Journal American Pomological Society 57(2):76-88 2003

Pear Cultivars as Interstems — The Initial Five Years. Do They Have Anything to Offer?

EUGENE A. MIELKE[1]* AND LAURIE SMITH[2]

Abstract

Size controlling rootstocks are available for a number of tree fruits, but are not widely available for pear. Interstems may reduce tree size, increase productivity and fruit size, and delay the onset of flowering in a number of tree fruits. The objective of this trial was to determine if the use of the pear cultivars 'd'Anjou', 'Bartlett', 'Bosc', and 'Conference' as interstems would reduce tree size, and improve fruit size and production. After the first five years of trial, 'Bartlett' or 'Comice' trees with 'Bartlett' interstems exhibited the worst survival rates. Trees with 'Conference' interstems had 100 % survival. Trees with 'Bartlett' interstems had the smallest trunk cross sectional area (TCSA) measured at 15 cm above the lower bud union, while trees with 'Bosc' interstems had the largest TCSA. Differential measurement 5 cm above the upper bud union indicated that trees with 'Conference' interstems exhibited the greatest reduction in TCSA, while trees with 'Comice' scions were generally overgrowing the interstems. Interstemmed trees produced more lateral branches as compared to non-interstemmed trees. Trees with 'Bosc' interstems produced the greatest number of lateral branches as compared to the non-interstemmed trees with one-year-old rootstocks. 'Comice' trees were the shortest with the least canopy spread. 'Bosc' and 'd'Anjou' interstem trees had the widest tree spread. By the end of the initial five-year trial, trees with either 'Bartlett' or 'Conference' interstems had the smallest canopy volume (CV). Interstem affected first but not full bloom dates. Final fruit set was not influenced by interstem. Initially, trees with 'Bosc' interstems produced the most flower clusters; however, by the end of the 5-year period, the non-interstemmed controls with 1-year-old rootstocks, and 'd'Anjou' and 'Bosc' interstem trees produced the most flower clusters. Trees with 'Bosc' interstems were the most productive over the 5-year trial. Trees with 'Conference' interstems had the greatest volume density (VD) due mainly to the fact that they had the smallest CV. VD and YE did not appear to be correlated. Although the trees in this trial were not fully mature, this 5-year study indicates that cultivars utilized as interstems may affect yields, growth habit, and crop density.

Introduction

Size-controlling rootstocks are available for a number of tree fruits, but are not widely available for pear production. 'Old Home x Farmingdale' rootstocks are precocious, but do not really offer dwarfing characteristics under high-density conditions (10) as previously reported (8). Interstems have been successfully used in the production of apple (1), apricot (12), cherry (3, 14), and peach (20). Westwood, et al. (23) successfully produced pear trees on M26 apple roots with 'Winter Banana' interstems. Pear interstems have been inconsistent in their effect on tree size (4, 6, 11, 15); however, some of the variability may have been due to the presence of virus (7, 22). Interstems have been found to increase productivity of cherry (5) and apricot (12) and increase fruit size in cherry (5). The objective of this research was to determine if the use of pear cultivars as interstems would influence tree size, production and fruit size.

Materials and Methods

'Bartlett' seedling rootstock liners were planted 30 cm apart in rows 1.5 m apart in

[1]Professor of Horticulture and [2]Faculty Research Assistant, Mid-Columbia Agricultural Research and Extension Center, Oregon State University, 3005 Experiment Station Drive, Hood River, OR 97031-9512, USA

Oregon Agricultural Experiment Station manuscript no. 11955. Use of trade name does not imply endorsement of the products named or criticism of similar ones not named.

*Corresponding author. Eugene A. Mielke, Tel.: 541-386-2030; Fax: 541-386-1905; e-mail: Eugene.Mielke@oregonstate.edu

spring 1991. Twenty percent of the liners were budded with buds of one of four pear scion cultivars (to serve as interstems) at 10 cm above the ground. The cultivars utilized as interstems were 'd'Anjou', 'Bartlett', 'Golden Russet Bosc' (Bosc), and 'Conference'. The remaining 20 % of the liners were left unbudded. In spring 1992, the unbudded 'Bartlett' seedling liners were cut back to two buds and one shoot was allowed to develop (2-yr old). Additional 'Bartlett' seedling rootstock liners were established in the nursery (1-yr old) in spring 1992. In fall 1992, 25 % of each lot of the interstems was budded 30 cm above the lower bud union to one of four cultivars to serve as the fruiting scion. The fruiting cultivars were 'd'Anjou', 'Bartlett', 'Golden Russet Bosc', or 'Comice' scions. The 1-yr- old and 2-yr-old 'Bartlett' liners were budded at 10 cm above the ground with the same four fruiting cultivars. The trees grew in the nursery through the 1993 season. The trees were dug in spring 1994 and established in six replicated plots with rows 5.49 m apart and with in-row spacing of 2.44 m (747 tree/ha). Each block consisted of three rows of eight trees, which were further subdivided into four sub-plots of three rows of two trees. Each sub-plot contained one of the four cultivars with the four interstem trees and the 1-yr-old and 2-yr-old 'Bartlett' seedling trees as a randomized complete block. The trees were arranged in a split-plot design with cultivar as the main plot and interstem treatment as the sub-plot. The trees were trained to a "Mid-Columbia Central Leader", which consisted of a standard central leader lower tier of branches, with everything above the lower tier of branches trained to a spindle. The central leader was headed to a weak lateral every year.

