Early Performance of ‘Conference’ Pear on Four Training Systems

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Abstract. To determine how different training systems affected early growth and fruiting (first 5 years), ‘Conference’ pear (*Pyrus communis* L.) trees on Quince A (*Cydonia oblonga* L.) rootstock were trained to angled trellis, slender spindle, vertical axe, or Y-trellis. The trees of the Y-trellis had the greatest spread after 5 years, and the vertical axe and slender spindle trees were the tallest. The Y-trellis trees had the highest light interception and had significantly higher yields in 1997 than the other training systems. Average fruit weight was inversely related to crop load.

‘Conference’ pear is a major cultivar in Europe but little planted in North America. It has many attributes that make it worthy of consideration for planting; it is precocious, productive, has good flavor, and can be stored until January or February. Possible concerns that may limit the interest in this cultivar include small fruit size, fruit russet, and susceptibility to fire blight [*Erwinia amylovora* (Burr.) Winslow et al.].

Few truly dwarfing rootstocks exist for pears. To date, clones of quince have been the only rootstocks to provide any control of vegetative growth. Some *P. communis* rootstocks, such as OHxF 51 and OHxF 333, are reported to be dwarfing, but they do not control vigor enough for use in intensive, high-density orchards.

A major objective when designing orchards is to arrange and train trees for maximum light interception. Apple (*Malus × domestica* Borkh.) yields are related to light interception of orchards (Hunter and Proctor, 1986; Palmer, 1989; Robinson and Lakso, 1991). To ensure the production of high quality fruit, light distribution throughout the tree is optimized by tree training. Light interception by spurs is extremely important for high quality fruit and optimum yields. In his review, Palmer (1989) reported that fruit color, weight, and soluble solids concentration are positively related to light levels within the canopy of trees. Kappel and Neilsen (1994) showed that fruit size of ‘Anjou’ pear is positively correlated with the amount of light received by spurs.

To reach the goal of an efficient orchard design, apple producers have adopted size-controlling, precocity-inducing rootstocks

and planted high-density orchards using many different training systems. Apple tree density affects the early productivity of the orchard; the higher the density, the higher the yield (Robinson et al., 1991, Ystaas et al. 1994, and Hampson et al., 1998). Wertheim and Wagenmakers (1984) showed that increasing tree density of ‘Conference’ pear on Quince C rootstock increased yield. At present, the only size-controlling rootstocks that have been evaluated fully and are commercially available for pears are clones of quince. However, possible lack of winter hardiness, insufficient size-control, and incompatibility with many pear cultivars limits the usefulness of some of the quince clones.

Presently, in British Columbia, pears are pruned and trained to a multiple-leader system or a modified-central-leader system on standard-size rootstocks. These training systems may not be suitable for pears on dwarfing rootstocks in high-density orchards. Trials need to be conducted for different cultivars and different locations. As Barritt (1987) reported, no one training system is optimum for all conditions (cultivar, rootstock, climate, or economic circumstances).

The objective of this study was to determine the effects of training system on ‘Conference’ pear growth and productivity. This report presents the results for the first 5 years after planting.

Materials and Methods

Trees were planted in Spring 1994 in a sandy loam soil (Naramata and Agar Lake sandy loam). The scion cultivar ‘Conference’ was propagated on Quince A rootstock with an ‘Old Home’ interstem. ‘Conference’ is graft-compatible on Quince A, but to ensure age synchrony of the ‘Conference’ trees with the various pollinizers that were being used, an interstem was used for all trees. Trees were planted in three-row plots and rows were oriented north-south. Each three-row plot was replicated four times, with the center row of each plot serving as the data row and the outside rows acting as guard rows. There

were five trees in each row, with the center three trees being used for data collection and the end trees acting as guard trees. Between each of the research plots, rows of five different pollinizers were planted.

Training systems and spacings were as follows: angle (A) 3.5 m between rows × 1.75 m within rows; vertical axe (VA) 3.5 m × 1.75 m; slender spindle (SS) 3.5 m × 1.75 m, and Y-trellis (YT) 4.0 m × 1.50 m, equivalent to 1632 trees/ha for A, VA, and SS and 1666 trees/ha for the YT training systems. Trees trained to the A system were planted at a 45° angle from the vertical with the leader pointing north. The leader was then tied to a bamboo stake that was supported at the same angle by a three-wire trellis. An attempt was made to train shoots that developed on the top of the trunk to a 90° angle to the tree. The leader was headed (removing about one-third) during each dormant pruning season. The maximum height of the trellis was 1.8 m to the top wire.

