

HIGH DENSITY ORCHARD SYSTEMS FOR EUROPEAN PEAR: 2013 NC-140 REGIONAL ROOTSTOCK PROJECT (2017 Progress Report)

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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 2014; Elkins, Bell and Einhorn 2012). Many remaining California growers are considering replanting options, or have already replanted relatively 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 cultivar '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. 2017 overall trial yield increased 590% over 2016 (a very low yielding year). Completely unpruned trees in an adjacent row to treatment trees yielded four times more than trained trees. V-T yielded most and 2-L and B-A least. 6' spaced trees yielded significantly more than 4.5' or 3'. OHxF 87 yielded most and Pyro 2-33 least. Fruit size increased from average 182 in 2016 to 232 gms in 2017. V-T, B-A and OHxF 69 fruit was largest, with no spacing differences. Fruit was harvested later and at slightly lower maturity 2017 (August 26 - 27) than 2016 (August 8) (8.4 vs. 9.6 kg. and 13.0 vs. 14.0 °B). Mid-day stem water potential (MSWP) never reached baseline in either 2016 or 2017. Final MSWP was similar to 2016, and August 11 MSWP ranged from 14-19 bars, versus 28-33 bars in 2016. There were no differences among treatments through 2017, however B-A x 3' x OHxF 87 trees were significantly more stressed than Pyro 2-33 within this combination. Pyro 2-33 exhibited slightly more stress than OHxF 87 (range 28-33 bars versus 26-31 bars) on August 11, 2016, the date of lowest recorded MSWP (OHxF 69 MSWP is not measured). Cumulative from 2013-2017, survival rate is 97.2%. B-A, TS, and V-T trees were largest (B-A trees had the largest total TCSA with both scaffolds combined). TS and V-T systems, 6' spaced, OHxF 87 trees were most precocious and efficient, while B-A, system, 4.5' spacing, and Pyro 2-33 rootstock trees the least. 6' spacing trended toward having the largest and most fruit. There were no root suckers differences. For spread versus unspread B-A trees on OHxF 87, there was a trend toward higher yield but smaller fruit in unspread versus spread trees. There were interactions for fruit number, yield, rootstock TCSA, and cultivar and yield efficiency. Effects of training, spacing, and rootstocks on tree growth, suckering, fruiting and harvest maturity will continue in 2018.

INTRODUCTION

The California pear industry has shrunk considerably in the past several decades, both in number of growers and total acreage. There are many reasons for this, which have been described (Elkins, Bell and Einhorn, 2012). Supply and demand have balanced, leading remaining growers to consider replanting older low density orchards. Several have either already replanted relatively small acreages, or are considering doing so. Economic evaluation, as well as one such planting in the Ukiah Valley of Mendocino County that has now completed its 12th year, 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 must be resubmitted for authorization every five years; the 2017-2022 NC140 Regional Research Project Proposal may be download 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 planned for North Carolina) 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.

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), and Geneva, New York (NY) to evaluate multiple combinations of training systems, spacings, and promising commercially-available rootstocks for the European pear cultivars ‘Bartlett’ (California), ‘D’Anjou’ (Oregon), and ‘Bosc’ (New York). The 2013 trial succeeds the 10-year 2005 multi-state rootstock trial that was formally completed in 2014 (Elkins 2014; 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 five growing seasons (5th 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. The information gained from the trial will benefit future planting decisions.

OBJECTIVES

The objectives of this multi-state, multi-factor trial are to 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);
- 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 Mussachi, formerly of the 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 none available, 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. Micropropagated 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. Final 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). 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 delays¹.

Data Collection

Tree training and crop load management: From 2013 through 2017 training emphasized leader development, proper shaping, and thinning to optimize fruiting wood distribution. 2017 pruning was modified from 3- to 2-dimensional (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 pruning was done using thinning rather than heading cuts. Fruit was removed on weak trees but left if vigor appeared adequate.

Tree survival, growth and vigor (2013-2017): Percent surviving trees was determined. Trunk cross-sectional area (TCSA) of both cultivar (10 cm. above graft union) and rootstock (5 cm. below graft union) was 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. 2017 tree height is yet to be measured. 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 will be 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 (2014-2017) per tree were measured and both cultivar and rootstock yield efficiency (YE) calculated (see above for why rootstock TCSA was recorded). 2015-2017 data also included number of fruit removed prior to harvest (an indicator of overall vigor) and firmness (kg) and soluble solids (°Brix). In 2014-2017, 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.

¹ While *Armillaria mellea* has infected trees in the orchard, average tonnage of existing trees approached 40 tons per acre; it is thus felt oak root fungus will not hinder trial results for the duration of the trial as long as prudent measures are taken to manage irrigation properly.

Data was analyzed using ANOVA and means separated using Tukey HSD test, $p \leq 0.05$ (rootsuckers by Duncans MRT, $p \leq 0.10$) (Statgraphics Centurion XVI, 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 2013-2017, there were some significant interactions among treatments, mainly training x rootstock, but also spacing x rootstock and training x spacing x rootstock (fruit number, yield). For this report, only overall differences among the three main treatments are discussed (training, spacing, rootstock); analysis for each individual combination (36 total) will commence in 2018.

2016-2017 AND CUMULATIVE 2013-2017 RESULTS (Tables 1-13) (2013-2014 results summarized in Elkins and Lampinen 2016 and 2015, Elkins 2014)).

Tree survival, growth, and vigor (Tables 1-3): Only two trees have died since 2014 and none in 2017. 15 out of 540 trees, or 2.8%, have succumbed (data not shown): 2 2-L/Pyro 2-33, 2 2-L/OHxF 87, 5 B-A/OHxF 87, 2 B-A OHxF 69, 1 B-A/Pyro 2-33, 1 TS/OHxF 69, 1 V-T/Pyro 2-33, and 1 V-T/OHxF 69, for a total of 4 Pyro 2-33, 4 OHxF 69, and 7 OHxF 87.

2017 cultivar and rootstock TCSA increased 22-23% from 2016, with all training systems and spacings increasing similarly. Pyro 2-33 tree size increased more than the OHxF trees. 2017 and cumulative 2013-2017 tree size results were very similar. 2-L trees had the smallest cultivar single leader TCSA with other systems being equal (averaging both B-A leaders). However, B-A and 2-L rootstock TCSAs (below graft union) were smaller than those of TS and V-T. 6' spaced trees were largest, followed by 4.5' then 3'. OHxF 69 trees were largest, with Pyro 2-33 and OHxF trees equally smaller. There was a training x rootstock interaction for rootstock (as well as trend toward spacing x rootstock) but not cultivar TCSA. There were few suckers.

Productivity (fruit number, fruit size, yield, yield efficiency) (Tables 1-3): Average fruit number increased 477% and yield 630% from 2016 (percent change not shown) across all treatments. TS fruit number increased most (595%) and 2-L least (365%). 3' and 4.5' spaced (520%) and OHxF 87 (500%) fruit number increased most. In 2017, TS and V-T had the most fruit (15.3 and 18.3 respectively). There were no differences among spacings (average 12.7). Among rootstocks, OHxF 87 had the most fruit (18.0), followed by OHxF 69 (11.9), then Pyro 2-33 (8.1).

Overall average fruit size increased 27% from 2016 to 2017 (average 182 to 232 gm). B-A and V-T increased most (average 34%) and 2-L least (16%). 6' spacing increased most (35%) and others about 25%. Rootstock differences were most apparent, with OHxF 69 size increasing 46%, Pyro 2-33 35% and OHxF 87 only 7% (208 to 222 gm), unsurprising given the large increase in fruit number (500% increase). Training systems V-T and B-A had the largest fruit (240 and 238 gm), followed by 2-L (229 gm) then TS (218 gm). There were no significant spacing differences. OHxF 69 had the largest fruit (242 gm), followed by Pyro 2-33 then OHxF 87 (222 gm).

