HIGH DENSITY ORCHARD SYSTEMS FOR EUROPEAN PEAR: THE 2013 NC-140 REGIONAL ROOTSTOCK PROJECT

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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). There are many reasons for this, which have been described (Elkins, Bell and Einhorn 2012). Many remaining California growers are now, or will be, considering their options regarding replanting of old orchards, and several have either already replanted relatively small acreages, or are considering doing so. 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 combinations of training systems, spacings, and promising commercially-available rootstocks for the European pear cultivar 'Bartlett' (California), 'D'Anjoy' (Oregon), and 'Bosc' (New York). California treatments consisted of Tall Spindle, "V" Trellis, parallel 2-leader, and nursery-formed bi-axis 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. After two seasons, survival rate is 97.6%. Tall spindle (TS) trees were tallest and V-trellis trees had the largest cultivar trunk cross-sectional area (TCSA). V'trellis and TS trees were most precocious and efficient. OHxF 69 was most and Pyro 2-33 least precocious. For the two systems (bi-axis and 2-leader) with both north and south oriented scaffolds, there were noticeably more new spurs and (to a lesser extent) feathers (those formed in 2013) on the north scaffolds of all the rootstocks, training systems, and spacings. There were no differences in number of terminal, spur, or rat-tail flower clusters on the south vs. north scaffolds. Differences between north and south were much less apparent for flower clusters but occurred slightly on both OHxF rootstocks. There was a trend toward more flower clusters and fruit on the north scaffolds, and total % fruit set, of spread versus unspread bi-axis trees. Data collection in 2015 will include growth and productivity, mid-day stem water potential, and canopy light interception.

INTRODUCTION

The California pear industry has shrunk considerably in the past two decades, both in number of growers and total acreage (USDA-NASS 2014). There are many reasons for this, which have been described (Elkins, Bell and Einhorn 2012). Many remaining California growers are now, or will be, considering their options regarding replanting of old orchards, and 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 tenth year have shown that higher density plantings can be successful (Elkins et al 2008; Chris Ruddick, pers. communication).

In coordination with Oregon State University (OSU) and Cornell University, an NC-140 project (see below) to study high density systems and 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 cultivar ‘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.

The North Central Regional Research Project NC-140 (*www.NC140.org*) is a federally (NIFA)-supported, multi-state rootstock project focused on perennial tree fruit crops. The goal of NC-140 is to disseminate information generated from long-term (generally 10 year) trials throughout the U.S. Each participating state (as well as Canada and Mexico) establishes and evaluates similar ("uniform") trials using the same rootstocks and similar plot design so that regional differences can be determined. Researchers share progress and results at the annual meeting and via the NC-140 website. Each state representative submits an annual report which is distributed at the meeting and then compiled into a national report for USDA and posted on the NC-140 website for public use. Data is also shared with growers and nurseries who can then select rootstocks suitable to their location and customer base. California began participating in NC-140 for apples in 1995 and peaches in 2001 and began participating actively in pears in 2005 with the establishment of three (now formally completed) trials (Elkins, R. 2015). All regional projects are re-evaluated every five years for re-authorization; the 2012-2017 continuing 5-year proposal was submitted and accepted by the North Central Regional Association (NCRA) of State Agricultural Station Directors.

The 2013 NC-140 trial compares 27 (OR, NY)-36 (CA) combinations of training systems, rootstocks, and spacings. The California trial was planted May 1-2, 2013 in Hopland, Mendocino County, California and has completed two growing seasons (2^{nd} leaf). Treatments consist of 4 training systems and 3 spacings that have shown promise in high density plantings, particularly apple and pear, and commercially-available rootstocks which have shown promise in previous trials. The 2013 California planting consists of four training systems (versus three in OR and NY), three spacings and three rootstocks (similar to OR and NY), for a total of 36 training-spacing-rootstock combinations. 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;
- 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.

PROCEDURES

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; Bruce Lampinen, Ted DeJong, and Chuck Ingels, collaborators). Soil type is a very deep Russian loam adjacent to the east bank of the Russian River.

