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Effect of Rootstock on Fruit Characteristics and Tree Productivity in Seven Red-Fruited Pear Cultivars

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Abstract

Seven red pear cultivars on seedling *Pyrus betulifolia, P. calleryana, P. communis* 'Winter Nelis,' clonal 'Old Home' x 'Farmingdale' (OH x F) 18 or 97 (*P. communis*), or Quince BA-29C (*Cydonia oblonga*) rootstocks were evaluated over a ten-year period. The effects of rootstock on fruit characteristics and tree productivity were specific to each cultivar. Rootstock tended to affect tree productivity more than it affected fruit characteristics. For 'Starkrimson,' fruiting began one year earlier with quince than with the other rootstocks. For 'Red Anjou,' fruiting began two years earlier with *P. calleryana,* and for 'Canal Red' fruiting began one year earlier with *P. calleryana* than with the other rootstocks. Fruiting of 'Sensation Red Bartlett' and 'Crimson Gem Comice' began one year later with 'Winter Nelis' than with the other rootstocks. Fruit from trees growing on *P. calleryana* seedling had the smallest length:diameter ratio in four of the seven cultivars tested. Cumulative yield efficiency in 'Red Anjou' and 'Crimson Gem Comice' was greatest on quince and *P. calleryana.* Yield efficiency in 'Sensation Red Bartlett' was highest on *P. betulifolia* and OH x F 97, although yield efficiency on *P. betulifolia* was not significantly different than on 'Winter Nelis.' For 'Canal Red,' yield efficiency was highest on quince and *P. calleryana,* although differences between *P. calleryana* and OH x F 18 were not significant. For 'Cascade,' yield efficiency was highest on quince, *P. calleryana,* and OH x F 97, although yield efficiency was not significantly different between OH x F 97 and 'Winter Nelis.'

Introduction

Red pear cultivars currently in commercial production in the United States originated either as spontaneous bud mutations on green-fruited trees, or as controlled crosses between red mutants and green-fruited pear cultivars (13, 16). Red-fruited pear cultivars which originated as mutants on green-fruited trees are generally less vigorous and less productive than their green-fruited source cultivars (10, 15, 16). Martin et al. (10) found that leaves of potted one-year-old trees of 'Sensation Red Bartlett' and 'Red Anjou' had lower maximum net photosynthetic rates and ratios of chlorophyll *a* to chlorophyll *b* than did their green-fruited source cultivars, 'Bartlett' and 'd'Anjou.' This reduced vigor and productivity compared to the more familiar green pear cultivars required adaptation of cultural practices, including the choice of a vigorous rootstock.

Planting of red pear cultivars in the United States and other countries expanded sharply during the 1980s and 1990s. However, little information is available on performance of specific red pear cultivars on different rootstocks. A preliminary report on the yield of four-year-old red pear trees indicated that high early yield was associated with rootstocks which induce precocious bloom (e.g., quince, OH x F, and *P. calleryana*) (16). The present study evaluated the performance of seven red pear cultivars on various rootstocks over a 10-year period following planting.

Materials and Methods

A planting was established in 1986 on Carney clay soil at the Medford sub-station of the Southern Oregon Research and Extension Center. Carney clay is a dark brown clay with low permeability and high shrink-swell potential. The clay content is 50-60% and organic matter is 2-3%. Pear orchards in southern Oregon are commonly grown on soils of this type.

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One-year-old "whip" trees were obtained from various nursery sources based on availability. Trees were planted 3.7 m apart in rows of a single cultivar, with 5.5 m between rows. Rootstocks were randomized within rows. Trees were headed at approximately 80 cm at planting, trained to a multiple-leader system, and maintained by winter pruning. Irrigation water was applied periodically via undertree sprinklers during the summers, and pest management followed standard commercial practices.

The specific cultivar-rootstock combinations studied are listed in Table 1. The cultivars evaluated were: 'Starkrimson,' also known as 'Red Clapp' and 'Kalle,' a bud mutation of 'Clapp's Favorite' found in South Haven, Michigan; 'Red Anjou' (Gebhard strain), a bud mutation of 'd'Anjou' found in Medford, Oregon; 'Sensation Red Bartlett,' a bud mutation of 'Bartlett' found in Australia; 'Canal Red,' a seedling of 'Max Red Bartlett' x 'Forelle'; 'Crimson Gem Comice,' a bud mutation of 'Regal Red Comice' found in Medford, Oregon; 'Cascade,' a seedling of 'Max Red Bartlett' x 'Doyenne du Comice'; and 'Rosired Bartlett,' a bud mutation of 'Bartlett' found in California (1).