Average yield for all treatments increased 590%. TS increased most (705%) and 2-L least (425%). 3' and 4.5' spacing increased most, and rootstocks increased similarly. V-T yielded most (4.3 kg), followed by TS (3.3 kg) then 2-L and B-A (2.1 and 1.9 kg). There were significant differences among spacings (following a trend in 2016). 6' yielded most (3.2 kg) followed by 3' (2.9) then 4.5' (2.6 kg). OHxF 87 yielded most (4.0 kg), followed by OHxF 69 (2.8 kg) then Pyro 2-33 (1.8 kg).

Yield efficiencies (YE) increased much less than other variables, reflecting the suppressive effect of increased crop load on vegetative growth and vigor. Cultivar (above graft union) YE increased slightly more than rootstock (below graft union) YE (average 11 vs. 8%). Among training systems, TS increased most (550%) and 2-L least (233%). 6' spacing YE increased one-third more than other spacings (650% vs. (about 400%)) and OHxF 87 YE (650%) increased twice or more than other rootstocks. Rootstock YE increases were much less than cultivar, averaging 75 (2-L) to 300% (TS) for training system, 100 (6') to 167% (3') for spacing, and 67 (Pyro 2-33) to 250% (OHxF 69) for rootstocks. On a single leader basis 2-L YE was less than other training systems (20 vs. 25 kg/cm²). Spacing YE was highest for 6' (.12) followed by 3' (.11) then 4.5' (.10). OHxF 87 YE (.15) was about one-third higher than OHxF 69 or Pyro 2-33 (.09 and .08, respectively). Rootstock YE pattern was similar to cultivar YE. The pattern of average cumulative 2013-2017 results was similar to 2017. TS and V-T trees were the most precocious based on number of fruit and yield (nearly to over double other systems), and were also most efficient, followed by 2-L and lastly, B-A. There were no spacing differences in fruit number, but 3' spacing had the largest fruit, followed by 6', then 4.5'. Yield efficiency was highest 6' followed by 4.5' then 3'. OHxF87 had the most fruit and highest yield efficiency followed by OHxF69. Pyro 2-33 had the largest fruit (205 gms) but lowest yield (2.9 gms) and yield efficiency (0.13 kg/cm²). OHxF69 and 87 fruit size was equal (195 and 1192 gms. respectively). There were training and rootstock interactions. OHxF 87 yielded the most (7.6 kg/tree), followed by OHxF 69 (5.6 kg), and lastly Pyro 2-33 (2.9 kg).

For treatments except V-T (6.6%), an average of 15-23% total fruit per tree was removed prior to harvest either to preserve vigor or facilitate leader development. OHxF69 had the largest fruit (242 gm), followed by Pyro 2-33 (231 and 222 gm respectively) and OHxF 87 (173 gm) (Table 4).

Firmness and soluble solids (Tables 5, 7): Values for both were higher in 2017. V-T fruit was least firm but sweetest, followed by OHxF 69, then Pyro 2-33. and OHxF 87 sweetest. Only soluble solid training x rootstock interactions were significant. firmness and soluble solids. Unpruned trees (see below) had lower firmness but higher soluble solids than trained trees.

Completely unpruned trees (Tables 6-9): OHxF 69 trees were significantly larger than OHxF 87. Fruit number was equal, though trended toward larger for OHxF 69. Fruit size was larger on trained trees (242 vs. 213 gms for OHxF 69; 222 vs. 191 gms for

OHxF 87). Yield, and yield efficiency were similar, though yield efficiency trended higher for OHxF 87. Fruit number, yield, and yield efficiency were about four times higher on unpruned trees, but fruit smaller (not compared statistically). Unpruned 2017 yield was three to four times greater than trained trees but rootstocks equal within untrained.

Spread versus unspread Bi-Axis/OHxF 87 (Tables 10-12): From 2013-2017, only cultivar yield efficiency differed significantly, likely due to fruit size difference. In 2017, unspread trees had significantly larger fruit (213 vs. 175 gms). Spread trees had numerically more fruit and yield, and significantly higher yield efficiency. There were no differences in firmness and soluble solids.

Mid-day Stem Water Potential (MSWP) (Table 14, Figures 2-8): Measurements ceased from August 11 - September 27, however final MSWP was similar to 2016, and August 11 MSWP ranged from 14-19 bars, versus 28-33 bars in 2016. There were no differences among treatments through 2017, however B-A x 3' x OHxF 87 trees were significantly more stressed than Pyro 2-33 for the same spacing and rootstock (Table 14). TCSA of both MSWP of Pyro 2-33 trees was lower than 2014 but slightly higher than 2015. OHxF 87 MSWP continued to decline in previous years. Values were consistently below baseline in all years. Maximum stress occurred in mid-August in 2016 versus mid-September in 2015. There were few differences among training systems (though OHxF 87 exhibited slightly more variability) however Pyro 2-33 exhibited slightly more stress than OHxF 87 (range 28-33 bars versus 26-31 bars) on August 11, 2016, the date of lowest recorded MSWP

2013-2017 DISCUSSION AND 2018 PLANS

After five growing seasons, training and rootstock appear to be the most important factors in determining early tree growth and productivity. TS and V-T are the most productive training systems to date, with V-T having the largest fruit of the two. Spacing differences were more subtle year to year but were significant in 2017 cumulatively. after . OHxF 69 and 87 fruit size was equal but OHxF 87 fruit number and yield exceeded that of OHxF 69 and Pyro 2-33 lags well behind both OHxF rootstocks. V-T has required the least fruit removal to maintain vigor and promote leader development. OHxF 87 exhibited more water stress in 2017.

Spreading of B-A trees has increased fruit number and yield efficiency, but reduced fruit size. Completely forgoing pruning in early years appears to encourage early fruiting however may compromise fruit size as trees mature.

Tree training and data collection will continue in 2018 (Year 6).

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Table 1: Cumulative effect of training system, spacing, and rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of 5th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2013-2017.

	Average Fruit No. (per tree)	Average Fruit Size ³ (g)	Average Yield (kg)	2017 Cultivar TCSA (cm ²)	Average Cumulative Cultivar Yield Efficiency ⁴ (kg/cm ²)	Root Suckers ⁵ (no./tree)
Training¹						
2-Leader	18.7 b	202 ab	3.8 b	19.9 c	.18 b	.47
Bi-axis [#]	15.7 b	209 a	2.3 b	51.7 a	.06 c	.27
Tall Spindle	36.6 a	183 c	6.9 a	25.0 b	.27 a	.23
V-Trellis	38.1 a	195 b	7.6 a	24.0 b	.30 a	.22
Spacing¹						
3 feet	26.5	202 a	5.2 ab	28.9 b	.21 ab	.34
4.5 feet	25.6	194 b	5.0 b	30.5 ab	.19 b	.23
6 feet	29.7	195 ab	5.9 a	31.2 a	.22 a	.33
Rootstock¹						
Pyrodwarf 2-33	14.4 c	205 a	2.9 c	27.7 b	.13 c	.31
OHxF 69	28.5 b	195 b	5.6 b	33.3 a	.19 b	.24
OHxF 87	39.0 a	192 b	7.6 a	29.4 b	.29 a	.35
ANOVA (<i>P</i> -values)²						
Training	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.17)
Spacing	NS (0.07)	*(0.04)	*(0.03)	** (0.01)	*(0.02)	NS (0.59)
Rootstock	***(<0.001)	** (0.002)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.51)
Block	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.10)
Interaction (<i>P</i> -values)²						
Training x Rootstock	***(<0.001)	NS (0.85)	** (0.002)	NS (0.35)	***(<0.001)	NS (0.21)
Spacing x Rootstock	*(0.04)	NS (0.10)	NS (0.08)	NS (0.45)	NS (0.33)	NS (0.71)
Training x Spacing	NS (0.40)	NS (0.20)	NS (0.29)	NS (0.35)	NS (0.08)	NS (0.48)
Training x Spacing x Rootstock	*(0.02)	NS (0.47)	*(0.03)	NS (0.42)	NS (0.19)	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 2017.