Training systems:

1) *Tall spindle* (developed by Terence Robinson for apple) (left unheaded);
2) *Tatura “V” trellis* (hereafter labeled *V-trellis*) (22° at the base, planted in-line with every other tree pulled to the opposite side of the trellis);
3) *Bi-axis* system planted parallel to the row. This system was developed by Stefano Mussachi, formerly of the University of Bologna, Italy, now with Washington State University. Bi-axis trees are pre-formed in the nursery; the California bi-axis 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* parallel to the hedgerow, created by choosing two appropriately placed “feathers” just above or below the first wire, 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, there is an adjacent row of extra bi-axis and single leader trees that have thus far been left completely unheaded. A replicated sub-trial was initiated on one set of the bi-axis trees to compare the effect of spreading vs. not spreading on vigor and precocity.

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 shich 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 delays[1].

PROCEDURES

Tree training and crop load management – 2014 training continued to emphasize leader development and proper shape. Nearly all training occurred between the start of terminal bud growth and terminal bud set in October. Emphasis was on encouraging 1) leaders to reach the top wire by reducing the influence of competing scaffolds, and 2) filling intra-row and inter-tree space along the supporting wire. 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.

Data Collection

Tree growth and vigor – The number of healthy, weak, and dead trees were counted at the end of the 2014 season. Tree height was measured on October 21. Trunk cross-sectional area (TCSA) of both cultivar (10 cm. above graft union) and rootstock (5 cm. below graft union) were measured on October 22. 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 on October 6.

[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.

Flowering and cropping – The number of laterals, spurs, and flower clusters formed during 2013 and those originally formed in the nursery were counted on March 20 on the north and south leaders of the 2-leader and bi-axis trees only. Number of flower clusters (May 6) and number of fruit (August 6) were counted and fruit set (% per 100 clusters) calculated. Crop load was calculated using cultivar TCSA. Baseline canopy light interception was initially measured on October 19, 2013 and again on October 11, 2014 to eventually develop a predictive model to inform future plantings. 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. serves as a continuous recording of seasonal growth pattern.

Data summarization and analysis

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. For 2014, there were some significant interactions among treatments, mainly training x rootstock, however, for this report, only overall differences among the three main treatments are discussed (training, spacing, rootstock). Differences among the 36 individual combinations of 4 training x 3 spacing x 3 rootstock will be reported in 2015.

RESULTS (Tables 1-3)

Tree survival, growth, and vigor – Out of 540 trees, 13, or 2.4%, have succumbed: 7 bi-axis/OHxF 87, 1 bi-axis/Pyro 2-33, 1 Tall spindle/OHxF 69, 1 V-trellis/Pyro 2-33, 1 V-trellis/OHxF 69, 1 2-leader/OHxF 87, and 1 2-leader/Pyro 2-33, for a total of 3 Pyro 2-33, 2 OHxF 69, and 2 OHxF 87. Bi-axis trees had the smallest cultivar TCSA but rootstock TCSA was equal to the 2-leader trees. "V" trellis had the largest cultivar TCSA but Tall spindle had the largest rootstock TCSA and were also the tallest trees, with many well above the 10' wire. OHxF 69 and 87 trees were taller than Pyro 2-33 trees. 3' spaced trees were tallest. There were few suckers but OHxF 87 had the most and OHxF 69 had none.

Flowering and fruiting – V-trellis and Tall spindle trees were the most precocious based on number of flower clusters, number of fruit and fruit set, and were also most efficient, based on crop load. This was likely due to lack of heading or feather removal at planting. OHxF 69 was the most precocious rootstock in terms of flowering and Pyro 2-33 the least. However, percent fruit set was equal for OHxF 69 and 87, with Pyro 2-33 having comparatively low set. Crop load efficiency was highest for OHxF 69 among rootstocks, followed by OHxF 87 and lagging far behind, Pyro 2-33.

For the two systems (bi-axis and 2-leader) with both north and south oriented scaffolds, there were noticeably more new spurs and (to a lesser extent) feathers (those formed in

2013) on the north scaffolds of all the rootstocks, training systems, and spacings. There were no differences in number of terminal, spur, or rat-tail flower clusters on the south vs. north scaffolds. There was a trend toward more flower clusters and fruit on the north scaffolds, and total % fruit set, of spread versus unspread bi-axis trees (data not shown).

Canopy light interception – This data will be analyzed in 2015.

DISCUSSION AND 2015 PLANS

After two growing seasons, training and rootstock appear to be the most important factors in determining tree growth and productivity. Spacing has yet to play a discernible role, except (slightly) for tree height. OHxF 69 shows similar precocity as in previous trials and in nursery beds (Elkins and DeJong 2011, Elkins and DeJong 2002; Fowler Nurseries, pers. communication). Pyro 2-33 lags well behind the OHxF rootstocks in both growth and cropping.