Each year the trees were evaluated for survival, trunk cross sectional area (TCSA) at 15 and 35 cm above the lower bud union (the non-interstemmed trees were only measured at 15 cm), tree height, and tree spread (both in-row and cross-row). Based on the growth habit of the trees, canopy volume (CV) was calculated using the formula $CV = (0.2454)(dia^2)(h)$. The number of lateral branches that grew during the 1994 growing season was determined during the 1994/1995 dormant period. From 1995 to 1998, the trees were evaluated for the date of first and full bloom. Full bloom was defined as the date when at least 95 % of the flowers on the south side of the tree were fully open. Beginning in 1994, the trees were evaluated for number of flower clusters and initial fruit set (late June). At harvest, the trees were evaluated for the number of fruit and yield, and average fruit weight was determined. Yield efficiency (YE) was calculated as yield (kg)/TCSA (cm^2) and volume density (VD) was calculated as yield (kg)/CV (m^3).

Data were analyzed as a split-plot design using the SAS general linear model procedure where the type III comparisonwise error rate was controlled (16). Data are reported as least square means (lsmeans) with LSD mean separation.

Results and Discussion

Survival

Five-year survival ranged from 66.7 ('Bartlett' or 'Comice' scions with 'Bartlett' interstems) to 100 % (14 of the 24 combinations). There was no significant cultivar by interstem interaction, or significant main cultivar effect (Table 1). Only scions with 'Conference' interstems exhibited 100 % survival, and scions with 'Bartlett' interstems exhibited the lowest survival rate (75.0 %). Overall scions with 1-yr-old rootstocks had a slightly higher survival rate as compared to scions with 2-yr-old rootstocks. This variable survival is consistent with previous reports (12).

Tree Growth

No significant cultivar by interstem interaction occurred in any TCSA parameter measured. Significant cultivar and interstems effects were observed in each of the five years of the study (Table 1). 'Comice' and 'Bosc' trees, while slightly different, exhibited the smallest TCSA, measured at 15 cm. 'Bartlett' and 'd'Anjou' trees exhibited the largest TCSA at 15 cm. Non-

Table 1. Effect of interstem on survival and trunk cross sectional area at 15 cm above the lower bud union on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Survival[Z]	Trunk cross sectional area at 15 cm (cm^2)				
	(%)	1994	1995	1996	1997	1998
Analysis of variance (df)[Y]						
Block (5)	ns	ns	*	**	**	**
Cultivar (3)	ns	**	***	***	***	***
Error A (15)	—	—	—	—	—	—
Interstem (5)	*	***	***	**	**	***
C x I (15)	ns	ns	ns	ns	ns	ns
Error B (84-98)[X]	—	—	—	—	—	—
Main effect - cultivar						
d'Anjou	94.4	3.3 a	6.1 a	10.6 a	19.2 a	30.1 a
Bartlett	91.7	3.4 a	6.0 a	10.2 a	16.8 a	24.3 b
Bosc	91.7	3.1 a	4.8 b	7.6 b	12.2 b	17.9 c
Comice	88.9	2.5 b	4.0 b	6.6 b	11.8 b	19.3 c
Main effect - interstem						
1-yr old	95.8 a	2.0 d	4.8 bc	8.9 bc	16.3 ab	26.1 ab
2-yr old	91.7 ab	2.0 d	4.4 c	7.4 c	13.6 bc	21.6 bc
d'Anjou	91.7 ab	3.4 b	5.7 ab	9.4 ab	16.3 ab	25.1 ab
Bartlett	75.0 b	3.9 a	5.2 bc	7.3 c	10.9 c	15.9 c
Bosc	95.8 ab	4.3 a	6.7 a	11.2 a	19.1 a	29.3 a
Conference	100.0 a	2.9 c	5.0 bc	8.1 bc	13.2 bc	20.0 c

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of missing data.

interstemmed trees with 2-yr old rootstocks exhibited the smallest TCSA in the first two years of trial, while trees with 'Bartlett' interstems exhibited the smallest TCSA at 15 cm in the last three years of the trial. Trees with 'Bosc' interstems exhibited the largest TCSA at 15 cm in all five years of the trial. This is consistent with other reports where interstems have caused both a promotion and retardation of growth (4, 11, 12, 15).

Significant cultivar and interstem effects were observed on TCSA measured 35 cm above the lower bud union (Table 2). 'Comice' trees at this height had the smallest TCSA in all five years of the study. 'Bartlett' trees had the largest TCSA in 1994. In 1995 and 1996 'd'Anjou' trees had the largest TCSA but was only statistically larger than 'Comice', and 'Comice' and 'Bosc' respectively. In the final two years of the study, 'Bosc' and 'd'Anjou' trees had the largest TCSA. Trees with 'Conference' and 'Bartlett' interstems had respectively the smallest TCSA in the last four years of the study. Trees with 'Bosc' and 'd'Anjou' interstems generally exhibited the largest TCSA at both height measurements. It is interesting to note that when 'Bartlett' was used as a scion it generally produced trees with one of the larger TCSA, but as an interstem it generally produced trees with one of the smaller TCSA. This was particularly true at the 35 cm height.