⁴ Based on cumulative yield (2014-17) and final TCSA (2017).

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

Table 2: Effect of training system, spacing, and rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of 5th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2017.

	No. Fruit (no./tree) 8/26-27/2017	Fruit Size (g) 8/26-27/2017	Yield (kg/tree) 8/26-27/2017	Cultivar TCSA ³ (cm ²) 10/27,11/1-2/2017	Cultivar Yield Efficiency (kg/cm ²)	Root Suckers ⁵ (no./tree) 11/3/2017
Training¹						
2-Leader	9.3 b	229 ab	2.1 c	19.9 c	.10 c	.13
Bi-axis [#]	7.9 b	238 a	1.9 c	51.7 a	.04 d	.08
Tall Spindle	15.3 a	218 b	3.3 b	25.0 b	.13 b	.08
V-Trellis	18.3 a	240 a	4.3 a	24.0 b	.17 a	.03
Spacing¹						
3 feet	12.4	234	2.9 b	28.8 b	.11 ab	.14
4.5 feet	11.8	228	2.6 c	30.5 ab	.10 b	.03
6 feet	13.8	233	3.2 a	31.2 a	.12 a	.08
Rootstock¹						
Pyrodwarf 2-33	8.1 c	231 ab	1.8 c	27.7 b	.08 b	.11
OHxF 69	11.9 b	242 a	2.8 b	33.3 a	.09 b	.06
OHxF 87	18.0 a	222 b	4.0 a	29.4 b	.15 a	.08
ANOVA (<i>P</i> -values)²						
Training	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.61)
Spacing	NS (0.06)	NS (0.39)	* (0.02)	** (0.01)	* (0.02)	NS (0.30)
Rootstock	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.87)
Block	***(<0.001)	NS(0.22)	***(<0.001)	***(<0.001)	***(<0.001)	* (0.04)
Interaction (<i>P</i> -values)²						
Training x Rootstock	NS (0.38)	NS(0.45)	NS(0.35)	NS (0.35)	* (0.03)	NS (0.08)
Spacing x Rootstock	NS (0.34)	NS (0.08)	NS (0.45)	NS (0.45)	NS (0.78)	NS (0.67)
Training x Spacing	NS (0.62)	NS (0.47)	NS (0.30)	NS (0.35)	* (0.04)	NS (0.79)
Training x Spacing x Rootstock	* (0.04)	NS (0.54)	* (0.04)	NS (0.42)	NS (0.21)	NS (0.08)

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

³ Measured 10 cm abo ⁵ Root sucker data normalized, SQRT(value+1) for *P*-value.

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

[#] Total of two scaffolds

Table 3: Effect of training system, spacing, and rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of 4th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2016.

	No. Fruit (no./tree)	Fruit Size (g)	Yield (kg/tree)	Cultivar TCSA ³ (cm ²)	Cultivar Yield Efficiency (kg/cm ²)	Rootstock TCSA ⁴ (cm ²)	Rootstock Yield Efficiency (kg/cm ²)	Tree Height ⁵ (cm)	Root Suckers ⁶ (no./tree)
	8/8/2016	8/8/2016	8/12-13/2016	11/3-4/2016		11/3-4/2016		11/18/2016	10/6-7/2015
Training¹									
2-Leader	2.0 b	197	.40 ab	14.8 c	.03 ab	23.7 b	.04	223 b	.35 a
Bi-axis [#]	1.5 b	180	.30 b	39.2 a	.01 c	26.2 b	.02	229 b	.17 ab
Tall Spindle	2.2 ab	175	.41 ab	19.3 b	.02 b	33.1 a	.02	249 a	.10 b
V-Trellis	3.0 a	176	.59 a	18.4 b	.03 a	32.8 a	.04	228 b	.18 ab
Spacing¹									
3 feet	2.0 ab	193	.41	22.6	.02	28.4	.03	239 a	.21
4.5 feet	1.9 b	181	.36	22.9	.02	29.2	.03	228 b	.17
6 feet	2.7 a	172	.50	23.3	.02	29.3	.04	229 b	.22
Rootstock¹									
Pyrodwarf 2-33	1.4 b	171 ab	.27 b	20.3 c	.02 b	25.6 c	.03 b	233 ab	.2
OHxF 69	2.2 b	166 b	.40 b	25.8 a	.02 b	33.2 a	.02 b	237 a	.16
OHxF 87	3.0 a	208 a	.60 a	22.7 b	.03 a	28.9 b	.04 a	225 b	.24
ANOVA (<i>P</i> -values)²									
Training	***(<0.001)	NS (0.53)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.09)	***(<0.001)	*(0.04)
Spacing	*(0.02)	NS (0.43)	NS (0.07)	NS (0.58)	NS (0.32)	NS (0.58)	NS (0.20)	** (0.003)	NS (0.90)
Rootstock	***(<0.001)	** (0.002)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	** (0.01)	NS (0.08)	NS (0.64)
Block	***(<0.001)	** (0.01)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS (0.02)	NS (0.59)
Interaction (<i>P</i> -values)²									
Training x Rootstock	*(0.02)	** (0.01)	*(0.02)	NS (0.14)	NS (0.16)	*(0.04)	NS (0.20)	NS (0.12)	NS (0.47)
Spacing x Rootstock	NS (0.52)	NS (0.27)	NS (0.45)	NS (0.33)	NS (0.51)	NS (0.83)	NS (0.23)	NS (0.85)	NS (0.68)
Training x Spacing	NS (0.13)	NS (0.70)	NS (0.15)	NS (0.75)	NS (0.41)	NS (0.59)	NS (0.97)	***(<0.001)	NS (0.38)
Training x Spacing x Rootstock	NS (0.59)	NS (0.11)	NS (0.61)	NS (0.28)	NS (0.60)	NS (0.18)	NS (0.31)	NS (0.17)	NS (0.54)

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, 8/8/2016

³ Measured 10 cm above union.

⁴ Measured 5 cm below union.

⁵ Average height of Bi-axis and 2-leader scaffolds.

⁶ Yield efficiency and root sucker data normalized, SQRT(value+1) for *P* -value.

Table 4: Effect of training system, spacing, and rootstock on the amount of fruit dropped or removed from 'Bartlett' pear 3rd, 4th, and 5th leaf trees, Hopland, Mendocino County, California, 2015-2017.

	Dropped and Removed Fruit (% / per tree)		
	6/10-11/2015	6/6 & 17/2016	6/26 & 7/6/2017
Training¹			
2-Leader	18.9 a	3.3 b	14.7 b
Bi-axis	18.5 a	0.1 b	15.5 b
Tall Spindle	4.3 b	18.5 a	23.1 a
V-Trellis	5.4 b	3.0 b	6.6 c
Spacing¹			
3 feet	14.4	7.2	14.4
4.5 feet	10.0	7.0	13.6
6 feet	11.1	4.4	17.0
Rootstock¹			
Pyrodwarf 2-33	13.0	4.6	12.4 b
OHxF 69	13.1	6.9	18.4 a
OHxF 87	9.3	7.1	14.2 ab
ANOVA² (<i>P</i> -values)			
Training	***(<0.0001)	*** (<0.001)	*** (<0.001)
Spacing	NS (0.08)	NS (0.67)	NS (0.28)
Rootstock	NS (0.13)	NS (0.83)	* (0.02)
Block	NS (0.11)	NS (0.06)	NS (0.34)
Interaction² <i>P</i> -values			
Training x Rootstock	NS (0.33)	NS (0.49)	* (0.05)
Spacing x Rootstock	* (0.02)	NS (0.30)	NS (0.32)
Training x Spacing	NS (0.19)	NS (0.67)	** (0.01)
Training x Spacing x Rootstock	NS (0.84)	~ ³	NS (0.38)

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 5: Effect of training system, spacing, and rootstock on firmness and soluble solids of 3rd-5th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2015-2017.

