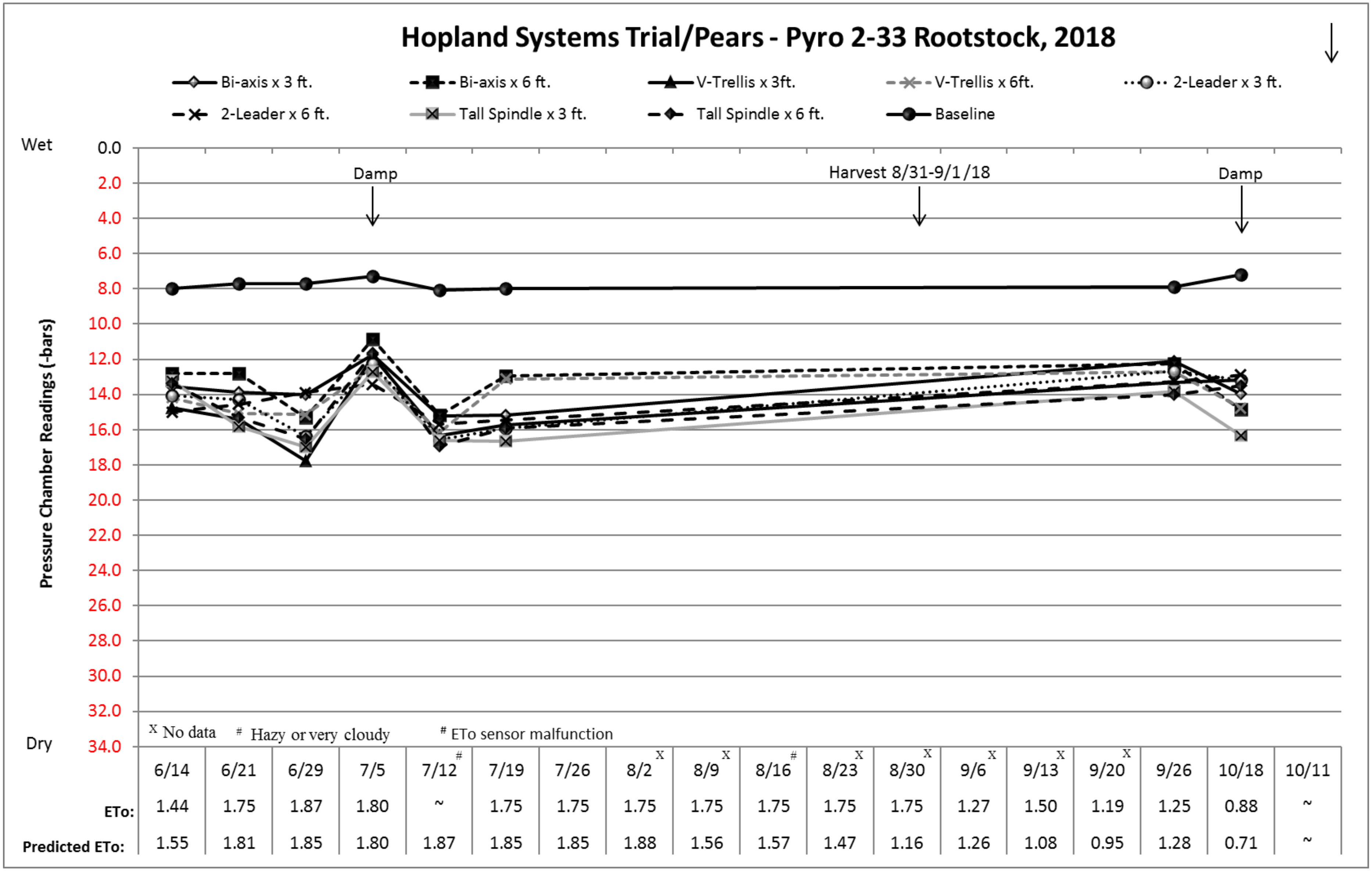


Figure 4: Comparison of mid-day stem water potential (MSWP) and baseline (-7 to-9 bars) among Pyro 2-33 rootstock, 6th-leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2018.