The differences between the TCSA at the two heights is shown in Table 3. Main cultivar effects on the difference in TCSA were significantly different in the last four years of the study, and varied from year to year. However, by the fifth year of the trial, 'Bartlett' trees had the largest difference in

Table 2. Effect of interstem on trunk cross sectional area at 35 cm above the lower bud union on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Trunk cross sectional area at 35 cm (cm^2)[Z]				
	1994	1995	1996	1997	1998
Analysis of variance (df)[Y]					
Block (5)	ns	ns	ns	*	ns
Cultivar (3)	**	*	*	*	*
Error A (15)	—	—	—	—	—
Interstem (3)	***	*	**	***	***
C x I (9)	ns	ns	ns	ns	ns
Error B (48-56)[X]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	2.8 ab	5.3 a	9.5 a	16.2 a	26.1 a
Bartlett	3.0 a	5.2 a	9.0 ab	11.2 b	17.9 b
Bosc	2.5 ab	4.3 ab	7.0 bc	17.5 a	27.2 a
Comice	2.0 c	3.7 b	6.4 c	10.6 b	16.2 b
Main effect - interstem					
1-yr old	—[W]	—	—	—	—
2-yr old	—	—	—	—	—
d'Anjou	2.5 b	5.0 ab	8.8 ab	16.1 a	25.9 a
Bartlett	2.6 ab	4.3 bc	6.5 bc	11.1 b	17.5 b
Bosc	3.1 a	5.6 a	10.0 a	17.9 a	27.5 a
Conference	2.0 c	3.7 c	6.3 c	10.5 b	16.2 b

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of missing data.
[W]Measurements not made.

TCSA between the two heights. 'Comice' trees had a negative value between the two heights indicating that the scion above the interstem TCSA was larger than the interstem. Interstem significantly influenced the difference in TCSA in four of the five years of the trial. In 1994 trees with 'Bartlett' and 'Bosc' interstems had the largest differential between the two heights, while trees with 'Conference' interstems had the greatest differential in TCSA between the two heights in 1995 through 1998. In the first four years of the trial, the interstem induced differentials in TCSA that were all positive. However, by the fifth year of the study trees with 'd'Anjou' and 'Bartlett' interstems had negative differentials in TCSA indicating that the scions were "overgrowing" the interstems. Non-interstemmed trees were not measured at 35 cm above the lower bud union. In a previous study, non-interstemmed 'd'Anjou' and 'Bartlett' trees had a positive differential of approximately 6 to 12 % of the lower TCSA (2 to 3 cm^2) (data not shown).

During the first dormant period, the number of lateral branches produced on each tree was determined. There were significant main cultivar and interstem effects, but no cultivar by interstem interaction, in the number of branches produced (Table 4). 'Bartlett' trees produced the greatest number of lateral branches, followed by 'Comice', 'd'Anjou', and 'Bosc'. All interstemmed trees produced more lateral branches (average 6.8) as compared to the non-interstemmed controls (1.9). Trees with 'Bosc' interstems produced the greatest number of lateral

Table 3. Effect of interstem on the difference in trunk cross sectional area between 15 and 35 cm above the lower bud union on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Difference in trunk cross sectional area between 15 and 35 cm (cm^2)[Z]				
	1994	1995	1996	1997	1998
Analysis of variance (df)[Y]					
Block (5)	ns	ns	ns	ns	ns
Cultivar (3)	ns	*	**	***	***
Error A (15)	—	—	—	—	—
Interstem (3)	*	ns	***	***	***
C x I (9)	ns	ns	ns	ns	ns
Error B (48-56)[X]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	1.0	0.9 ab	1.3 ab	0.1 c	1.1 b
Bartlett	1.1	1.2 a	1.6 a	0.1 c	3.4 a
Bosc	1.1	1.0 ab	1.0 bc	1.2 b	1.5 b
Comice	1.1	0.8 b	0.5 c	2.6 a	-2.0 c
Main effect - interstem					
1-yr old	—	—	—	—	—
2-yr old	—	—	—	—	—
d'Anjou	0.9 b	0.6	0.6 b	0.1 c	-1.0 c
Bartlett	1.3 a	0.9	0.9 b	0.2 c	-1.1 c
Bosc	1.2 ab	1.1	1.1 b	1.3 b	1.8 b
Conference	0.9 b	1.2	1.7 a	2.6 a	3.7 a

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of missing data.
[W]Measurements not made.

branches (9.4) as compared to the non-interstemmed controls with 1-yr-old rootstocks (1.6).

TCSA was positively correlated with the total above ground fresh biomass of trees (24), and has come to be used as a measure of tree size. However, in apples Strong and Azarenko found as tree size increased, the reliability of TCSA to predict the total dry mater in the tree decreased (19). As early as 1958, Maggs (9) suggested that rootstocks could influence tree size by altering dry matter partitioning, and apple rootstocks have been shown to influence the partitioning of dry matter between fruit and the above ground vegetative portions of the tree (2, 17). More recently, rootstock was found to significantly alter the ratio of aboveground to root dry matter, and as tree size increased, the percentage of dry matter partitioned to the roots decreased (18). The dramatic change in the relative differential between TCSA as measured at different heights indicates that we can prejudice our perception of tree size by where we measure TCSA. The use of TCSA therefore may not be a good measure for estimating tree size when comparing different scions, rootstocks and/or interstem combinations.