The VA trees were supported by a bamboo stake that was tied to a three-wire trellis 2.8 m in height. Trees were headed at planting, and thereafter the leader was tied to the bamboo stake. A bottom tier of branches was developed, and shoots on the trunk above this tier were renewed to maintain young fruiting wood.

The SS trees were supported by individual 1.8-m wooden posts. The central leader was tied to the post, and a tier of scaffold branches was developed, as with the vertical axe. The leader was headed at planting, and during each dormant pruning season, a weak replacement leader was chosen from the current season’s shoots, tied vertically to the post, and lightly headed. Small, temporary, fruiting branches were developed above the bottom tier of branches. No summer pruning was performed.

The YT trees were headed at ≈0.6 m at the time of planting. Two main shoots were allowed to grow and were trained to the arms of the trellis. The base of the V for each tree was the point of heading, ≈0.6 m from the ground. The arms of the trellis were 60° apart and the height to the top wire was 2.0 m. Branches that developed between the arms were trained to the trellis. Some shoots in the interior of the trellis were removed if they could not be trained to one of the arms.

Fruit were removed in Spring 1994 and 1995 to allow for establishment of the trees. Irrigation consisted of trickle emitters with fertigation, and over-tree sprinklers for maintenance of sod alleyways. A total of 5 g of actual N was applied per tree per year through the irrigation system. Local recommendations were followed for insect and disease control. Fruit were hand-thinned in 1996, 1997, and 1998 by spacing single fruit ≈15 cm apart.

Data collected included trunk diameter and tree height and spread at the end of each growing season. Tree spread was measured for all systems by recording the distance from longest shoot tip to longest shoot tip perpendicular to and within the tree row. The two

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measurements were then averaged. Yield by weight and fruit number were recorded once the trees were allowed to fruit, and the average fruit weight was calculated. In 1998, light interception by the tree canopy was measured as a percentage of total above-canopy photosynthetically active radiation (*PAR*) using a LI-COR Line Quantum Sensor (LI-191S; LI-COR, Lincoln, Nebr.). Measurements were made after shoot growth had stopped. Readings were taken on bright sunny days (within 2 h of solar noon), because diffuse light conditions do not occur consistently enough during the summer under our climatic conditions. Two cross-row transects of readings from the center of the alley to the center of the next alley were taken at the base of the canopy under one tree per replication for each of the training systems. The first transect was at the midpoint between trees in the row, and the next was taken at the tree trunk. The light intercepted by the tree was expressed as a percentage of the above canopy reading. The number of leaves and spurs were counted on trees used for the light interception measurements. Leaf area of every tenth leaf and leaf area index (LAI) were calculated from these samples.

Plots were arranged in a randomized complete-block design and Duncan's new multiple range test was used for mean separation. Analysis of covariance, with annual crop density [fruit number per tree/trunk cross-sectional area (TCA)] used as a covariate, was used to determine if crop load had an effect on fruit size.

Results and Discussion

The YT trees had the greatest spread after 5 years but there were no significant differ-

ences among the other systems (Table 1). The tallest trees were those trained to the VA and SS, whereas the shortest trees were those as the A system, with the YT trees intermediate in height. There were no significant differences in TCA at the end of the 1998 season.

Height of trees of the A and YT systems was low enough that most of the work could be done from the ground. The VA trees, however, were tall enough that a short ladder was required to reach the top of the trees to complete some of the orchard tasks (e.g., pruning, thinning, and harvesting). Quamme et al., (1997) reported that VA and central-leader trees in an apple training-system trial also required ladders to complete the tasks, but were considered to have good labor efficiency (kg of fruit harvested per hour of labor). The least labor-efficient system in their trial was the SS system. Labor usage was not recorded in the present trial, therefore the efficiencies of these systems cannot be determined. A goal of any training system is to ensure that the canopy develops quickly. The YT and the A systems most quickly "filled" their within-row space (data not shown). By 1996, the within-row spacing that was filled was 83%, 79%, 58%, and 47% for the YT, A, SS, and VA trees, respectively.

Yields did not differ significantly in either 1996 or 1998, but cumulative yields and those for 1997 were higher for YT trees than for the other training systems (Table 2), with yields for SS and VA trees being lowest. The most efficient trees in terms of cumulative yield per TCA or cumulative yield per increase in TCA were the YT and A trees.