Theoretically, the north (south-facing) scaffolds received more sun than the south (north-facing) scaffolds of the bi-axis trees. This may have been the reason for greater 2013 spur development on the north scaffolds. The trend toward more fruiting on spread trees needs more data to confirm.

Tree training and data collection will continue in 2015, with added harvest (fruit number, total yield, and fruit size per tree). A field meeting was held on October 22, 2014 and at least one will be held in 2015.

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Table 1: Effects of rootstock, training, and spacing systems on number of clusters and fruit, fruit set, crop load, and tree growth in 'Bartlett' pear trees, Hopland, Mendocino, California, 2014.

	No. Clusters 5/6/2014 (no./tree)	No. Fruit[2] 8/6/2014 (no./tree)	Fruit Set 8/6/2014 (% fruit/100 clusters)	Cultivar TCSA[3] 10/22/2014 (cm^2)	Rootstock TCSA[4] 10/22/2014 (cm^2)	Crop Load[2] Efficiency 10/22/2014 (no./cm^2)	Tree Height 10/21/2014 (cm)	Root Suckers[2] 10/6/2014 (no./tree)
TRAINING[1]								
2-Leader	3.6 bc	0.6 b	12.0 b	16.6 c	9.6 c	0.04 b	181 b	0.02 ab
Bi-axis	2.8 c	0.3 b	9.1 b	8.2 d	10.6 c	0.04 b	157 c	<0.01 b
Tall Spindle	5.2 ab	1.4 a	22.7 ab	20.3 b	14.1 a	0.08 a	210 a	0.04 a
V-Trellis	6.5 a	1.9 a	29.1 a	23.9 a	12.6 b	0.07 ab	191 b	<0.01 b
SPACING[1]								
3 feet	4.9	1.0	18.0	17.4	11.7	0.04	189 a	<0.01
4.5 feet	4.8	1.1	18.8	17.2	11.8	0.07	182 b	0.01
6 feet	3.9	1.1	17.9	17.6	11.6	0.06	184 ab	0.03
ROOTSTOCK[1]								
Pyro 2-33	1.6 c	0.3 b	8.0 b	14.5 b	9.3 b	0.01 c	179 b	0.01 ab
OHxF 69	8.0 a	1.7 a	24.1 a	18.6 a	13.1 a	0.09 a	189 a	0.00 b
OHxF 87	4.1 b	1.2 a	22.5 a	18.6 a	12.7 a	0.06 b	186 ab	0.03 a
ANOVA (*P*-values)								
Rootstock	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	0.23
Training	<0.001	<0.001	<0.001	<0.001	<0.001	<0.01	<0.001	0.14
Spacing	0.14	0.71	0.62	0.79	0.72	0.19	0.10	0.33
Block	<0.001	<0.001	0.16	<0.001	<0.01	0.16	<0.001	0.20
INTERACTION *P*-values								
Training x Spacing	0.39	0.86	0.32	0.15	0.14	0.47	0.03	0.62
Rootstock x Training	0.001	0.01	0.85	<0.01	0.05	0.54	0.64	0.42
Spacing x Rootstock	0.38	0.12	0.07	0.22	0.01	0.38	0.29	0.72
Rootstock x Training x Spacing	0.06	0.06	0.04	0.92	0.74	0.02	0.53	<0.01

[1] Within columns, treatment means significantly different (Tukey HSD test, $P \leq 0.05$), root sucker means (Duncan MRT, $P \leq 0.1$).
[2] Root sucker data normalized, SQRT(vlue+1) for p-value
[3] Measured 10 cm. above union.
[4] Measured 5 cm. below union.

Table 2. Effects of rootstock, training, and spacing systems on lateral growth in bi-axis and 2-leader 2nd-leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2014.