The use of canopy volume (CV), while not giving a good measure of total biomass, would seem to be a better measure of potential tree size as it indicates the physical space occupied by the canopy. No significant cultivar by interstem interactions in tree height occurred (Table 4). 'Comice' trees were consistently and significantly the shortest. Generally non-interstemmed trees with 1-yr-old and 2-yr-

Table 4. Effect of interstem on number of lateral branches and tree height of 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	1994[Z] Branches per tree	Average height (m)				
		1994	1995	1996	1997	1998
Analysis of variance (df)[Y]						
Block (5)	ns	ns	ns	***	***	**
Cultivar (3)	***	***	***	***	***	**
Error A (15)	—	—	—	—	—	—
Interstem (5)	***	ns	*	***	***	***
C x I (15)	ns	ns	ns	ns	ns	ns
Error B (84-96)[X]	—	—	—	—	—	—
Main effect - cultivar						
d'Anjou	4.4 b	1.2 b	1.7 a	2.3 b	2.8 a	3.5 a
Bartlett	7.6 a	1.2 bc	1.9 a	2.6 a	3.0 a	3.5 a
Bosc	1.6 c	1.4 a	1.8 a	2.5 ab	2.8 a	3.4 a
Comice	5.3 b	1.1 c	1.5 b	2.0 c	2.3 b	2.9 b
Main effect - interstem						
1-yr old	1.6 d	1.3	1.9 a	2.7 a	3.1 a	3.7 a
2-yr old	2.2 d	1.2	1.7 ab	2.3 bc	2.7 ab	3.4 a
d'Anjou	4.2 c	1.3	1.8 ab	2.5 ab	3.0 a	3.5 a
Bartlett	6.5 b	1.2	1.6 b	1.9 d	2.4 b	2.9 b
Bosc	9.4 a	1.3	1.9 a	2.5 ab	2.9 a	3.6 a
Conference	4.6 c	1.2	1.6 b	2.1 cd	2.3 b	2.7 b

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of missing data.

old rootstocks and 'd'Anjou' and 'Bosc' interstem trees were the tallest over the five years of the experiment. Trees with 'Bartlett' or 'Conference' interstems were the shortest. 'Bartlett' and 'Bosc' trees with 'Conference' interstems were 66 % and 65 %, respectively, the height of the non-interstemmed controls with 1-yr-old rootstocks, while 'd'Anjou' and 'Comice' trees with 'Conference' interstems were 78 % and 77 %, respectively, the height of the non-interstemmed controls with 1-yr-old rootstocks.

The maximum branch spread of trees was significantly affected by both cultivar and interstem (Table 5). Additionally there was a significant cultivar by interstem interaction in 1994. Non-interstemmed 'd'Anjou' trees with 1-yr-old rootstocks exhibited the largest spread of branches (0.51 m), while non-interstemmed 'd'Anjou' trees with 2-yr-old rootstocks were the narrowest (0.25 m) (data not shown). 'Bartlett', 'Bosc', and 'Comice' trees with 'Bosc' interstems exhibited the widest spread of branches. Non-interstemmed 'Bartlett' and 'Comice' trees with 1-yr-old rootstocks were the narrowest, while non-interstemmed 'Bosc' trees with 2-yr-old rootstocks were the narrowest. 'Bartlett' and 'd'Anjou' trees exhibited similar branch spread throughout the trial. In all five years of the study, 'Comice' trees were the narrowest. In 1995 through 1998, trees with 'Bosc' interstems exhibited the largest spread of branches. Trees with 'Bartlett' and 'Conference' interstems were only 69% and 74% of 'Bosc' inter-

Table 5. Effect of interstem on average tree spread of 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Average tree spread (m)[z]				
	1994	1995	1996	1997	1998
Analysis of variance (df)[y]					
Block (5)	ns	*	**	***	***
Cultivar (3)	*	***	***	***	***
Error A (15)	—	—	—	—	—
Interstem (5)	***	*	***	***	***
C x I (15)	**	ns	ns	ns	ns
Error B (84-96)[x]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	0.38 ab	0.73 a	1.46 a	1.80 a	2.29 a
Bartlett	0.44 a	0.83 a	1.44 a	1.84 a	2.20 a
Bosc	0.43 a	0.70 a	1.26 a	1.56 b	2.06 a
Comice	0.34 b	0.50 b	0.89 b	1.05 c	1.55 b
Main effect - interstem					
1-yr old	0.35 bc	0.77 a	1.45 a	1.71 ab	2.23 a
2-yr old	0.27 c	0.63 abc	1.16 b	1.45 bc	2.02 ab
d'Anjou	0.41 b	0.77 ab	1.43 a	1.68 ab	2.16 a
Bartlett	0.45 ab	0.55 c	0.93 c	1.26 c	1.61 b
Bosc	0.54 a	0.79 a	1.47 a	1.88 a	2.32 a
Conference	0.36 bc	0.61 bc	1.10 c	1.33 c	1.73 b

[z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[x]Degrees of freedom vary due to the number of missing data

stem trees. By the fifth year of the trial, trees with 'Bartlett' interstems were only 69 % as wide as trees with 'Bosc' interstems.