	Firmness (kg. force)			Soluble Solids (°Brix)		
	8/12-13/2015	8/8/2016	8/26-27/2017	8/12-13/2015	8/8/2016	8/26-27/2017
Training¹						
2-Leader	9.4 ab	8.8	8.6 a	14.1	12.9 a	13.1 ab
Bi-axis	9.5 a	8.7	8.5 a	13.9	12.2 b	12.7 b
Tall Spindle	9.4 ab	8.5	8.4 a	14	12.5 ab	12.8 b
V-Trellis	9.1 b	8.6	7.9 b	14.1	12.8 a	13.2 a
Spacing¹						
3 feet	9.4	8.6	8.3	13.9	12.6 ab	13.0
4.5 feet	9.3	8.6	8.3	14.1	12.4 b	12.9
6 feet	9.4	8.7	8.5	14.1	12.9 a	13.0
Rootstock¹						
Pyrodwarf 2-33	9.5	8.7	8.5	13.7 b	12.3 b	12.8 b
OHxF 69	9.3	8.6	8.4	14.0 ab	12.6 ab	13.0 ab
OHxF 87	9.2	8.7	8.3	14.4 a	12.9 a	13.2 a
ANOVA² (P -values)						
Training	*(0.02)	NS (0.24)	*** (<0.001)	NS (0.53)	** (0.002)	** (0.01)
Spacing	NS (0.82)	NS (0.44)	NS (0.56)	NS (0.64)	** (0.01)	NS (0.91)
Rootstock	NS (0.19)	NS (0.85)	NS (0.15)	** (0.01)	*** (0.001)	** (0.01)
Block	*(0.03)	*(0.04)	NS (0.40)	*(0.03)	NS (0.36)	*(0.02)
Interaction² P -values						
Training x Rootstock	NS (0.54)	NS (0.07)	NS (0.47)	** (0.01)	NS (0.39)	NS (0.90)
Spacing x Rootstock	NS (0.56)	NS (0.15)	NS (0.82)	NS (0.18)	NS (0.91)	NS (0.18)
Training x Spacing	NS (0.28)	NS (0.92)	*** (<0.001)	NS (0.13)	NS (0.23)	NS (0.97)
Training x Spacing x Rootstock	NS (0.43)	~ ³	NS (0.51)	NS (0.18)	~ ³	NS (0.67)

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 6: Cumulative effect of rootstock on fruit number and size, tree vigor, and yield efficiency of completely unpruned 3rd, 4th, and 5th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2013-2017.

Treatment ¹	Total	Average	Total	Cultivar	Cultivar	Rootstock	Rootstock
	Fruit No. ³ (no./tree)	Fruit Size (g)	Yield (kg/tree)	TCSA (cm ²)	Yield Efficiency ⁴ (kg/cm ²)	TCSA (cm ²)	Yield Efficiency ⁴ (kg/cm ²)
OHxF 69	124	182	23.3	32.1 a	0.73	54.6	.43
OHxF 87	124	167	21.6	26.9 b	0.83	43.2	.51
ANOVA (<i>P</i> -values)²							
Treatment	NS (1.00)	NS (0.11)	NS (0.50)	* (0.03)	NS (0.19)	** (0.01)	NS (0.08)
Block	NS (0.47)	NS (0.49)	NS (0.59)	NS (0.14)	* (0.04)	NS (0.40)	NS (0.06)

¹ Within columns, treatment means significantly different (Duncan Multiple Range test, $P \leq 0.05$).

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

³ Based on fruiting years 2014-2017.

⁴ Based on cumulative yield (2014-2017) and final TCSA (2017).

Table 7: Effect of rootstock on firmness and soluble solids of completely unpruned 3rd, 4th, and 5th leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2015-2017.

Treatment ¹	Firmness (kg force)			Soluble Solids (° Brix)		
	2015 ³	2016 ⁴	2017 ⁵	2015 ³	2016 ⁴	2017 ⁵
OHxF 69	9.2	8.1	7.7	14.1	14.1	13.6 b
OHxF 87	9.4	8.3	7.9	14.5	14.5	14.2 a
ANOVA (<i>P</i> -values)²						
Treatment	NS (0.52)	NS (0.53)	NS (0.12)	NS (0.07)	NS (0.07)	** (0.01)
Block	NS (0.20)	NS (0.24)	NS (0.51)	** (0.01)	* (0.03)	** (0.01)

¹ Within columns, treatment means significantly different (Duncan multiple range test), $P \leq 0.05$. 2017 (Tukey HSD test, $P < 0.05$).

² *, ** Indicate 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.

Table 8 : Effect of rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of completely unpruned 'Bartlett' pear trees, Hopland, Mendocino County, California, 2017.

Treatment ¹	No. Fruit	Fruit Size	Yield	Cultivar	Cultivar	Rootstock	Rootstock	Root
	(no./tree)	(g)	(kg/tree)	TCSA ³ (cm ²)	Yield Efficiency (kg/cm ²)	TCSA ⁴ (cm ²)	Yield Efficiency (kg/cm ²)	Suckers (no./tree)
	8/26/2017	8/26/2017	8/26/2017	11/1/2017		11/1/2017		11/1/2017
OHxF 69	59.3	213 a	12.4	32.1 a	0.38	54.6 a	0.23 b	0.0
OHxF 87	64.7	191 b	12.2	26.9 b	0.46	43.2 b	0.28 a	0.0
ANOVA (<i>P</i> -values)²								
Treatment	NS (0.48)	* (0.02)	NS (0.89)	* (0.03)	NS (0.11)	** (0.01)	* (0.04)	~
Block	NS (0.10)	* (0.02)	NS (0.64)	NS (0.14)	NS (0.66)	NS (0.40)	NS (0.60)	~

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

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

³ Measured 10 cm above union.

⁴ Measured 5 cm below union.

Harvest date: 8/26/2017

Table 9 : Effect of rootstock on number and size of fruit, tree yield and growth, yield efficiency and root suckers of completely unpruned 'Bartlett' pear trees, Hopland, Mendocino County, California, 2016.

Treatment ¹	No. Fruit	Fruit Size	Yield	Cultivar	Cultivar	Rootstock	Rootstock	Tree	Root
	(no./tree)	(g)	(kg/tree)	TCSA ³ (cm ²)	Yield Efficiency (kg/cm ²)	TCSA ⁴ (cm ²)	Yield Efficiency (kg/cm ²)	Height (cm)	Suckers (no./tree)
	8/8/2016	8/8/2013	8/8/2016	11/18/2016		11/18/2016		11/18/2016	11/18/2016
OHxF 69	18.7 a	196	3.2	24.4	0.14 a	42.3	0.08 a	282 a	0.0
OHxF 87	8.9 b	186	1.6	20.9	0.08 b	36.8	0.05 b	245 b	0.0
ANOVA (<i>P</i> -values)²									
Treatment	* (0.02)	NS (0.44)	** (0.01)	NS (0.06)	* (0.04)	NS (0.09)	* (0.04)	** (0.01)	~
Block	NS (0.19)	NS (0.29)	NS (0.21)	NS (0.11)	NS (0.62)	NS (0.27)	NS (0.79)	** (0.004)	~

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

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

³ Measured 10 cm above union.

⁴ Measured 5 cm below union.

Harvest date: 8/8/16

Table 10: Cumulative effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 4th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2013-2017*.