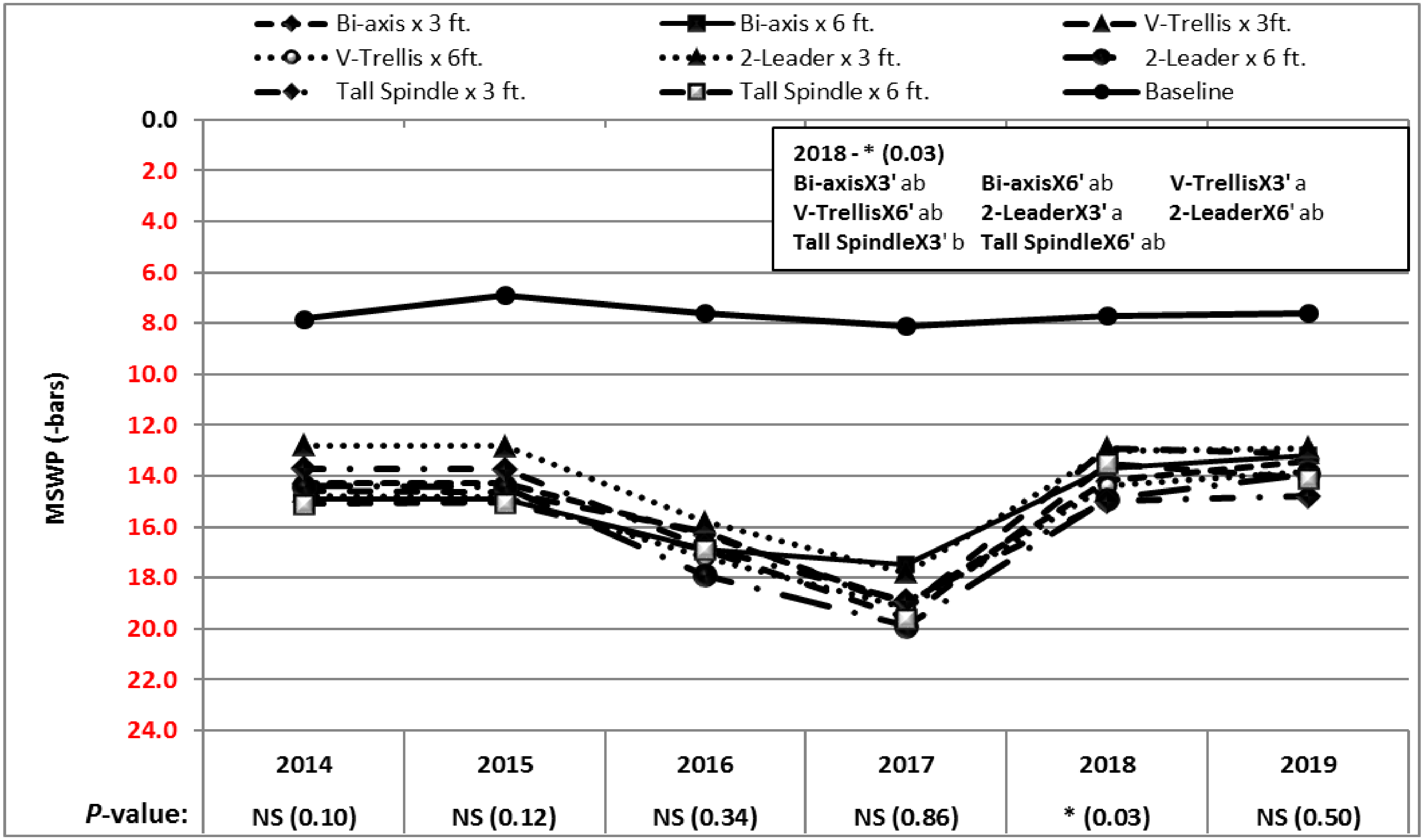