Based on the observed growth habit of the trees, a model was developed to calculate canopy volume (CV). The formula used was: $CV = (0.2454)(dia^2)(h)$. Tree height and spread affected canopy volume (Table 6). 'Comice' trees had the smallest CV from 1996 to 1998. In general, the other cultivars had similar CV. The CV of 'Comice' trees was only 52 % of 'd'Anjou' trees. Trees with 'Bosc' and 'd'Anjou' interstems had the largest CV throughout the trial. From 1995 through 1998, trees with 'Conference' and 'Bartlett' interstems had the lowest CV. By the fifth year of the trial, trees with either 'Bartlett' or 'Conference' interstems were only 50 % of the CV on the non-interstemmed trees with 1-yr-old rootstocks.

Based on TCSA at 15 cm 'Bosc' and 'Comice' trees were the smallest, while 'Comice' was the smallest based on CV. Both measures of growth similarly ranked the largest four interstems, reversing only the smallest two; however, the relative difference between interstems were different with the two systems. 'Conference' and 'Bartlett' interstem trees generally had the smallest TCSA at 15 cm and CV.

Flowering and Fruit Set

No flower clusters were observed until the second (1995) year of the trial, and then a significant cultivar by interstem interaction was observed (Table 7). 'Bartlett' and 'Comice' trees with 'Bosc' interstems produced the greatest number of flower clusters (17.2 and 11.7, respectively),

Table 6. Effect of interstem on canopy volume of 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Canopy volume (m^3)[Z]				
	1994	1995	1996	1997	1998
Analysis of variance (df)[Y]					
Block (5)	ns	*	**	***	***
Cultivar (3)	*	***	***	***	***
Error A (15)	—	—	—	—	—
Interstem (5)	***	***	*	***	***
C x I (15)	ns	ns	ns	ns	ns
Error B (84-96)[X]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	0.05 bc	0.27 b	1.36 a	2.62 ab	5.09 a
Bartlett	0.07 ab	0.46 a	1.68 a	3.10 a	4.78 a
Bosc	0.08 a	0.28 b	1.25 a	2.14 b	4.27 a
Comice	0.04 c	0.14 b	0.64 b	0.95 c	2.63 b
Main effect - interstem					
1-yr old	0.06 bc	0.38 a	1.62 ab	2.75 ab	5.30 a
2-yr old	0.03 c	0.24 ab	1.15 bc	2.01 bc	4.17 ab
d'Anjou	0.06 bc	0.32 ab	1.50 ab	2.49 ab	4.57 a
Bartlett	0.07 ab	0.17 b	0.57 c	1.30 c	2.63 bc
Bosc	0.11 a	0.42 a	1.77 a	3.27 a	5.64 a
Conference	0.04 bc	0.17 b	0.75 c	1.27 c	2.57 c

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of mising data.

while the non-interstemmed controls with 1-yr-old rootstocks produced the least (0.1 and 0.2, respectively). Within 'Bartlett' and 'Comice', the number of clusters was related to the number of lateral branches formed the first growing season; however, this relationship was not observed with 'd'Anjou' or 'Bosc' (data not shown). 'D'Anjou' and 'Bosc' trees produced few, if any flowers. In 1996 and 1997, only the main effect of cultivar was significant, with 'Bartlett' trees producing the most flowers, and the other cultivars producing the least. In the fifth year of the trial, both significant interstem and cultivar main effects were observed. Non-interstemmed trees with 1-yr-old rootstocks and 'Bosc' and 'd'Anjou' interstem trees produced a greater numbers of flower clusters than 'Bartlett' interstem trees.

A significant cultivar by interstem interaction occurred in the date of first bloom (Table 8). Non-interstemmed 'd'Anjou' trees or 'd'Anjou' trees with 'Conference' interstems bloomed the earliest, while 'd'Anjou' trees with 'Bosc' interstems began bloom the latest (data not shown). 'Bartlett' and 'Comice' trees with 'Bosc' interstems began bloom the earliest, while non-interstemmed 'Bartlett' trees with 1-yr-old rootstocks and 'Comice' trees with 'd'Anjou' interstems began bloom the latest. 'Bosc' trees with 'd'Anjou' interstems were the earliest to bloom while 'Bosc' trees with 'Bartlett' interstems began bloom the latest. Full bloom was reached earliest in 'd'Anjou' trees, with 'Bartlett', 'Comice', and 'Bosc' trees significantly later. Interstem did not significantly affect the date of full bloom. 'Bartlett' trees had the longest bloom period, as measured by

Table 7. Effect of interstem on the number of flower clusters on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Number of flower clusters[z]				
	1994	1995	1996	1997	1998
Analysis of variance (df)[y]					
Block (5)	ns	ns	*	*	***
Cultivar (3)	ns	***	***	***	***
Error A (15)	—	—	—	—	—
Interstem (5)	ns	***	ns	ns	*
C x I (15)	ns	***	ns	ns	ns
Error B (78-86)[x]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	0.0	0.1 c	0.9 b	14.3 b	44.4 b
Bartlett	0.0	6.2 a	15.1 a	101.8 a	158.0 a
Bosc	0.0	0.1 c	2.6 b	17.3 b	25.9 b
Comice	0.0	2.9 b	4.1 b	16.8 b	28.5 b
Main effect - interstem					
1-yr old	0.0	0.1 b	3.9	36.4	80.2 a
2-yr old	0.0	1.0 b	5.1	50.1	70.5 ab
d'Anjou	0.0	0.8 b	5.0	36.1	72.0 a
Bartlett	0.0	1.9 b	3.9	19.7	34.8 b
Bosc	0.0	7.5 a	9.4	45.3	77.6 a
Conference	0.0	2.8 b	6.6	37.6	50.1 ab