Treatment¹	Average Fruit No. (per tree)	Average Fruit Size (g)	Average Yield (kg)	2017 Cultivar TCSA ³ (cm ²)	Cultivar Yield Efficiency (kg/cm ²)	2016 Rootstock TCSA (cm ²)	Rootstock Yield Efficiency (kg/cm ²)	Root Suckers (per tree)
Spreading	174	170	28.8	66.6	0.44	45.5	.63	0.0
No Spreading	129	183	24.5	77.0	0.31	50.0	.49	0.0
P -value²	NS (0.51)	NS (0.24)	NS (0.37)	NS (0.35)	* (0.02)	NS (0.50)	NS (0.07)	~

* Data begins with fruiting year 2014.

Table 11: Effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 4th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2017.

Treatment¹	No. Fruit (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 (kg/cm ²)	Root Suckers (per tree)
Spreading	91.4	175	15.7	66.6	0.24	45.5	.35	0.0
No Spreading	56.4	213	11.9	77.0	0.15	50.0	.23	0.0
P -value²	NS (0.07)	* (0.04)	NS (0.28)	NS (0.35)	* (0.03)	NS (0.50)	* (0.04)	~

¹ Means analyzed by T-test, $P \leq 0.05$.

² * Indicates significance at $P \leq 0.05$. NS indicates not significant.

³ Average of two scaffolds.

Table 12: Effect of scaffold spreading on number and size of fruit, tree yield and growth, yield efficiency, and root suckers of 4th leaf Bi-axis-trained 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2016.

Treatment ¹	No. Fruit (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 Height (cm)	Root Suckers (per tree)
Spreading	12.4	188	2.2	58.2	.04	38.9	.06	204	0.0
No Spreading	20.2	188	3.8	59.2	.07	41.2	.10	263	0.0
P -value ²	NS (0.13)	NS (0.96)	NS (0.10)	NS (0.94)	NS (0.06)	NS (0.67)	NS (0.08)	** (0.01)	~

¹ Means analyzed by T-test, $P \leq 0.05$.

² ** Indicates significance at $P \leq 0.01$. NS indicates not significant.

³ Average of two scaffolds.

Table 13: Effect of scaffold spreading on firmness and soluble solids on Bi-axis-trained 3rd, 4th, and 5th leaf 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2015-2017.

Treatment ¹	2015 ³		2016 ⁴		2017 ⁵	
	Firmness (kg force)	Soluble Solids (°Brix)	Firmness (kg force)	Soluble Solids (°Brix)	Firmness (kg force)	Soluble Solids (°Brix)
Spreading	8.7	14.4	8.2	13.1	6.9	13.6
No Spreading	8.7	14.3	8.3	13.1	7.1	14.2
P -value ²	NS(1.00)	NS(0.73)	NS(0.84)	NS(0.86)	NS(0.76)	NS(0.22)

¹ Means analyzed by T-test, P<0.05).

² ** Indicates significance at $P \leq 0.01$. NS indicates not significant.

³ Harvest date: 8/17/15, Testing dates: 8/24-31/16.

⁴ Harvest date: 8/8/16, testing dates: 8/26, 28 & 31.

⁵ Harvest date: 8/26/17, testing dates: 8/28, 30 & 31/17.

Table 14. 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, California, 2014-2017.

Treatment ¹	2014 ⁴ (n=5)			2015 ⁴ (n=10)			2016 ⁴ (n=14)			2017 ⁴ (n=9)		
	OHxF 87	Pyro 2-33	<i>P</i> -value ²	OHxF 87	Pyro 2-33	<i>P</i> -value ²	OHxF 87	Pyro 2-33	<i>P</i> -value ²	OHxF 87	Pyro 2-33	<i>P</i> -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)	17.7	15.9	* (0.03)
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)	16.6	15.2	NS (0.18)
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)	18.6	17.7	NS (0.51)
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)	18.6	17.6	NS (0.41)
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)	16.6	18.4	NS (0.12)
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)	19.0	17.7	NS (0.30)
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)	17.9	18.2	NS (0.85)
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)	18.3	18.9	NS (0.73)
Baseline ³	7.7			7.7			7.6			8.1		

¹ Means analyzed by T-test, $P \leq 0.05$.

² * Indicates significance at $P \leq 0.05$. NS indicates not significant.

³ For comparison.

⁴ Monitor period: 2014: 6/3-10/6, 2015: 6/4-10/1, 2016: 6/23-9/26, 2017: 6/2-9/27.

2013 NC-140 PEAR SYSTEMS TRIAL - Rep I (Rows 1-4)

Shadowbrook Farms, Hopland, Mendocino, CA. Planted May 1-2, 2013.



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

Training Spacing/Rootstock

Row 2	BI-AXIS	3	69
		3	69
		3	69
		3	2-33
		3	2-33
		3	2-33
		3	87
		3	87
Buffer	PYRO 2-33	3	87
		3	87
Row 2	BI-AXIS	6	69
		6	69
		6	69
		6	2-33
		6	2-33
		6	2-33
		6	87
		6	87
Buffer	PYRO 2-33	6	2-33
		6	2-33
Row 2	BI-AXIS	4.5	2-33
		4.5	2-33
		4.5	2-33
		4.5	87
		4.5	87
		4.5	87
		4.5	69
		4.5	69
Buffer	PYRO 2-33	4.5	69
		4.5	69

Training Spacing/Rootstock

Row 3	BI-AXIS	4.5	2-33
		4.5	2-33
		4.5	2-33
		4.5	87
		4.5	87
		4.5	87
		4.5	69
		4.5	69
Buffer	PYRO 2-33	4.5	69
		4.5	69
Row 3	BI-AXIS	6	87
		6	87
		6	87
		6	69
		6	69
		6	69
		6	2-33
		6	2-33
Buffer	PYRO 2-33	6	2-33
		6	2-33
Row 3	BI-AXIS	3	2-33
		3	2-33
		3	2-33
		3	87
		3	87
		3	87
		3	69
		3	69
Buffer	PYRO 2-33	3	69
		3	69

Training Spacing/Rootstock

Row 3	BI-AXIS	6	2-33
		6	2-33
		6	2-33
		6	69
		6	69
		6	69
		6	87
		6	87
Buffer	PYRO 2-33	6	87
		6	87
Row 4	BI-AXIS	4.5	87
		4.5	87
		4.5	87
		4.5	2-33
		4.5	2-33
		4.5	2-33
		4.5	69
		4.5	69
Buffer	PYRO 2-33	4.5	69
		4.5	69
Row 4	BI-AXIS	3	87
		3	87
		3	87
		3	69
		3	69
		3	69
		3	2-33
		3	2-33
Buffer	PYRO 2-33	3	2-33
		3	2-33
Buffer	PYRO 2-33	3	69
		3	69

