# Training and Performance of Pillar, Upright, and Standard Form Peach Trees – Early Results

Stephen Miller and Ralph Scorza
United States Department of Agriculture, ARS
Appalachian Fruit Research Station
Kearneysville, WV
USA

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**Abstract**

**Peach production in the U.S. relies on standard size trees on vigorous, seedling rootstocks grown at low-densities (≤ 297 trees/ha). Production per hectare is low. Peach tree growth habits, such as pillar (P) (columnar canopy shape) and upright (U), can be planted in high-density systems with the potential for increased production per hectare. Pillar and upright, advanced breeding selections, and standard (S) (‘Harrow Beauty’) trees on ‘Lovell’ rootstock were planted at 4 densities (135 trees/ha to 1112 trees/ha) and trained to a central leader (CL) or multiple leader (ML) form. Trees were dormant pruned and trained, then summer pruned (SP) in the first growing season after fall planting. One-half of the trees were SP in the second growing season after dormant pruning. Growth habit affected trunk and canopy size after two growing seasons. SP reduced canopy spread. Dormant CL training after one growing season required more time than ML training for all growth habits, however, the difference was greater for U and P trees (110% more time) than for S trees (39%). Branch spreading with training aids contributed to the greater training time for CL trees. Summer pruning increased light levels in the lower canopy with the greatest effect in S and U trees. Yields in the second leaf were greater for ML trained trees than CL trees. SP reduced the yield of U trees but not S or P trees. Based on these data and observations of U and P peach trees growing on a deep, well-drained fertile site, it appears that pruning and training of P and U trees to conform to a specific form may result in excessive tree vigor. Reduced early training to allow for expression of the natural growth habit may be preferable.**

## INTRODUCTION

Commercial peach [*Prunus persica* (L.) Batsch] production is based on standard size trees budded on vigorous, seedling rootstocks grown in low-density [≤ 297 trees/ha (120 t/acre)] systems. In recent years, fruit researchers and growers have used various training and pruning techniques to conform these standard growth habit trees to several high density planting systems (Bargioni et al., 1985; Chalmers et al., 1978; DeJong et al., 1994; Erez, 1982; Hayden and Emerson, 1988).

An alternative approach to high density is the development of growth habits suited to high-density systems (Scorza, 1984). Two growth habits with the most potential for high density planting are the pillar and upright form trees (Scorza, 1988). Performance tests of peach tree growth habits, in general, have been conducted and published (Bargioni et al., 1985; Bassi et al., 1994), but large-scale evaluations for pillar and upright trees at several planting densities and with different training methods have not been conducted to-date in the United States. This is a preliminary report of observations and findings on the pruning and training of pillar and upright peach trees growing at several planting densities at the USDA Appalachian Fruit Research Station (AFRS), Kearneysville, WV.

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## MATERIALS AND METHODS

A commercial nursery propagated advanced selections of pillar and upright form trees developed at AFRS. 'Harrow Beauty', a standard growth habit commercial peach cultivar, was included for comparison. All trees were budded in August 1997 on 'Lovell' rootstock and grown for one year in the nursery. Trees were dug in Fall 1998 and planted in December in north-south oriented rows. Upright and P trees had larger trunk diameters, more laterals, especially in the upper canopy, and were about twice as tall as standard trees when received from the nursery. Differences in branch angle were readily apparent at the time of planting with P trees having very upright branches and narrow crotch angles, U trees slightly more horizontal branches, while S trees had the most spreading branch structure.

Four planting densities [135 trees/ha (6.0 x 6.0 m), 418 trees/ha (4.0 x 6.0 m), 833 trees/ha (2.0 x 6.0 m), and 1112 trees/ha (1.5 x 6.0 m)] with three replications of eight trees each for each of three tree growth habits [standard (S), upright (U), and pillar(P)] were planted in a randomized complete block. Two training systems [central leader (CL) or multiple leader (ML)] were assigned randomly to four adjacent trees within each 8–tree plot. Border trees were used to separate blocks between and within rows. A commercially recommended spray schedule was followed for pest control, and fertilization and herbicides were applied as required.