[z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[x]Degrees of freedom vary due to the number of missing data.

the number of days between first and full bloom. The bloom of 'Bosc' trees was 55% shorter than 'Bartlett'. Interstem alteration of the bloom period, and the variability between cultivars and within years has been previously reported (6, 12, 13).

Significant main effect differences of both cultivar and interstem on initial fruit set were observed (Table 8). Initial fruit set was highest in 'Bosc' trees and least in 'Comice' trees. Initial fruit set was only statistically different between 'Bosc' and 'Comice'. However, the final fruit set was highest for 'Bosc' trees, intermediate for 'd'Anjou', and lowest for 'Bartlett' and 'Comice' trees. Interstems did not influence final fruit set.

Fruit Production and Size

'Bartlett' was the only cultivar to bear fruit in 1995 (Table 9), and this explains the cultivar by interstem interaction observed. A few 'Bosc' trees bore fruit in 1996; while, 'd'Anjou' and 'Comice' did not produce harvestable fruit until the fourth year of the trial (1997). 'Bartlett' trees produced the greatest number of fruit each year, and the greatest number of fruit over the five years of the trial. 'Comice' trees were the least productive. Trees with 'Bosc' interstems produced the most harvestable fruit followed by non-interstemmed trees with 1-yr-old and 2-yr-old rootstocks. Significant interstem effects on yield were not observed until 1998. Trees with 'Bartlett' interstems produced the least harvestable fruit in 1998, and over the five years of the trial.

Per tree yields followed a pattern similar to fruit numbers (Table 10). No significant cultivar by interstem interactions

Table 8. Effect of interstem on the average date of first and full bloom, the number of bloom days, and initial and final fruit set on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Average[z] date first bloom	Average date full bloom	Average days of bloom (No.)	Average fruit set (Fruit per 100 clusters) Initial	Final
Analysis of variance (df)[y]					
Block (5)	*	ns	ns	ns	ns
Cultivar (3)	***	***	***	***	***
Error A (15)	—	—	—	—	—
Interstem (5)	**	ns	ns	*	ns
C x I (15)	**	ns	ns	ns	ns
Error B (78)	—	—	—	—	—
Main effect - cultivar					
d'Anjou	5 Apr b	20 Apr b	10.2 b	54.4 b	44.4 b
Bartlett	9 Apr b	22 Apr a	13.1 a	50.6 b	29.9 bc
Bosc	17 Apr a	24 Apr a	7.2 c	119.3 a	94.0 a
Comice	15 Apr a	23 Apr a	7.6 bc	29.3 c	23.7 c
Main effect - interstem					
1-yr old	11 Apr ab	19 Apr	6.7	53.7 ab	39.0
2-yr old	10 Apr b	23 Apr	11.8	68.8 ab	57.0
d'Anjou	12 Apr a	23 Apr	10.1	59.2 ab	45.7
Bartlett	12 Apr a	22 Apr	9.4	48.8 b	44.6
Bosc	12 Apr a	22 Apr	11.0	79.4 a	57.9
Conference	11 Apr ab	22 Apr	10.5	70.6 ab	44.1

[z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.

were observed. Significant main cultivar effects were observed by 1996, and significant main interstem effects were observed by 1997. 'Bartlett' trees produced the largest yields each year and over the five years of the trial, followed by 'Bosc', 'd'Anjou', and lastly 'Comice'. Trees with 'Bosc' interstems were the most productive. The variable effects of interstem and cultivar are consistent with cultivar and interstem effects on yields reported in other trials (5, 12, 14, 21).

Average fruit weight was significantly affected by cultivar but not by interstem (Table 11). 'Bartlett' trees produced the smallest fruit, while 'Comice' trees produced the largest fruit. These interstem results are not consistent with those reported for 'Conference' pear, where fruit weight was negatively affected by interstem (21). However, in that study the plant material was suspect for virus contamination, and it has been shown that the presence of a virus could adversely affect growth and production (7, 22). Drawing conclusions about interstem effects on fruit size is difficult when many of the trees were still coming into bearing in the fifth year of the trial.

Yield Efficiency and Volume Density

Yield efficiency (YE) followed a similar pattern to production with respect to cultivar and interstem (Table 11); however, interstem differences in YE were not detectable as they were for yield. 'Bartlett' trees were the most yield efficient while 'Comice' and 'd'Anjou' trees were the least yield efficient. Yield efficiency was not statistically different between interstem trees.