In this trial, the lowest yielding system, SS, produced $\approx 59\%$ of the yield/ha of the highest yielding system, YT. Robinson et al. (1991) showed that TCA/ha was highly cor-

related with cumulative yield in the first 10 years of an apple orchard's life. In our study, the YT had the highest TCA per ha (data not shown). Hampson et al., (1997) reported that apple trees trained to a YT had significantly greater spur leaf area, whereas there were no differences in leaf area (shoot, spur, or total) for any of the systems in our trial (Table 1). The YT trees intercepted almost twice as much light as did those in the other training systems. The differences in light interception that we measured probably were due to the presentation of the branches and leaves; that is, the shoots of the YT trees were spread and maintained at a 60° angle, and the canopy extended into the tractor alley. The higher light interception and yield of the YT trees supports the data of Robinson and Lakso (1991), Robinson et al., (1991), and Hampson et al. (1998) for apples. Robinson and Lakso (1991) reported that fruit yield was correlated with the level of *PAR*.

Average fruit weight was inversely related to crop load in 1996 and 1997 (Table 3). In 1996 and 1998, average fruit weight was significantly affected by training system, with the largest fruit on SS trees and the smallest fruit on YT trees. Fruit size was in the range reported in another trial with 'Conference' (Wertheim and Wagenmakers, 1984). Robinson et al. (1991) reported that fruit size of 'Empire' and 'Delicious' apple was inversely related to crop load, and Sugar and Van Buskirk (1994) reported similar results for 'Bosc' and 'Comice' pear.

This trial has shown that the YT system meets the requirements for a successful training system in the early life of a pear orchard. It filled its space quickly and produced high yields in the first 5 years of growth. More attention needs to be paid to managing crop load to ensure that fruit size is not reduced excessively because of increased yield. Fruit thinning, depending on severity, may increase fruit size, but reduce yield. The economic consequences will be determined by market outlets and prices obtained for the different sized fruit. We collected no economic data, but the YT system was very labor intensive in the early years. By year 5, however, the canopy was established and little further training was needed.

Table 1. Effect of training system on tree spread, height, trunk cross-sectional area, and shoot, spur, and total leaf area, and light interception of 'Conference' pear.

Observation	Training system				Significance
	Angled	Slender spindle	Verticle axe	Y-trellis	
Canopy spread (m)	1.2 b ^z	1.2 b	1.1 b	1.4 a	0.0099 ^y
Tree height (m)	2.3 c	3.0 ab	3.3 a	2.7 b	0.0001
Trunk cross-sectional area (cm ²)	31.0 a	35.4 a	32.3 a	36.0 a	0.3756
Leaf area per tree (m ²)					
Shoot	1.8 a	1.1 a	1.6 a	1.4 a	0.7660
Spur	1.1 a	0.6 a	1.2 a	1.4 a	0.4097
Total	2.9 a	1.7 a	2.8 a	2.8 a	0.6334
Total light interception (%)	16.8 b	15.8 b	17.2 b	32.9 a	0.0119

^zMean separation within observation by Duncan's new multiple range test, $P \leq 0.05$.

^ySignificance levels for observations from analysis of variance.

Table 2. Effect of training system on yield per tree and yield efficiencies of 'Conference' pear in the first 3 years of fruiting.

Training system	Yield (kg)				Cumulative yield efficiency (kg/cm ²)	
	1996	1997	1998	Cumulative	A ^z	B ^y
Angle	4.8 a ^x	11.2 b	7.2 a	23.2 b	0.75 a	1.32 a
Slender spindle	3.6 a	8.8 b	5.0 a	17.3 c	0.52 b	0.82 b
Vertical axe	4.1 a	10.7 b	5.8 a	20.6 bc	0.60 b	0.91 b
Y-trellis	4.9 a	17.9 a	6.0 a	28.7 a	0.82 a	1.43 a
Significance	0.5886	0.0001	0.4113	0.0001	0.0004	0.0006

^zA = Cumulative yield (1996 to 1998)/TCA Fall 1998.

^yB = Cumulative yield (1996 to 1998)/TCA increase from Fall 1995 to 1998.

^xMean separation within columns by Duncan's new multiple range test, $P \leq 0.05$.

Table 3. Effect of training system on average fruit weight of 'Conference' pear in the first 3 years of fruiting.^z

Training system	Average fruit wt (g)		
	1996	1997	1998
Angle	209 ab ^x	171 a	197 ab
Slender spindle	232 a	195 a	211 a
Verticle axe	182 b	176 a	183 b
Y-trellis	195 b	176 a	154 c
Significance ^y			
System	0.0142	0.0919	0.0002
Crop density	0.0355	0.0001	0.7671

^zLeast-squares means within columns separated by *t* test ($P \leq 0.001$).

^ySignificance levels for annual average fruit weight are from analysis of covariance with annual crop density (fruit number/trunk cross-sectional area) used as a covariate.

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