Trees were pruned and trained in March and April 1999 before flower buds opened. Central leader trees were trained using techniques traditionally applied to apple. The leader was selected, and headed back to a bud between 120 and 180 cm (some standard tree's height did not exceed 100 cm, so heading was at a lower height) from the graft union. Shoots competing with the leader were removed. When possible, two layers of primary scaffold limbs were developed along the CL, the first beginning about 60 cm above the union and a second layer about 60 to 90 cm above the first. Three to four laterals were selected around the CL and retained as permanent scaffolds. These shoots were headed by removing about 20 – 30% of their length. A few weaker shoots along the trunk or on laterals of scaffolds selected were retained if they were not competing. Rubber bands and clip-on weights were used as training aids to spread limbs primarily in the P and U growth habit trees. The desire with these more vertical growth habits was to produce a tree with a candelabra form, thereby initially developing a more open tree than had been observed in the breeding plots while ultimately retaining a narrow canopy. Multiple leader trees were trained using techniques associated with the commonly used open vase system for peach. The leader was headed about 60 cm above the graft union at planting and 3 to 4 permanent scaffold limbs were retained. The major difference between our ML training and commercial open vase training was the use of training aids to spread the shoots retained on the ML trees.

Starting in early June 1999, summer pruning (SP) was utilized to further aid in developing the CL and ML forms. Training aids were again utilized to orient shoots that were retained as part of the canopy's main structure. In the CL trees, new shoots developing from the leader were selected where positioning favored a height nearer 150 to 180 cm above the graft. This approach allowed the second layer of scaffold limbs to be more than 60 cm above the first layer. The time to SP and train each 4-tree subplot was recorded and the average time per tree calculated.

The 1-year-old trees were dormant pruned between 28 March and 7 April 2000. Pruning consisted of thinning cuts to space limbs within the canopy and removal of unwanted or broken shoots. The leader and main terminal shoots were headed to remove about 20% of the previous season's growth. For ML trained trees, "bench" type cuts were used to open and redirect growth rather than using training aids, as in the case of the CL trained trees. The time to prune individual trees and the fresh weight of prunings was recorded. If a tree received training aids, the type of training aid used was also recorded.

In May 2000, because of excellent vigor, the decision was made to SP two trees in each of the 4-tree plots. SP began 7 weeks after full bloom and required about 3 weeks to complete. Thinning and heading cuts were used in SP to open the canopy and to assist in developing the desired tree form (CL or ML). Heading cuts were confined to laterals on the leader or secondary laterals on main scaffolds (no terminals on primary scaffolds were headed in SP). Where heading cuts were used, shoots were pruned back to 2 to 4 nodes from the point of origin. Pruning aids (bands, weights, and clothespins) were employed to improve limb position and aid in achieving the desired tree form. The time to prune individual trees, fresh weight of prunings, and the type(s) of pruning aid used was recorded. Two and one-half weeks and again at 4.5 weeks after SP the photosynthetic photon flux (PPF) in the center of the canopy was measured with a Li-Cor Model LI-189 Light Meter (Li-Cor, Inc., Lincoln, NE) fitted with a Li-Cor LI-190SA Quantum sensor calibrated to read in $\mu$ mol $s^{-1}m^{-2}$. The sensor was positioned about 15 cm from the center in the south half of the canopy at a height between 90 and 110 cm above the orchard floor. Incident PPF was measured after every fourth tree with the sensor placed at the same height as in canopy readings, but in the row middle. PPF was measured between 1130 hrs and 1300 hrs eastern daylight time and percent PPF for the tree canopy was calculated.

All trees had good bloom at the beginning of the second growing season (April 2000). Fruit set was heavy and because of the small canopy size, trees were hand thinned to leave approximately 10 fruit per tree. Fruit clusters were reduced to single fruits, regardless of spacing, in the hand thinning operation. Fruits were harvested on 1 and 13 August. On the first harvest date only fruit meeting commercially acceptable color were harvested (fruit size was not considered as a harvest criteria). On the second harvest date, all remaining fruits were harvested. Total yield per tree and average fruit weight and size was recorded. Trunk circumference 30 cm above the graft union was measured on 29 March and 30 Oct. 2000. Canopy height, width (in row spread), and depth (across row spread) were recorded on 30 Oct. 2000.