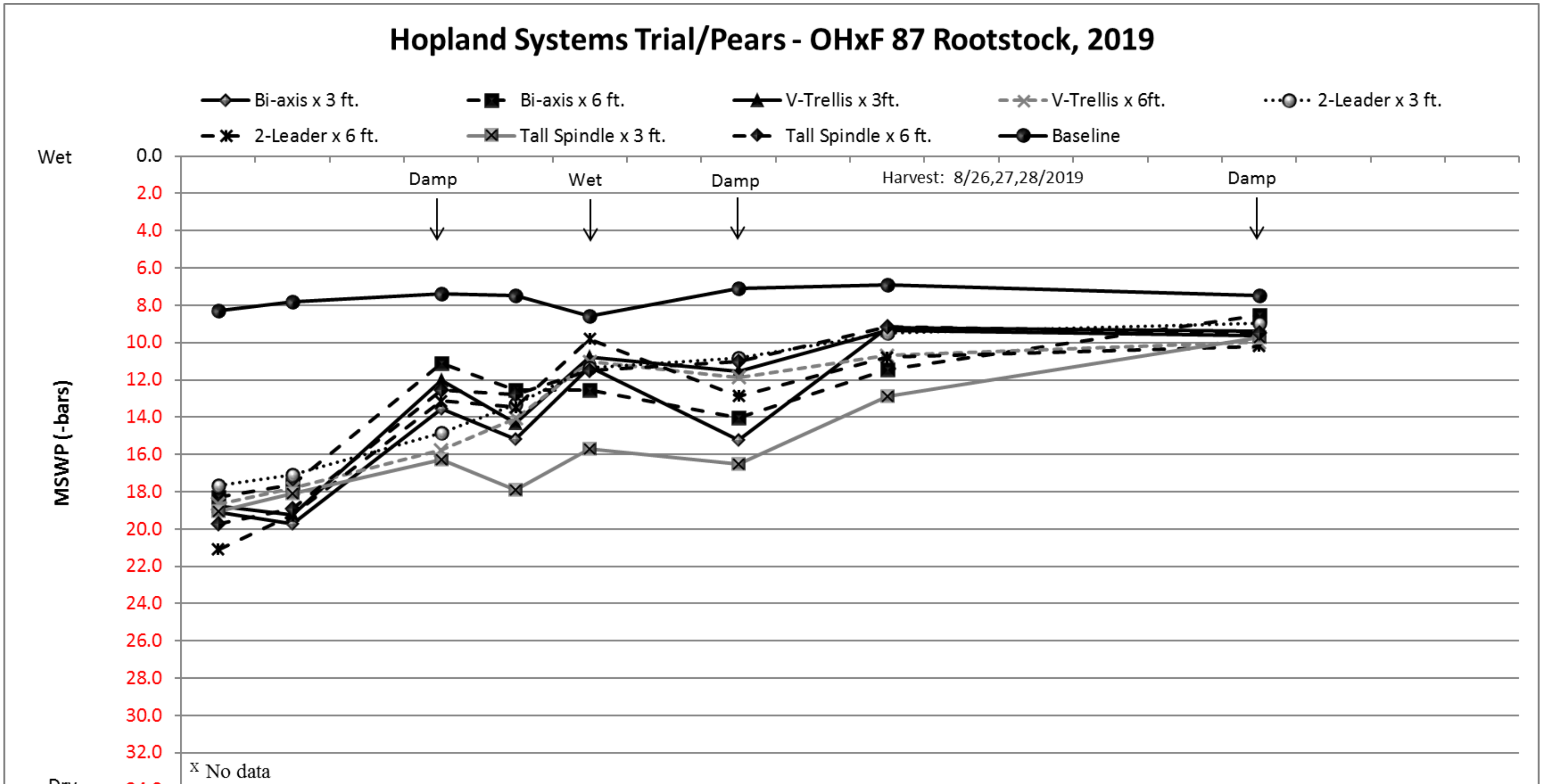