All cultivars were grown on 'Winter Nelis' (*Pyrus communis* L.) and *P. calleryana* Decne. seedling rootstocks. All cultivars except 'Cascade' were grown on *P. betulifolia* Bunge seedling rootstock. Cultivars derived from 'Bartlett' ('Sensation Red Bartlett' and 'Rosired Bartlett') were not grown on quince (*Cydonia oblonga* L.) rootstock; the remaining cultivars were grown on Provence Quince BA-29C. 'Starkrimson,' 'Red Anjou,' 'Canal Red,' and 'Rosired Bartlett' were grown on 'Old Home' x 'Farmingdale' 18 (OH x F 18; *P. communis*); 'Sensation Red Bartlett' and 'Cascade' were grown on OH x F 97 (2). Ten replicate trees on each rootstock were grown for "Sensation Red Bartlett,' 'Red Anjou,' and 'Crimson Gem Comice.' Five replicate trees on each rootstock were grown for all other cultivars.

In each year of the study, all fruit produced on each tree were harvested and weighed. The cumulative yield of each tree from planting through 1995 (year 10) was divided by the trunk cross-sectional area of the tree at the end of 1995 to give the cumulative yield efficiency of the tree. Trunk cross-sectional area was calculated from the trunk diameter, measured with calipers at 5-10 cm above the graft union. The date of full bloom (petals open on 80% of the flower buds) on each tree was recorded each year. The year in which more than one-half of the replicate trees of a cultivar-rootstock combination yielded at least one fruit was considered the year in which fruiting began.

In years 8-10, subsamples of 25 fruit were collected randomly from the harvested fruit from each tree for measurement of fruit weight, length:diameter ratio, soluble solids concentration, firmness, and color. Firmness was measured using a U.C. penetrometer fitted with an 8 mm tip. Color was measured in the CIELAB L*, a*, b* color space coordinates with a Minolta portable tristimulus colorimeter, where L* indicates relative lightness (lower values) or darkness (higher values), a* indicates value from green to red, and b* indicates value from blue to yellow. Hue was calculated as $\tan^{-1}$ b*/a* (11).

Data were subjected to analysis of variance (ANOVA) based upon a completely random design and least significance difference values for mean separation were calculated where ANOVA *F* values were <0.05. Analyses were made comparing rootstock effects for each cultivar; no comparisons were made between cultivars.

Results

The effects of rootstock on fruit characteristics and tree productivity were specific to each cultivar (Tables 1 and 2). In 'Red Anjou,' the date of full bloom was delayed by approximately one day for trees on *P. calleryana* and *P. betulifolia* as compared to quince and OH x F 18. 'Sensation Red Bartlett' bloomed one day later on OH x F 97 than on *P. betulifolia*.

Table 1. Effect of rootstock on fruit characteristics at harvest in red pear cultivars grown in a heavy clay soil in Medford, Oregon.