To minimize variability due to individual pruning biases, the senior author performed all pruning. The experiment had a factorial arrangement of treatments with tree growth habit, training system and SP in 2000 in a split-split-split plot design. The whole plot was tree density (spacing). Data were analyzed by ANOVA as a factorial and means separated by Duncan's new multiple range test at $P = 0.05$. Tree spacing was not included as a factor in the 1999 data analysis since none of the trees filled their allotted space until the 2000-growing season.

## RESULTS

Growth habit had a significant effect on trunk and canopy size (Table 1). The two-way interaction of growth habit X spacing was significant for canopy width. There was also an interaction of growth habit X SP for canopy depth. Upright trees had significantly larger trunks after two growing seasons than P or S trees. Trunk circumference more than doubled between year 1 and 2 for S and U trees with somewhat less increase for P trees. Upright trees were taller than P trees and S trees and the latter differed from each other with S trees being the shortest trees. Pillar trees had the narrowest canopy among the three growth habits and S trees had greater canopy spread than P or U trees. Training system affected canopy height, but not canopy spread or trunk circumference. Central leader trees had a taller canopy than ML trained trees. Summer pruning had no affect on trunk circumference or canopy height, but did reduce canopy spread measured at the end of the second growing season. There was a trend toward greater tree height and smaller trunk size and reduced canopy width as tree spacing was reduced, but not all growth habits responded alike (data for individual growth habits not shown).

When trees were SP in May/June 1999, S trees required significantly less pruning time per tree (63 sec) than U (130 sec) or P (141 sec) trees. Central leader training required about 67% more time (140 sec/tree) than ML training (84 sec/tree) (significant at $P$=0.0001). The two-way interaction of growth habit X training system was not significant.

The interaction of growth habit and training system for summer pruning time for 1-year-old trees was significant ($P$=0.0003) (Table 2). The time required to SP S trees did not differ with training system, but significantly more pruning time (about 52%) was required for CL trained U and P trees compared to ML trained trees. Training system had no effect on the weight of summer prunings per tree, but growth habit did have an effect. Upright and P trees produced more fresh weight of prunings than S trees (Table 2). Training aids were used on 40% (58 of 144 trees) of the SP trees. Ninety-seven percent of the trees that received training aids were CL trained trees. Clothespins were the most common training aid used at this time followed by bands and the least used aid was weights.

Growth habit or training system did not affect the % PPF levels within the canopy 2.5 weeks after SP, however, there was a slight trend toward higher levels of PPF interception in the lower canopy progressing from P (16%) to U (18%) to S (24%) habit trees. Summer pruning increased the % PPF reaching the lower portion of the inner canopy on average from 3% to 36% after 2.5 weeks. Growth habit affected light levels within the lower canopy at 4.5 weeks after SP. Standard trees had higher light levels (16% PPF) than P trees (3%) with U trees (9% PPF) not different from P or S trees. After 4.5 weeks, average % PPF light levels were greater (16%) in SP trees compared to non-SP trees (2%). The three-way interaction of growth habit X training system X SP for light levels was not significant.

There was a significant interaction (*P*=0.0004) of growth habit X training system for pruning time and pruning weight for the dormant pruned 1-year-old trees (Table 3). Central leader training required more dormant pruning time for all growth habits, but U and P trees required more than double the dormant pruning time while S-CL trees required only about one-third more pruning time compared to ML training. Fresh weight of prunings for S and U trees was greater for CL than ML trained trees, but P trees showed no difference in pruning weights between CL and ML trained trees (Table 3).

No training aids were used in the dormant pruning of 1-year-old ML trained U and S trees. Bands accounted for 75% of all the training aids used in the 1-year-old dormant trees and about 91% of all trees that received training aids were P or U trees.