Table 9. Effect of interstem on the number of fruit on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Number of fruit per tree [Z]				
	1995	1996	1997	1998	Total
Analysis of variance (df)[Y]					
Block (5)	ns	ns	*	*	*
Cultivar (3)	***	***	***	***	***
Error A (15)	—	—	—	—	—
Interstem (5)	**	ns	ns	**	*
C x I (15)	***	ns	ns	ns	ns
Error B (67-86)[X]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	0.0 b	0.0 b	0.7 c	28.5 c	29.5 b
Bartlett	1.2 a	3.7 a	17.3 a	69.1 a	92.1 a
Bosc	0.0 b	0.7 b	11.4 b	34.3 b	43.0 b
Comice	0.0 b	0.0 b	0.2 c	16.9 c	16.8 b
Main effect - interstem					
1-yr old	0.1 b	1.7	9.4	45.6 b	51.8 ab
2-yr old	0.2 b	1.3	8.3	37.7 bc	48.1 abc
d'Anjou	0.2 b	0.9	8.3	33.4 bc	43.2 bc
Bartlett	0.1 b	0.6	3.4	19.1 c	22.7 c
Bosc	1.1 a	1.3	11.7	60.1 a	74.0 a
Conference	0.1 b	0.7	4.9	27.1 bc	32.2 bc

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of missing data.

The ability of TCSA to accurately predict dry matter accumulation decreased as TCSA increased (19), the effect of rootstock altering the partitioning of dry matter between the top and the root (2, 17, 18), and different relative TCSAs depending on where on the trunk TCSA is measured strongly suggests that the calculated YE may not accurately estimate productivity on a tree size basis.

Significant main effects, but no significant cultivar by interstem interaction, were observed in volume density (VD). The cultivar effects on VD followed a pattern that was similar to production and YE, with 'Bartlett' trees having the greatest VD and 'Comice' and 'd'Anjou' trees having the smallest VD. Interstem main effects followed a distinctively different pattern compared to both production and YE. Trees with 'Conference' interstems had the largest VD, while having the lowest production and YE. CV was smallest for 'Conference' interstem trees and could explain this difference. Trees with 'Bartlett' interstems had the lowest VD, and the lowest productivity and YE.

Conclusions

This initial five-year study indicates that cultivars utilized as interstems may increase yields, alter growth habits, and affect volume density. Similar findings have been previously reported for apple (1), apricot (12), cherry (3, 5), peach (20), and pear (6). Whether these interstem effects persist as trees attain full production remains an interesting question.

Literature Cited:

1. Ferree, D. C. 1992. Performance of 'Golden Delicious' on two rootstocks and four dwarfing interstems over 10 years. Fruit Var. J.

Table 10. Effect of interstem on the kg of fruit per tree on 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Yield (kg/tree)[Z]				
	1995	1996	1997	1998	Total
Analysis of variance (df)[Y]					
Block (5)	ns	ns	*	*	*
Cultivar (3)	ns	***	***	**	***
Error A (12-15)	—	—	—	—	—
Interstem (3-5)	ns	ns	*	*	*
C x I (9-15)	ns	ns	ns	ns	ns
Error B (83-86)[X]	—	—	—	—	—
Main effect - cultivar					
d'Anjou	0.0	0.0 b	0.2 b	6.3 b	6.5 bc
Bartlett	0.0	0.7 a	3.3 a	11.0 a	15.1 a
Bosc	0.0	0.2 b	2.3 a	6.0 b	7.2 b
Comice	0.0	0.0 b	0.1 b	4.1 b	3.0 c
Main effect - interstem					
1-yr old	0.0	0.4	1.7 ab	8.5 ab	9.2 ab
2-yr old	0.4	0.3	1.6 ab	6.5 abc	8.1 b
d'Anjou	0.1	0.2	1.7 ab	6.4 abc	7.8 b
Bartlett	0.1	0.1	0.4 b	3.8 c	3.8 b
Bosc	0.7	0.3	2.4 a	10.6 a	13.4 a
Conference	0.1	0.1	0.9 b	5.2 bc	5.5 b

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.
[X]Degrees of freedom vary due to the number of missing data.

46:93-97.
2. Forshey, C. G. and D. C. Elfving. 1989. The relationship between vegetative growth and fruiting in apple trees. Hort. Rev. 11:229-287.
3. Grzyb, Z. S., S. W. Zagaja, and J. Zdyb. 1985. Growth and yield of sweet cherry trees with interstem. Acta Hort. 169:311-317.
4. Hilkenbäumer, F. 1973. Einfluß von Quittenunterlagen und Zwischenveredlungen auf die Leitstung wichtiger βirensorten. Erwerbsobstbau 15:161-164.
5. Hrotkó, L., L. Magyar, and G. Simon. 1998. Growth and productivity of sweet cherry interstem trees. Acta Hort. 468:353-362.
6. Larsen, F. E. and S. S. Higgins. 1997. Scion/rootstock interactions determine tree size of ten Asian pear scion cultivars on five Old Home x Farmingdale rootstocks. Fruit. Var. J. 51:48-52.
7. Lemoine, J. and J. Michelesi. 1990. Effect of three virus diseases on three pear cultivars. Sci. Hort. 44:69-81.
8. Lombard, P. B. and M. N. Westwood. 1987. Pear rootstocks. p. 145-173 In: (eds.) R. C. Rom and R. F. Carlson, Rootstocks for fruit crops. J. Wiley and Sons, Inc. New York.
9. Maggs, D. H. 1958. A comparison of the growth patterns of two apple rootstocks varieties during their first year. Ann. Rpt. E. Malling Res. Sta. 1957. p. 101-105.
10. Mielke, E. A. 1998. The effect of rootstock and angle of shoot positioning on the productivity and nutrient content of 'd'Anjou' pears. Acta Hort. 475:149-156.
11. Monin, A. 1974. Étude de la greffe intermediaire chez le poirier. Le Fruit Belge. 42:250-258.
12. Ogasanovic, D., R. M. Plazinic, and V. M. Papic. 1991. Results from the study of some early apricot cultivars on various interstocks. Acta Hort. 293:383-389.
13. Reighard, G. L. 1998. Manipulation of peach phenology, growth, and fruit maturity using interstems. Acta Hort. 465:567-572.
14. Rozpara, E., Z. S. Grzyb, and H. Zdyb. 1997. Growth and fruiting of two sweet-cherry cultivars with different interstems. Acta Hort. 468:345-352.
15. Sansavini, S. and A. Bosi. 1969. Ricerche sul sovrainnesto del pero: primo osservazion sul compartmento di 120 combinazioni di