	New Spurs			Old Spurs			New Feathers			Old Feathers		
	North	South	**Total**	North	South	**Total**	North	South	**Total**	North	South	**Total**
TRAINING[1]												
Bi-axis	0.65 b	0.40 b	0.95	0.34 a	0.32 a	0.65 a	0.69	0.71 a	1.38	1.06 a	1.45 a	2.72 a
2-leader	1.16 a	0.97 a	0.97	0.04 b	0.07 b	0.11 b	0.71	0.44 b	1.16	0.66 b	0.66 b	1.32 b
SPACING[1]												
3 feet	1.06	0.86	1.22	0.18	0.25	0.44	0.74	0.67	1.36	0.99	1.13	2.13
4.5 feet	0.84	0.54	0.80	0.23	0.21	0.44	0.59	0.53	1.13	0.72	1.03	1.85
6 feet	0.80	0.65	0.86	0.15	0.13	0.27	0.76	0.54	1.30	0.86	0.01	2.07
ROOTSTOCK[1]												
Pyrodwarf 2-33	0.62 b	0.11 b	0.62 b	0.16	0.20	0.36	0.43 b	0.45	0.86 b	0.56 b	0.70 b	1.27 b
OHxF 69	0.96 ab	0.12 a	0.97 ab	0.22	0.23	0.44	0.88 a	0.71	1.61 a	1.02 a	1.35 a	2.46 a
OHxF 87	1.12 a	0.11 a	1.29 a	0.18	0.15	0.34	0.78 ab	0.57	1.33 ab	1.00 a	1.12 a	2.32 a
ANOVA[2] **(*P*-values)**												
Rootstock	* (0.02)	***(<0.001)	***(<0.001)	NS (0.65)	NS (0.48)	NS (0.38)	** (<0.01)	NS(0.15)	** (<0.01)	** (0.01)	***(<0.001)	*** (<0.001)
Training	**(<0.01)	*** (<0.001)	NS (0.80)	***(<0.001)	***(0.001)	***(0.001)	NS (0.91)	**(0.01)	NS (0.08)	**(<0.01)	***(<0.001)	*** (<0.001)
Spacing	NS (0.34)	NS (0.09)	NS (0.11)	NS (0.58)	NS (0.26)	NS (0.31)	NS (0.62)	NS(0.58)	NS (0.50)	NS (0.25)	NS (0.74)	NS (0.63)
Block	NS (0.36)	* (0.05)	* (0.04)	***(<0.001)	***(0.001)	***(0.001)	***(0.001)	* (0.05)	***(0.001)	** (0.01)	** (<0.01)	*** (<0.001)
INTERACTION *P*-values												
Rootstock x Training	**(<0.01)	***(<0.001)	***(0.001)	NS (0.91)	NS (0.13)	NS (0.53)	***(0.001)	NS(0.07)	***(0.001)	**(<0.01)	* (0.03)	*** (00.01)
Rootstock x Spacing	NS (0.68)	NS (0.47)	NS (0.46)	NS (0.73)	NS (0.63)	NS (0.71)	NS (0.93)	NS(0.57)	NS (0.66)	NS (0.30)	NS (0.59)	NS (0.31)
Training x Spacing	NS (0.89)	NS (0.06)	NS (0.39)	NS (0.44)	NS (0.14)	NS (0.08)	NS (0.68)	NS(0.13)	NS (0.20)	NS (0.92)	NS (0.14)	NS (0.43)
Rootstock x Training x Spacing												

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

[2] *, **, *** Indicates significance at $P \leq 0.05$, 0.01, 0.001. NS indicates not significant. All data normalized using SQRT (value+1) for *P*-value only. 247 complete cases.

Sample date: 3/20/2014

Table 3. Effects of rootstocks, training, and spacing on number of flower clusters on bi-axis versus 2-leader 2nd-leaf 'Bartlett' pear trees, Hopland, Mendocino, California, 2014