Two-year-old P trees required the least amount of dormant pruning time and they had the lowest weight of prunings (Table 4). Spacing had no effect on dormant pruning time for 2-year-old trees, however, there was a trend toward more time required for trees at the wider spacings. In contrast to the 1-year-old trees, training system had no effect on the dormant pruning time for 2-year-old trees. There was a significant growth habit X SP interaction (Table 4). Summer pruning reduced dormant pruning time among all growth habits, but the difference was not as great for standard trees as for P and U trees (data not shown).

There were no interactions among main treatment effects for the number of fruit harvested in the second leaf (Table 5). Standard and U trees had more fruits harvested per tree than P trees and more fruits were harvested from the ML trained trees than CL trees (Table 5). Yields were significantly higher for ML trained trees than CL trained trees (Table 5). While S trees had the highest number of fruit per tree, they had the smallest sized fruits (diameter and weight) (Table 5). In contrast, U trees not only had a high number of fruits per tree and high yield, but the largest sized fruit. There was an interaction of growth habit X SP for yield (Table 6). Summer pruning did not affect the number of fruits harvested per tree. Summer pruning reduced the yield of U trees but not S or P trees (Table 6). Training system or SP had no effect on fruit size.

## DISCUSSION

All trees made exceptional growth in the second growing season, most notably the S and the U trees. The size difference initially observed between the three growth habits was not due to inherent differences in the tree types, necessarily, but rather the greater space provided for the P and U trees compared to the space allotted to the S trees in the nursery (personal communication, Adams County Nursery). Characteristics of the test-planting site would not fully explain the level of vigor observed. It is likely that the heavy pruning used in these test trees contributed to the high level of vigor observed since the bud source trees, located on a nearby site, did not exhibit high vigor and had never been pruned.

Except for SP second-leaf S trees (Table 2), CL training consistently required more pruning time than ML training during the first two years. Two factors appeared to contribute significantly to the greater pruning time for CL U and P trees: the use of training aids to position the limbs, and the density of canopy in these growth habits. On P trees, and to some extent U trees, numerous laterals were produced on the leader with very narrow branch angles. Thinning out some of these branches required more time to position the lopping shears. When summer pruning, locating the origin of these laterals was often difficult due to the density of branches and foliage.

Experience gained in this study suggests that training aids, such as rubber bands, weights or clothespins are more difficult and time consuming to use in peach than in apple. Great care was necessary in positioning the bands and clip-on weights as it was discovered these methods could easily overspread limbs after several days and often led to breakage of the spread limb. Clothespins worked quite well on the new shoot growth if applied when growth was about 10 to 15 cm long.

Measurement of the PPF within the canopy and calculation of % PPF levels confirmed observations concerning the dense canopy for P and U tree habits. Summer pruning improved light interception, but the effect appeared to be short lived. While the level of light within the lower canopy of P and U trees would normally be considered detrimental to fruit coloring, fruits harvested from the center of these trees had commercially acceptable color (although no measurements of color were taken). A close examination of the inner canopy of P and U trees in Aug. illustrated the effect of very low light levels when numerous short shoots (≤ 20 cm long) and twigs in the innermost canopy were completely defoliated.

Considering the level of tree vigor in the second growing season, hand thinning to about 10 fruits per tree was excessive, even for these young trees. A primary objective in thinning was to reduce fruit clusters to single fruits and space fruits 15 to 20 cm apart on limbs, a common commercial practice. This approach resulted in crop loads below the target level of 10 fruit per tree for P trees and fewer fruits at harvest than for S or U habit trees (Table 5). Pillar trees appeared to have more fruit clusters located close to the center of the canopy and thinning methods (spacing and singles) led to over thinning. The higher yields (kg/tree) and larger fruits harvested from U trees is partially due to more fruits harvested from these trees on the second harvest date compared to the S and P trees. Why SP reduced the yields of U trees is not readily explained.

The distributions of growth in the current study are interesting in light of those reported earlier by Bassi et al. (1994). While trunk sizes for S, P, and U trees were very similar between the current study and those reported by Bassi et al., canopy sizes (height and spread) in our study were much greater. In addition, the P trees in their study had significantly lower branch density and less dormant pruning weight than the upright form trees. In contrast, our study generally showed little difference between P and U trees in terms of vigor, canopy density, or pruning weights (dormant or SP). While the genotypes used in the two studies differed, the results illustrate the importance of site and pruning on the response that may be obtained.