Cultivar/ Rootstock	Firmness (lb)	Soluble solids (°Brix)	Weight (g)	Length: diameter ratio	Sun-exposed surface Hue	Sun-exposed surface L*	Shaded surface Hue	Shaded surface L*
Starkrimson/								
Winter Nelis	16.5	12.7	160	1.22	20.0	31.4	21.7	33.6
Quince BA-29C	17.8	12.4	171	1.27	20.1	32.1	20.8	34.2
P. calleryana	17.7	12.2	194	1.14	20.9	31.5	21.9	33.5
P. betulaefolia	16.8	12.1	155	1.24	21.5	31.7	24.7	35.5
OHxF 18	16.4	12.2	168	1.19	20.9	31.2	21.8	33.2
LSD (0.05)	0.8	ns	15	0.05	1.4	ns	ns	1.4
Red Anjou/								
Winter Nelis	15.3	14.6	179	1.19	26.4	33.7	35.1	38.8
Quince BA-29C	15.6	15.7	171	1.16	26.6	35.2	32.0	38.9
P. calleryana	14.8	15.9	171	1.12	26.8	34.4	33.8	38.3
P. betulaefolia	15.6	14.6	188	1.16	27.1	34.3	32.7	38.9
OHxF 18	15.6	15.2	188	1.18	27.2	33.4	35.1	38.2
LSD (0.05)	ns	0.5	ns	0.02	ns	0.7	ns	ns
Sensation Red Bartlett/								
Winter Nelis	19.8	12.5	161	1.25	28.0	35.8	43.5	40.5
P. calleryana	21.8	12.2	151	1.13	32.8	35.9	47.0	40.4
P. betulaefolia	20.5	12.7	183	1.28	30.0	35.1	43.8	40.5
OHxF 97	19.8	12.1	168	1.24	30.0	36.9	43.8	42.5
LSD (0.05)	ns	ns	17	0.04	2.2	0.9	ns	ns
Canal Red/								
Winter Nelis	13.0	11.0	169	1.25	27.1	33.4	51.7	42.6
Quince BA-29C	13.3	11.8	194	1.17	24.9	32.5	43.2	40.3
P. calleryana	13.8	11.6	178	1.21	26.5	32.4	51.4	40.8
P. betulaefolia	13.4	10.8	183	1.29	27.4	33.3	58.8	45.9
OHxF 18	13.5	11.1	174	1.24	26.4	32.5	71.8	45.5
LSD (0.05)	ns	ns	15	0.06	ns	ns	12.2	3.8
Crimson Gem Comice/								
Winter Nelis	13.4	10.5	205	1.00	25.7	32.9	36.5	39.6
Quince BA-29C	13.9	12.0	227	0.97	25.8	32.5	38.9	39.6
P. calleryana	14.3	11.5	186	0.97	26.6	32.5	37.9	39.0
P. betulaefolia	14.3	11.1	212	0.98	25.5	32.2	42.1	41.2
LSD (0.05)	ns	ns	17	ns	ns	ns	ns	ns
Cascade/								
Winter Nelis	15.8	12.9	239	1.06	29.8	36.1	59.2	47.7
Quince BA-29C	16.3	12.5	212	1.08	27.5	35.4	55.2	48.2
P. calleryana	15.7	12.3	223	1.03	28.2	34.8	57.0	46.3
OHxF 97	16.2	12.6	215	1.06	28.3	35.2	62.1	48.0
LSD (0.05)	ns	ns	ns	0.02	ns	ns	ns	ns
Rosired Bartlett/								
Winter Nelis	20.4	12.9	153	1.17	26.4	32.5	37.0	35.5
P. calleryana	20.9	13.2	155	1.15	26.2	32.7	35.2	33.4
P. betulaefolia	20.4	13.6	153	1.15	24.9	32.1	33.5	34.1
OHxF 18	20.1	13.3	154	1.16		32.7		35.9
LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	ns

'Canal Red' bloom was delayed 1-2 days on *P. calleryana* and *P. betulifolia*, while 'Crimson Gem Comice' bloom was delayed 1-2 days on 'Winter Nelis.'

The year in which fruiting began was not affected by rootstock for 'Cascade' or 'Rosired Bartlett' (Table 2). For 'Starkrimson,' fruiting began one year earlier with quince than with the other rootstocks. For 'Red Anjou,' fruiting began two years earlier with *P. calleryana*, and for 'Canal Red' fruiting began one year earlier with *P. calleryana* than with the other rootstocks. Fruiting of 'Sensation Red Bartlett' and 'Crimson Gem Comice' began one year later with 'Winter Nelis' than with the other rootstocks.

Fruit firmness at harvest was not affected by rootstock except with 'Starkrimson,' where fruit from trees on quince and *P. calleryana* were approximately one pound firmer than from trees on the other rootstocks. Fruit soluble solids at harvest were not affected except with 'Red Anjou,' where fruit from trees on quince and *P. calleryana* had a higher percent soluble solids. Average individual fruit weight in 'Starkrimson' was greatest on *P. calleryana*, while in 'Sensation Red Bartlett' fruit weight was greatest on *P. betulifolia*. In 'Canal Red' and 'Crimson Gem Comice,' fruit weight was greatest on quince, although the average weight of fruit from trees on quince was not significantly different from the weight of fruit from trees on *P. betulifolia*. Fruit from trees growing on *P. calleryana* had the smallest length:diameter ratio in 'Starkrimson,' 'Red Anjou,' 'Sensation Red Bartlett,' and 'Cascade,' while the rootstock inducing the largest length:diameter ratio varied among cultivars.

Hue values on the sun-exposed fruit surface were increased with 'Sensation Red Bartlett' by *P. calleryana*. Higher hue values indicate that the color is redder and less yellow than lower values. On the shaded surface, hue values were higher only for 'Canal Red' on OH x F 18. 'Red Anjou' fruit were darkest (highest L* value) on the sun-exposed surface on quince, while 'Sensation Red Bartlett' fruit were darkest on the sun-exposed surface on OH x F 97. 'Starkrimson' fruit were slightly darker on the shaded surface on *P. betulifolia*. 'Canal Red' fruit were darkest on the shaded surface on *P. betulifolia* and OH x F 18, although not significantly darker than fruit on 'Winter Nelis.'