Figure 5: Effect of training system and spacing on seasonal average mid-day stem water potential (MSWP) of 2nd-7th leaf "Bartlett" pear trees on OHxF 87 rootstock, Hopland, Mendocino County, 2014-2019.



	6/12	6/18	6/29[x]	7/9	7/18	7/23	7/31[x]	8/6	8/16[x]	8/20	9/1[x]	9/9[x]	9/17[x]	9/25[x]	10/14	10/21[x]	10/28[x]	11/4[x]
ETo:	1.69	1.70	~	1.63	1.63	1.75	~	1.72	~	1.57	~	~	~	~	0.87	~	~	~
Predicted ETo:	1.55	1.75	~	1.69	1.79	1.72	1.80	1.67	~	1.57	~	~	~	~	0.89	~	~	~

Figure 6: Effect of training system and spacing on weekly mid-day stem water potential (MSWP) of 7th-leaf 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2019.

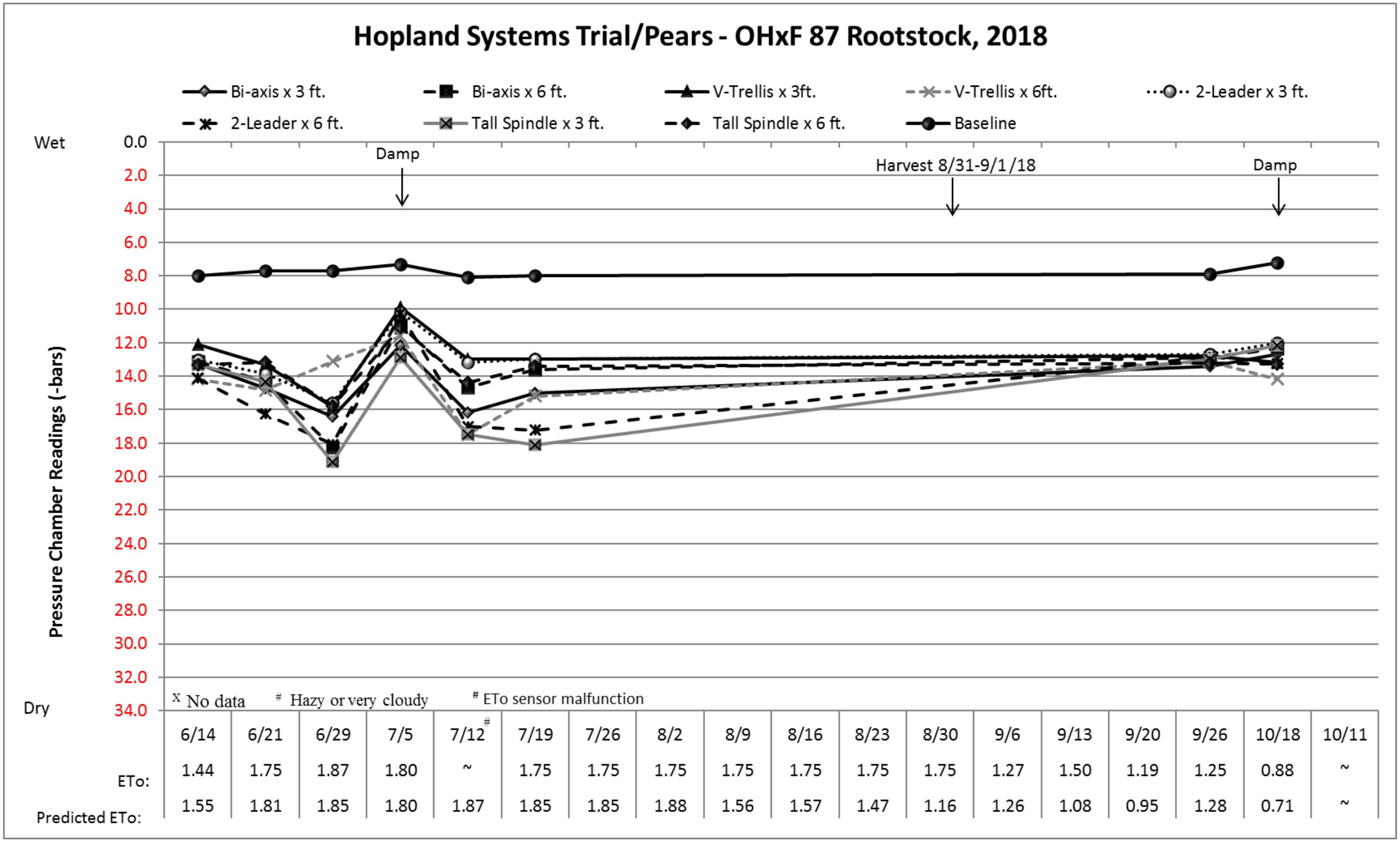


Figure 7. Effect of training system and spacing on weekly mid-day stem water potential (MSWP) of 6th-leaf 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2018.