Based on two years data and our observations of U and P peach trees growing on deep, well-drained fertile sites, it would appear that pruning and training of P and U trees to conform to a specific form, such as the CL or ML, may be detrimental, resulting in excessive tree vigor and a need for more time consuming SP. Allowing their natural form to develop, at least for the first few years after planting, may be a more practical and economical approach to the cultural management for these tree habits. Conclusions on the potential and full performance of P and U trees in high-density plantings will require at least three additional years data.

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## **Tables**

Table 1. Effect of peach tree growth habit, spacing, training system, and summer pruning on the trunk circumference of peach trees after one and two growing seasons and canopy size at the end of the second growing season in the orchard.

| Main treatment effect[1] | Trunk circumference (cm) | | Canopy size (m)10/30/00 | | |
|---|---|---|---|---|---|
| | 3/29/00 | 10/30/00 | height | width[2] | depth[2] |
| Growth Habit | | | | | |
| Standard | 8.8 a[3] | 19.6 a | 2.77 a | 2.11 c | 2.28 c |
| Upright | 10.3 b | 21.7 b | 3.32 c | 1.95 b | 2.03 b |
| Pillar | 9.8 ab | 18.4 a | 3.14 b | 1.29 a | 1.22 a |
| Spacing(m) | | | | *[3] | |
| 1.5 | 9.3 a | 18.5 a | 3.20 a | 1.45 a | 1.82 a |
| 2.0 | 9.8 a | 19.0 a | 3.06 a | 1.67 b | 1.80 a |
| 4.0 | 9.6 a | 20.4 b | 3.01 a | 2.00 c | 1.88 a |
| 6.0 | 9.9 a | 21.6 b | 3.05 a | 2.01 c | 1.89 a |
| Training System | | | | | |
| CL | 9.7 a | 20.1 a | 3.17 b | 1.79 a | 1.84 a |
| ML | 9.6 a | 19.7 a | 2.99 a | 1.78 a | 1.85 a |
| Summer pruned | | | | | * |
| Yes | ---- | 19.7 a | 3.09 a | 1.76 a | 1.82 a |
| No | ---- | 20.0 a | 3.07 a | 1.81 b | 1.87 b |

[1] Standard trees are 'Harrow Beauty'; Upright and pillar trees are from the AFRS breeding program: All trees on 'Lovell' rootstock planted December 1998. ML=multiple leader; CL= central leader. Summer pruning initiated 7 weeks after full bloom.
[2] Canopy width = spread measured within the row; depth = spread measured across the row.
[3] Mean separation within main treatment effects by Duncan's new multiple range test, $P$=0.05. * = interaction with growth habit.

Table 2. Summer pruning time and fresh pruning weight for three peach tree growth habits trained to two systems in the second growing season[1].

| Growth Habit[2] | Training system[2] | Pruning time (sec/tree) | Main treatment effect (growth habit) | Pruning weight (g/tree) |
|---|---|---|---|---|
| Standard | CL | 247 a [3] | Standard | 877 a |
| | ML | 224 a | | |
| Upright | CL | 430 b | Upright | 1591 b |
| | ML | 290 a | | |
| Pillar | CL | 429 b | Pillar | 1317 b |
| | ML | 276 a | | |
| | | | (training system) | |
| | | | CL | 1275 a |
| | | | ML | 1254 a |

[1] Trees pruned in late May and early June, 2000.
[2] Standard trees are 'Harrow Beauty'; Upright and Pillar are from the AFRS breeding program. All trees on 'Lovell' rootstock. ML= multiple leader; CL= central leader.
[3] Mean separation within main treatment effects by Duncan's new multiple range test, *P*=0.05. Interaction for pruning time; no interaction for pruning weight.