Trees on *P. betulifolia* had the largest trunk cross-sectional area for 'Starkrimson,' 'Red Anjou,' 'Sensation Red Bartlett,' and 'Canal Red,' while the largest trunk area of 'Crimson Gem Comice' was on *P. betulifolia* and quince. The largest trunk area of 'Rosired Bartlett' was on 'Winter Nelis,' although the area was not significantly larger than on OH x F 18. Trees of 'Sensation Red Bartlett' and 'Rosired Bartlett' were smallest on *P. calleryana*. 'Starkrimson' trees were smallest on *P. calleryana* and quince, and 'Crimson Gem Comice' trees were smallest on *P. calleryana* and 'Winter Nelis.' Quince-rooted trees were smallest for 'Red Anjou,' while 'Canal Red' trees were smallest on quince, *P. calleryana*, and 'Winter Nelis.'

Cumulative yield was greatest with 'Starkrimson' and 'Sensation Red Bartlett' on *P. betulifolia*, although not significantly different than cumulative yield on OH x F 18 and OH x F 97, respectively. For 'Crimson Gem Comice,' cumulative yield was greatest on quince. Cumulative yield efficiency in 'Red Anjou' and 'Crimson Gem Comice' was greatest on quince and *P. calleryana*. Yield efficiency in 'Sensation Red Bartlett' was highest on *P. betulifolia* and OH x F 97, although yield efficiency on *P. betulifolia* was not significantly different than on 'Winter Nelis.' For 'Canal Red,' yield efficiency was highest on quince and *P. calleryana*, although differences between *P. calleryana* and OH x F 18 were not significant. For 'Cascade,' yield efficiency was highest on quince, *P. calleryana*, and OH x F 97, although yield efficiency was not significantly different between OH x F 97 and 'Winter Nelis.'

Table 2. Effect of rootstock on tree performance and productivity in red pear cultivars grown in a heavy clay soil in Medford, Oregon.

Cultivar/ Rootstock	Full Bloom (Julian date)	Year fruiting began (year of planting = 1)	Trunk cross-sectional area (cm^2)	Cumulative yield 1986-1995 (kg)	Cumulative yield efficiency (kg/cm^2)
Starkrimson/					
Winter Nelis	95.9	5	84.3	53.1	0.65
Quince BA-29C	95.6	4	63.7	58.9	0.94
P. calleryana	95.5	5	57.3	47.8	0.85
P. betulifolia	95.4	5	124.7	86.5	0.70
OHxF 18	95.3	5	87.8	70.4	0.82
LSD (0.05)	ns		24.0	21.5	ns
Red Anjou/					
Winter Nelis	90.3	7	72.7	7.2	0.10
Quince BA-29C	89.6	7	21.9	7.0	0.32
P. calleryana	90.8	5	43.0	14.6	0.34
P. betulifolia	90.5	7	121.8	11.4	0.09
OHxF 18	89.5	7	78.6	11.3	0.14
LSD (0.05)	0.9		17.3	ns	0.07
Sensation Red Bartlett/					
Winter Nelis	96.3	5	40.8	29.1	0.68
P. calleryana		4	18.8	12.9	0.66
P. betulifolia	95.6	4	74.7	62.5	0.86
OHxF 97	96.9	4	56.1	51.1	0.91
LSD (0.05)	0.9		12.1	15.3	0.19
Canal Red/					
Winter Nelis	99.2	5	43.8	18.4	0.43
Quince BA-29C	99.7	5	29.8	23.0	0.76
P. calleryana	101.3	4	36.1	25.9	0.71
P. betulifolia	100.6	5	79.3	30.2	0.38
OHxF 18	99.5	5	61.7	34.9	0.54
LSD (0.05)	1.1		16.6	ns	0.17
Crimson Gem Comice/					
Winter Nelis	100.7	6	24.9	3.0	0.13
Quince BA-29C	99.0	5	45.4	17.3	0.49
P. calleryana	99.8	5	12.9	4.4	0.40
P. betulifolia	99.3	5	50.2	8.4	0.20
LSD (0.05)	0.7		18.5	4.1	0.15
Cascade/					
Winter Nelis	96.4	5	45.6	20.2	0.44
Quince BA-29C	96.7	5	26.8	23.4	0.87
P. calleryana	96.9	5	39.0	31.1	0.76
OHxF 97	95.9	5	56.3	36.1	0.63
LSD (0.05)	ns		ns	ns	0.28
Rosired Bartlett/					
Winter Nelis	98.9	4	67.6	50.8	0.80
P. calleryana	99.1	4	20.2	20.0	0.82
P. betulifolia	98.4	4	41.3	38.6	0.94
OHxF 18	98.7	4	51.8	56.9	1.12
LSD (0.05)	ns		17.5	21.3	ns

Discussion

Rootstock had little effect on date of full bloom with the cultivars studied. Griggs (6) also reported that several different rootstocks had only slight influence on bloom dates of three pear cultivars in California.