	Terminal Clusters			Spur Clusters			Rat Tail Clusters			All Clusters		
	North	South	**Total**	North	South	**Total**	North	South	**Total**	North	South	**Total**
TRAINING[1]												
Bi-axis	0.33	0.34	0.67	0.81 b	0.69 b	1.50 b	0.21	0.19	0.40	1.36 b	1.22 b	2.58 b
2-leader	0.45	0.43	0.88	1.51 a	1.60 a	3.10 a	0.32	0.30	0.62	2.28 a	2.33 a	4.61 a
SPACING[1]												
3 feet	0.50	0.39	0.89	1.48	1.38	2.87	0.26	0.22	0.48	2.24	2.00	4.24
4.5 feet	0.32	0.43	0.74	0.94	0.99	1.93	0.24	0.28	0.52	1.50	1.40	3.20
6 feet	0.36	0.33	0.69	1.05	1.06	2.11	0.30	0.23	0.52	1.71	1.62	3.33
ROOTSTOCK[1]												
Pyrodwarf 2-33	0.28 b	0.22 b	0.50 b	0.51 b	0.87 b	1.37 b	0.12 b	0.18 b	0.30 b	0.91 b	1.27 b	2.18 b
OHxF 69	0.60 a	0.65 a	1.25 a	2.09 a	1.80 a	3.89 a	0.45 a	0.37 a	0.82 a	3.14 a	2.83 a	5.97 a
OHxF 87	0.29 ab	0.28 b	0.57b	0.89 b	0.76 b	1.65 b	0.22 ab	0.18 b	0.40 b	1.41 b	1.22 b	2.63 b
ANOVA[2] (*P*-values)												
Rootstock	* (0.05)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	***(<0.001)	** (<0.01)	* (0.04)	***(0.001)	***(<0.001)	***(<0.001)	***(<0.001)
Training	NS (0.23)	NS (0.35)	NS (0.19)	*** (0.001)	***(<0.001)	***(<0.001)	NS (0.27)	NS(0.08)	NS (0.06)	** (<0.01)	***(0.001)	***(<0.001)
Spacing	NS (0.35)	NS (0.64)	NS (0.53)	NS (0.12)	NS (0.39)	NS (0.08)	NS (0.70)	NS(0.80)	NS (0.89)	NS (0.17)	NS (0.46)	NS (0.21)
Block	* (0.02)	* (0.02)	*** (0.001)	*** (0.001)	***(<0.001)	***(<0.001)	***(<0.001)	NS(0.41)	***(0.001)	***(<0.001)	***(<0.001)	***(<0.001)
INTERACTION *P*-values												
Rootstock x Training	NS (0.37)	NS (0.37)	NS (0.22)	NS (0.51)	NS (0.71)	NS (0.35)	NS (0.45)	NS(0.40)	NS (0.96)	NS (0.28)	NS (0.67)	NS (0.22)
Rootstock x Spacing	NS (0.96)	NS (0.70)	NS (0.90)	NS (0.13)	NS (0.07)	NS (0.19)	NS (0.23)	NS(0.99)	NS (0.56)	NS (0.42)	NS (0.24)	NS (0.39)
Training x Spacing	NS (0.13)	NS (0.75)	NS (0.23)	NS (0.38)	NS (0.61)	NS (0.31)	NS (0.89)	NS(0.77)	NS (0.72)	NS (0.17)	NS (0.67)	NS (0.19)

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

[2] *, **, *** Indicates significance at $P \le 0.05$, 0.01, 0.001. NS indicates not significant. All data normalized using SQRT (value+1) for *P*-value only. 266 complete cases.

Sample date: 3/20/2014

Table 4: Comparison of north and south effects of training, and spacing, and rootstock systems on number of clusters in bi-axis and 2-leader, 2nd-leaf 'Bartlett' pear trees, Hopland, Mendocino County, California, 2014

	Terminal Clusters			Spur Clusters			Rat Tail Clusters			Total Clusters		
	North	South	**P-value**	North	South	**P-value**	North	South	**P-value**	North	South	**P-value**
TRAINING[1]												
Bi-axis	0.33	0.34	**0.85**	0.80	0.68	**0.73**	0.21	0.19	**0.79**	1.34	1.2	**0.86**
2-leader	0.45	0.43	**0.96**	1.51	1.61	**0.84**	0.32	0.3	**0.84**	2.24	2.3	**0.93**
SPACING[1]												
3 feet	0.50	0.40	**0.56**	1.51	1.40	**0.77**	0.26	0.23	**0.93**	2.25	2.00	**0.70**
4.5 feet	0.31	0.43	**0.32**	0.93	0.99	**0.72**	0.24	0.28	**0.51**	1.47	1.68	**0.48**
6 feet	0.40	0.33	**0.93**	1.03	1.06	**0.95**	0.29	0.22	**0.51**	1.67	1.59	**0.78**
ROOTSTOCK[1]												
Pyrodwarf 2-33	0.28	0.22	**0.51**	0.50	0.86	**0.19**	0.11	0.18	**0.24**	0.89	1.25	**0.35**
OHxF 69	0.60	0.65	**0.50**	2.08	1.81	**0.51**	0.45	0.37	**0.65**	3.09	2.80	**0.64**
OHxF 87	0.29	0.28	**0.93**	0.89	0.76	**0.69**	0.22	0.18	**0.76**	1.39	1.21	**0.75**

[1] Means analyzed by T-test, $P \leq 0.05$). All values normalized, SQRT (value+1) for *P*-values.

[2] Samples collected 3/20/2014.

Training: n=133, Spacing: n=89, Rootstock: n=89