Table 3. Dormant pruning time and fresh pruning weight for three 1-year-old peach tree growth habits trained to the multiple leader or central leader systems [1].

| Growth Habit[2] | Training System[2] | Pruning Time (sec/tree) | Pruning Weight (g/tree) |
|---|---|---|---|
| Standard | CL | 57 b[3] | 186 b |
| | ML | 41 a | 111 a |
| Upright | CL | 132 b | 272 b |
| | ML | 58 a | 206 a |
| Pillar | CL | 112 b | 184 a |
| | ML | 58 a | 224 a |

[1]Trees pruned in late March and early April, 2000.
[2] Standard trees are 'Harrow Beauty'; Upright and Pillar are from the AFRS breeding program. All trees are on 'Lovell' rootstock. ML= multiple leader; CL= central leader
[3]Mean separation within main treatment effects by Duncan's new multiple range test, *P*=0.05.

Table 4. Effect of peach tree growth habit, tree spacing, training system, and summer pruning on the dormant pruning time and weight of prunings for 2-year-old peach trees.

| Main effects [1] | Dormant pruning | |
|---|---|---|
| | Time (sec/tree) | Weight (kg) |
| Growth Habit | | |
| Standard | 263 b [2] | 3.72 b |
| Upright | 263 b | 4.50 c |
| Pillar | 225 a | 2.42 a |
| Spacing (m) | | |
| 1.5 | 233 a | 3.04 a |
| 2.0 | 247 a | 3.34 ab |
| 4.0 | 261 a | 3.95 b |
| 6.0 | 260 a | 3.86 ab |
| Training System | | * |
| CL | 254 a | 3.67 a |
| ML | 247 a | 3.43 a |
| Summer Pruned | * | |
| Yes | 219 a | 3.19 a |
| No | 282 b | 3.90 b |

[1] Standard trees are 'Harrow Beauty'; Upright and pillar trees are from the AFRS breeding program: All trees on 'Lovell' rootstock planted December 1998. ML=multiple leader; CL= central leader. Summer pruning initiated 7 weeks after full bloom.

[2] Mean separation within main treatment effects by Duncan's new multiple range test, *P*=0.05. * = interaction with growth habit.

Table 5. Effect of peach tree growth habit, training system, and summer pruning on fruit numbers, yield per tree and size of harvested fruit in the second growing season.

| Main treatment effect[1] | No. fruit harvested per tree | Yield[2] (kg/tree) | Mean fruit diam (mm) | Mean fruit weight (g) |
|---|---|---|---|---|
| **Growth Habit** | | | | |
| Standard | 10.0 b [3] | ------ | 59 a | 113 a |
| Upright | 9.7 b | ------ | 70 c | 184 c |
| Pillar | 4.0 a | ------ | 63 b | 134 b |
| **Training System** | | | | |
| ML | 8.8 b | 1.28 b | 64 a | 143 a |
| CL | 7.1 a | 1.06 a | 64 a | 145 a |
| **Summer Pruning** | | | | |
| Yes | 7.5 a | ------ | 64 a | 142 a |
| No | 8.3 a | ------ | 64 a | 146 a |

[1]Standard trees are 'Harrow Beauty'; Upright and pillar from the AFRS breeding program. All trees on 'Lovell' rootstock. ML = multiple leader; CL = central leader. Summer pruning initiated 7 weeks after full bloom.

[2] There was a significant interaction of growth habit X summer pruning; see Table 6.

[3] Mean separation within main treatment effects by Duncan's new multiple range test, *P*=0.05.

Table 6. Yields for three peach tree growth habits with and without summer pruning in the second leaf.

| Growth habit[1] | Summer pruned | Yield (kg/tree) |
|---|---|---|
| Standard | Yes | 1.2 a [2] |
| | No | 1.2 a |
| Upright | Yes | 1.5 a |
| | No | 2.1 b |
| Pillar | Yes | 0.6 a |
| | No | 0.5 a |

[1] Standard trees are 'Harrow Beauty'; Upright and pillar trees are from the AFRS breeding program: All trees on 'Lovell' rootstock planted December 1998. ML=multiple leader; CL= central leader. Summer pruning initiated 7 weeks after full bloom.

[2] Mean separation within main treatment effects by Duncan's new multiple range test, *P*=0.05.