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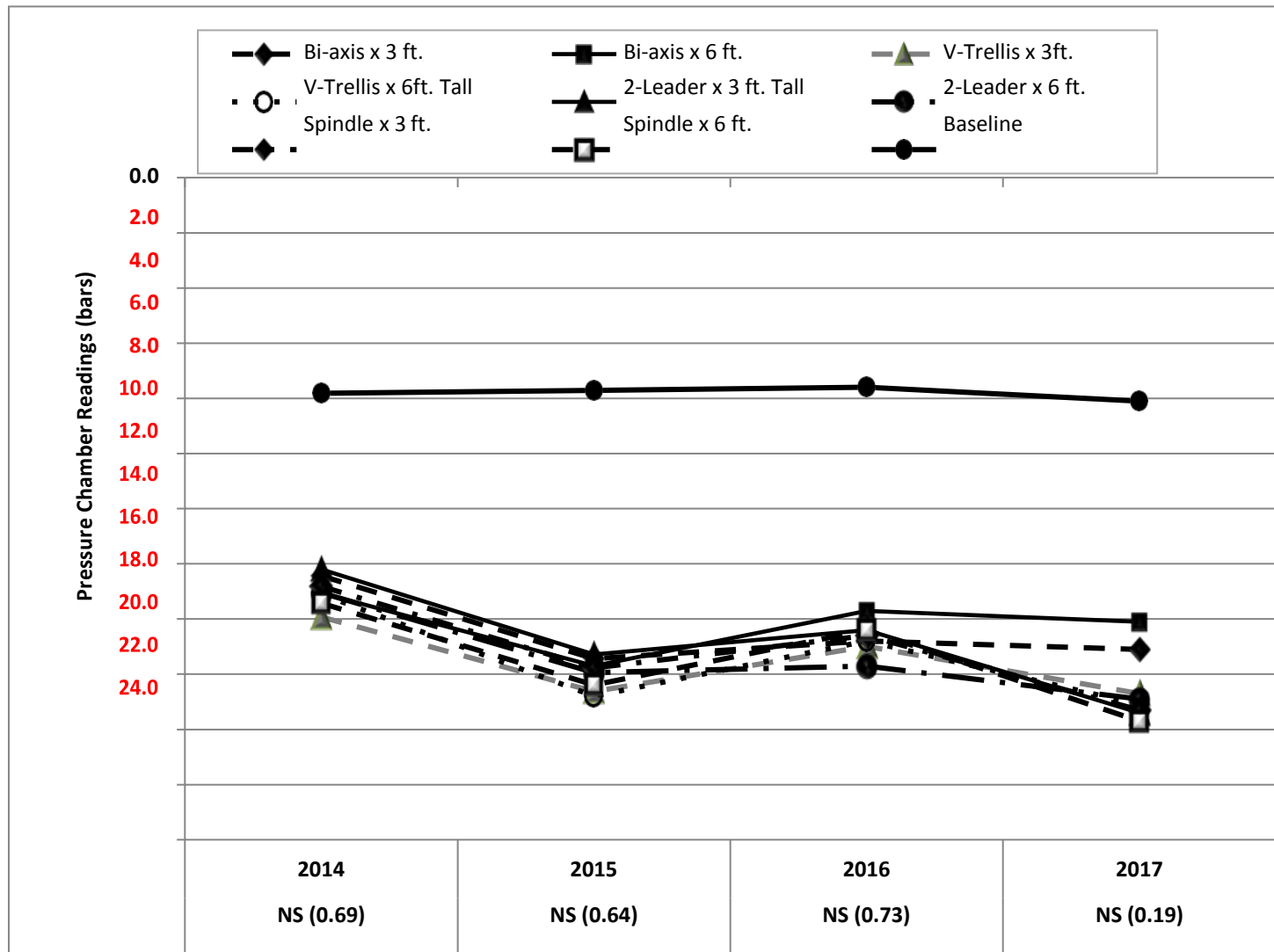


Figure 2: Effect of training system and spacing on seasonal average mid-day stem water potential (MSWP) of 2nd-5th leaf "Bartlett" pear trees on Pyro 2-33 rootstock, Hopland, Mendocino County, California, 2014-2017.

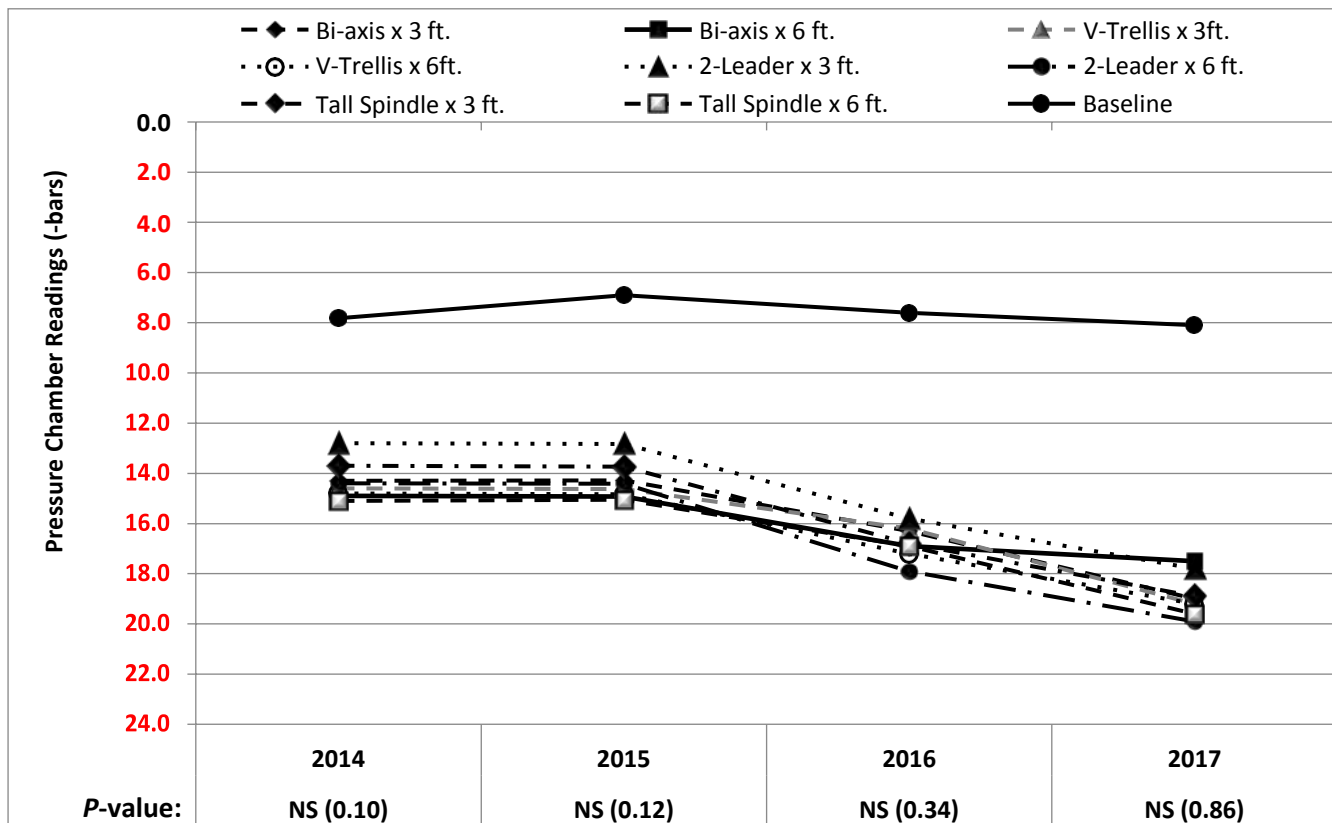


Figure 3: Effect of training system and spacing on seasonal average mid-day stem water potential (MSWP) of 2nd-5th leaf "Bartlett" pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2014-2017.