Mielke and Facteau (12) found the effect of rootstock on productivity in red pear cultivars to be highly variable, depending on the fruiting cultivar. In the first five years from planting, 'Sensation Red Bartlett' cumulative yield efficiency was greatest on *P. betulifolia*, OH x F 40 and OH x F 97, which corresponds to the results for the first ten years in the present trial. Griggs et al. (7) found that 'Bartlett' pears on *P. betulifolia* had the greatest vigor and yield among several rootstocks tested in California. Thus despite its vigor, yield of 'Sensation Red Bartlett' with *P. betulifolia* rootstock in two locations in Oregon and in California has been sufficient to result in high efficiency.

Fruit from trees growing on *P. calleryana* had the smallest length:diameter ratio with four of the seven cultivars tested. This effect was also noted in 'Bartlett' pears grown on *P. calleryana* as compared to fruit from several other rootstocks (7). Although the productivity of trees on *P. calleryana* in the present study was generally good, especially with respect to precocity (data not shown), there was a great deal of variability among trees on this rootstock. Stebbins (14) described variable performance among seedlings of *P. calleryana*, and Lombard et al. (8) found substantial variability in yield efficiency of 'Comice' on several clonally propagated *P. calleryana* selections.

Mielke and Facteau (12) found the highest early yield efficiency for 'Crimson Gem Comice' and 'Columbia Red Anjou' on Quince C. Although this quince was not included in the present trial, it is apparent that quince rootstocks are appropriate for 'Crimson Gem Comice' where winter temperatures allow the use of quince, as has been found with 'Comice' (8, 14). In the last two years of our study we observed that trees of 'Red Anjou' on quince developed red leaf color prematurely in late summer and produced little extension shoot growth. This decline may indicate a relatively short field life of this combination.

Trees on 'Winter Nelis' rootstock had relatively low yield efficiency with five of the seven cultivars tested. This may reflect a combination of lack of precocity and relatively weak adaptation to clay soil (9). *P. betulifolia* also lacks precocity, but is well adapted to clay soil. *P. calleryana* and quince are both precocious and tolerant to clay soils, while OH x F selections tend to be less well-adapted to clay soils, but precocious (9, 17).

Apart from the effect of *P. calleryana* on fruit shape, rootstock effects on fruit characteristics at harvest were highly variable among cultivars. Fruit color (hue) on the sun-exposed fruit surface was not affected by rootstock except with 'Starkrimson' and 'Sensation Red Bartlett.' Fruit color in most red pear cultivars tends to change most rapidly during fruit maturation prior to harvest, and color is strongly affected by exposure to light (3, 4, 5). Accordingly, rootstocks could influence fruit color indirectly by affecting fruit maturity and by affecting the tree canopy and consequent light penetration. The differences in fruit firmness in 'Starkrimson' in this study do not correspond to color differences among rootstocks, and fruit firmness differences were not significant in other cultivars (Table 1). There was no measurement of canopy density or light exposure to the fruit on which color was evaluated.

The most pronounced effects of rootstock in this study were on tree productivity. Relative tree size and yield efficiency may be useful in choosing appropriate planting densities for specific cultivar-rootstock combinations. The relatively low vigor of some red pear cultivars may commend the choice of more vigorous rootstocks, but it is important to also consider rootstock effects on precocity and soil adaptation. Each cultivar-rootstock combination must be considered individually in assessing the potential vigor and

performance of red pear cultivars. Accordingly, combinations such as 'Red Anjou' on *P. betulifolia* may be considered overly vigorous, as reflected by the large trunk size and low yield efficiency (Table 2). In contrast, 'Sensation Red Bartlett' yield efficiency on *P. betulifolia* was relatively high. Although quince rootstocks may be considered more dwarfing than *P. betulifolia* (9), 'Crimson Gem Comice' with Quince BA29-C rootstock in our study had a trunk area comparable to that with *P. betulifolia* rootstock, but yielded approximately twice as much fruit with quince.

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Cause of Double Pistils in Cherry

At 25°C all flower buds had a single pistil whereas at 36°C the percentage of double pistils increased and at 35°C more than 80% were double. Soil moisture did not affect frequency of double pistils. From Bejau and Katooka. 1999. Sci. Horticulturae 81(2):1215-134.