innesto. Rivista dell' Ortoflorofruitcoltura Italiana 93(LIII,4):17-21.
16. SAS User's Guide: Statistics, version 8.0. 1999. SAS Institute Inc., Cary, NC.
17. Schechter, I., D. C. Elfving, and J. T. A. Proctor. 1991. Rootstock affects vegetative growth characteristics and productivity of 'Delicious' apple. HortScience 26:1145-1148.
18. Strong, D. and A. N. Azarenko. 2000. Altered dry matter partitioning of 'Starkspur Supreme Delicious' apple trees by nine rootstocks. J. Amer. Pomol. Soc. 54:11-17.
19. Strong, D. and A. N. Azarenko. 2000. Relationship between trunk cross sectional area, harvest index, total tree dry weight and yield components of 'Starkspur Supreme Delicious' apple trees. J. Amer. Pomol. Soc. 54:22-27.
20. Werner, D. J. and E. Young. 1987. Effect of 'Siberian C' interstem, and scion on foliar calcium content in peach. Fruit Var. J. 41:140-141.
21. Wertheim, S. J. and J. Vercammen. 2000. A multi-site pear-interstem trial in the Netherlands and Belgium. J. Amer. Pomol. Soc. 54:199-207.
22. Wertheim, S. J. and H. J. van Oosten. 1986. Comparison of virus-free and virus-infected clones of two pear cultivars. Acta Hort. 170:51-60.
23. Westwood, M. N., P. B. Lombard and H. O. Bjornstad. 1989. Pear on 'Winter Banana' interstem with M26 apple rootstock as a compatible combination. HortScience 24:765-767.
24. Westwood, M. N. and A. N. Roberts. 1970. The relationship between trunk cross-sectional area and weight of apple trees. J. Amer. Soc. Hort. Sci. 95:28-30.

Table 11. Effect of interstem on average fruit weight and yield efficiency of 5-year-old 'd'Anjou', 'Bartlett', 'Bosc', and 'Comice' trees. Data are lsmeans for six blocks.

	Average fruit[Z] weight (g)	Yield efficiency (kg/cm^2)	Volume density (kg/m^3)
Analysis of Variance (df)[Y]			
Block (5)	ns	**	ns
Cultivar (3)	***	***	***
Error A (15)	—	—	—
Interstem (5)	ns	ns	**
C x I (15)	ns	ns	ns
Error B (84)	—	—	—
Main effect — cultivar			
d'Anjou	204 b	0.18 c	1.23 c
Bartlett	178 c	0.53 a	2.95 a
Bosc	194 bc	0.35 b	2.04 b
Comice	254 a	0.10 c	0.77 c
Main effect — interstem			
1-yr old	207	0.33	1.58 bc
2-yr old	201	0.30	1.59 bc
d'Anjou	217	0.28	1.49 bc
Bartlett	199	0.17	1.13 c
Bosc	220	0.38	2.00 b
Conference	200	0.26	2.70 a

[Z]Means within a column and section followed by the same letter are not significantly different at p=0.05.
[Y]ns, *, **, ***, not significant or significant at p=0.05, p=0.01, or p=0.001, respectively.

❖ ❖ ❖ ❖ ❖ ❖ ❖

Genotype x Environment Interactions in Highbush Blueberry

Twenty blueberry (*Vaccinium sp.* L.) families were grown in Oregon and Michigan to assess variablilty among families, locations, and the significance of family x location interaction. The families were from crosses among parents with a wide genetic background. Plants were grown at Corvallis, OR and East Lansing, MI. In 1998-2000 evaluations were made on survival, date of bloom, ripening date, and plant size. Fruit were rated for crop load, color, size of scar, size, and firmness. Most traits varied between locations. Plant survival was better in Oregon by 36%. Plants were both taller and wider in Oregon than in Michigan. On the basis of these results, individuals selected on the basis of crop load, fruit color, and fruit firmness should perform similarly in both locations. The family x location interaction was significant for other traits such as survival, bloom date, ripening date, ripening interval, and plant size. The authors concluded that there is a need for individual selection programs at each location. From: Finn, C.E., J. F. Hancock, T. Mackey, and S. Serce 2003. J. Amer. Soc. Hort. Sci. 128:196-200.