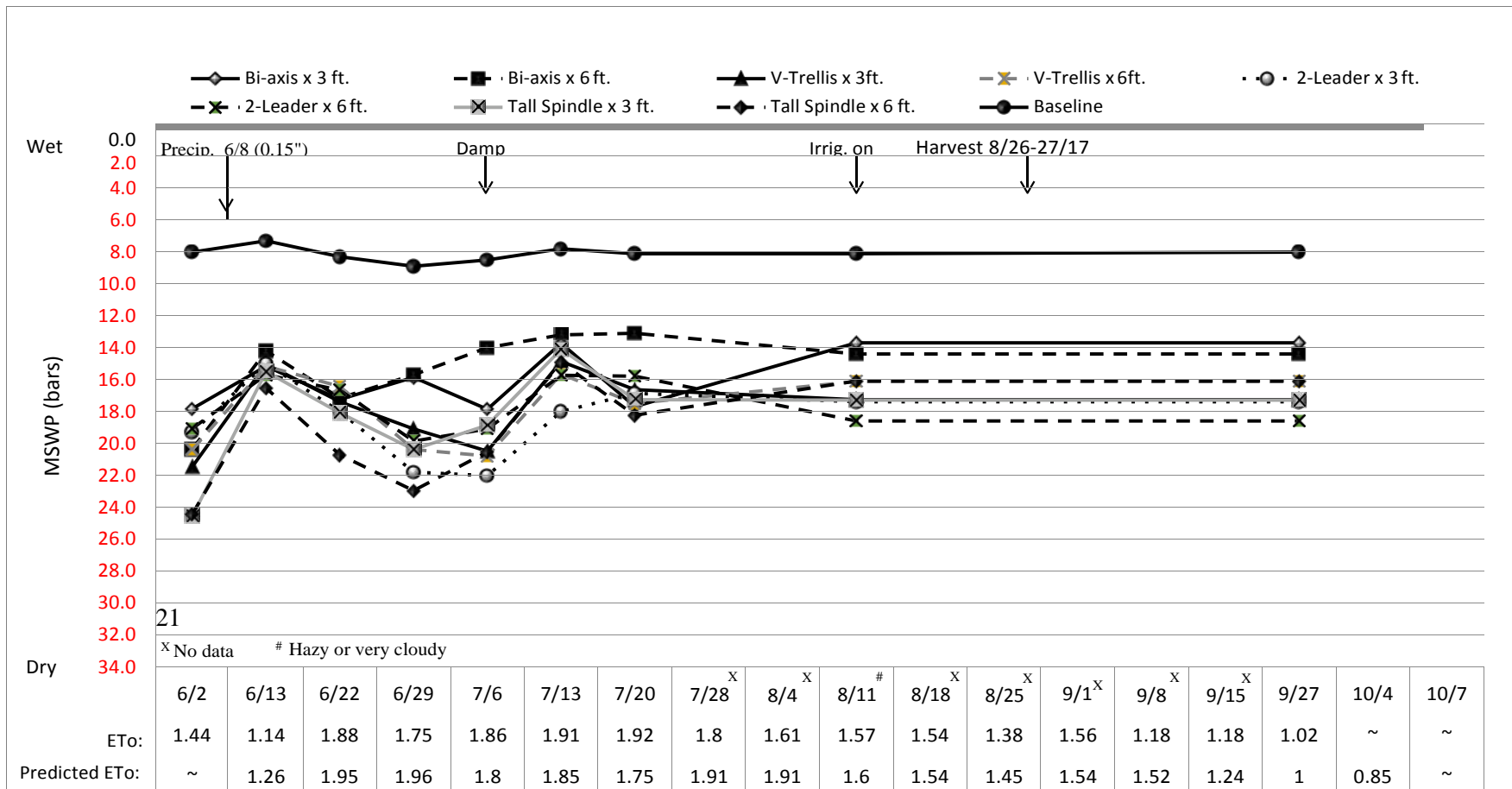


Figure 4. Effect of training system and spacing on weekly mid-day stem water potential (MSWP) of 5th-leaf 'Bartlett' pear trees on Pyro 2-33 rootstock, Hopland, Mendocino County, California, 2017.

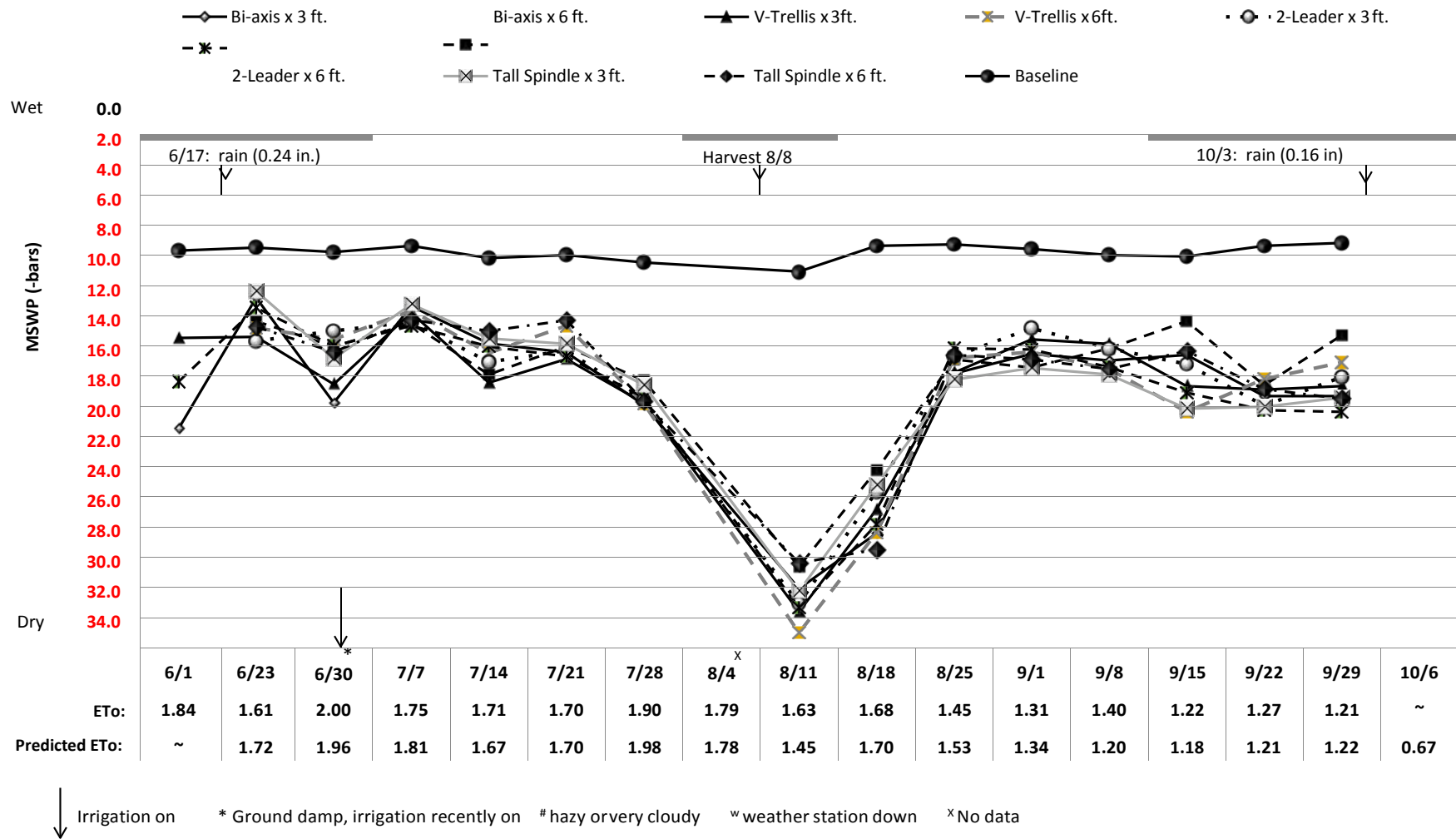


Figure 5. Effect of training system and spacing on weekly mid-day stem water potential (MSWP) of 4th-leaf 'Bartlett' pear trees on Pyro 2-33 rootstock, Hopland, Mendocino County, California, 2016.

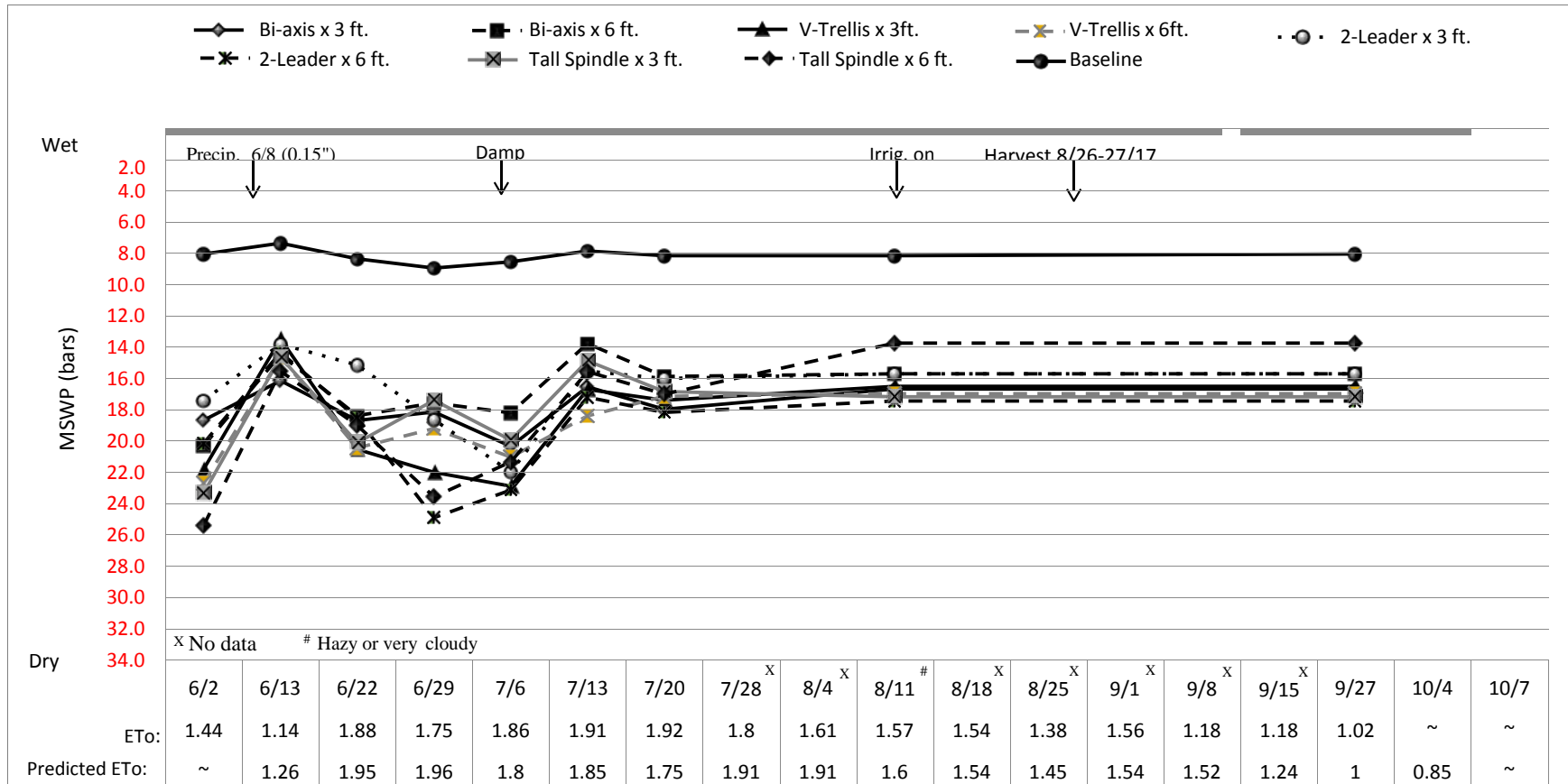


Figure 6. Effect of training system and spacing on weekly mid-day stem water potential (MSWP) of 5th-leaf 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2017.

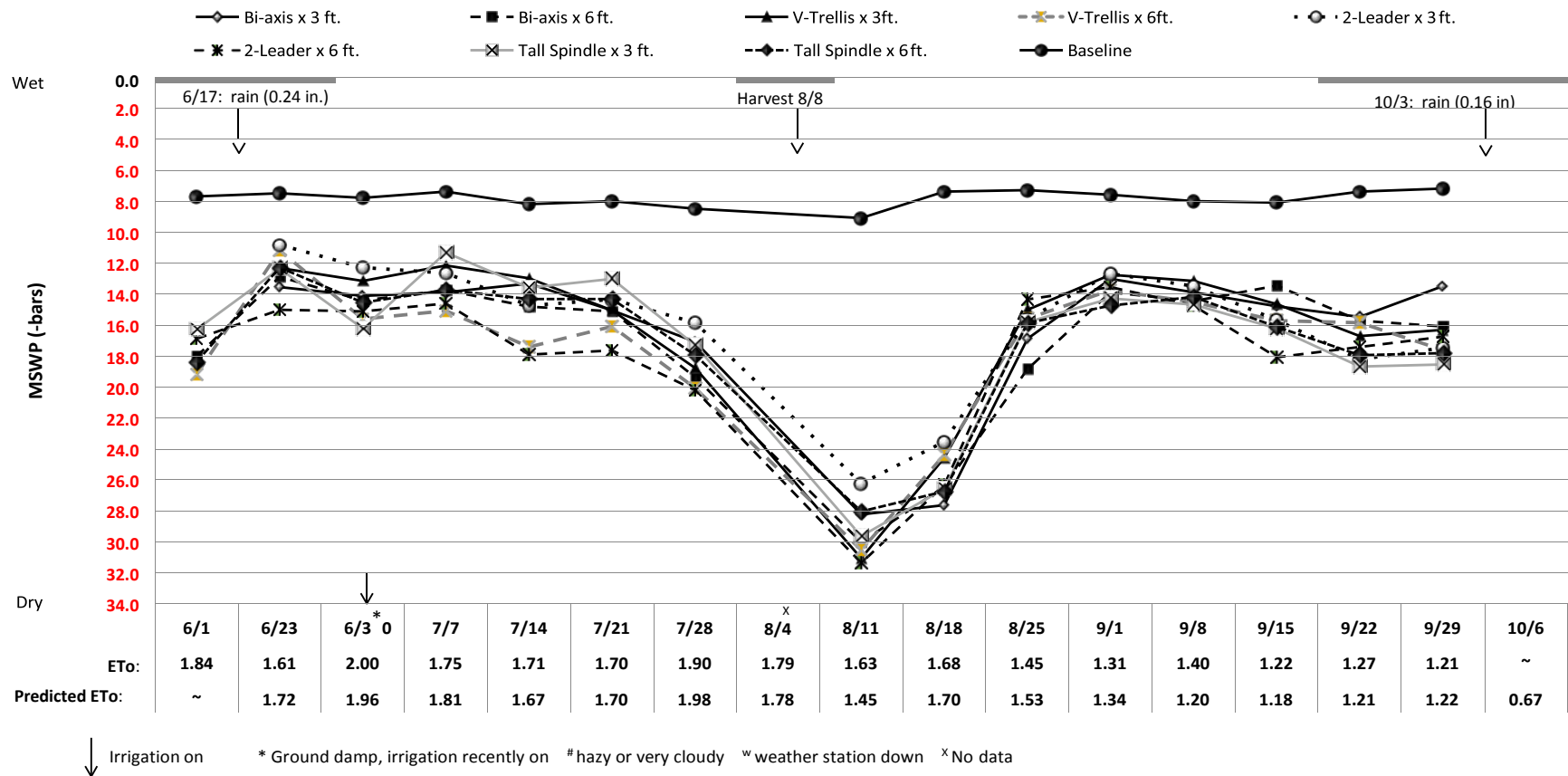


Figure 7. Effect of training system and spacing on weekly mid-day stem water potential (MSWP) of 4th-leaf 'Bartlett' pear trees on OHxF 87 rootstock, Hopland, Mendocino County, California, 2016.