

Cookbook Guidelines for Training Various Apple Production Systems

As the Pennsylvania fruit industry moves from conventional medium-density, freestanding orchards to high-density, supported orchards, many pruning and training modifications must be made.



The tall spindle was developed as an offshoot of the slender spindle training system to take advantage of increased canopy volume by increasing tree height.

Conversely, in [high-density systems](#) excessive growth is discouraged; and instead of a large, strong framework, a weak-framed tree is desirable. To achieve these ends in a system such as tall spindle or French axe, very little pruning is done in early years. The goal is to promote early fruiting, which itself will inhibit future growth. All high-density systems require a greater knowledge and understanding of plant growth and of how the tree will respond to cuts. In early years, more attention is paid to training and positioning limbs than to pruning them.

High-density systems also demand greater precision in spacing trees. Since trees are not meant to be vigorous, too wide a spacing is an uneconomical use of the land. Conversely, too narrow a spacing will necessitate more pruning, increasing vigor and reducing light and fruit quality. Below are “cookbook recipes” on pruning and training several apple systems.

Tall spindle

This is the system many growers are successfully using in new plantings. The tall spindle is a supported training system that depends on utilizing well-feathered (branched) trees that can produce a crop the year after planting and continue to increase fruiting in the immediate subsequent years. The tall spindle was developed as an offshoot of the slender spindle training system to take advantage of increased canopy volume by increasing tree height. To develop this training system, several components are important: (1) plantings must utilize high densities (800 to 1,500 trees per acre); (2) fully dwarfing rootstocks such as M.9, B.9, G.41, G.16 must be used; (3) nursery trees must have 10 to 15 feathers; (4) minimal pruning occurs at planting; (5) feathers are bent below horizontal after planting; (6) permanent scaffold branches are not be allowed to develop; (7) branches are renewed as they get too large. Go to [extension fruit advisor](#) to see an extensive listing of publications and videos from the University of Massachusetts on tall spindle training.

Comparison of Medium and High Density Systems

In the medium-density central leader system, portions of trees are cut back severely for several years to stimulate growth. Emphasis is placed on building a large, strong framework to support future crops.



PennState Extension

First leaf

- At planting: Plant highly feathered trees (10 to 15 feathers) at a spacing of 3 to 4 feet by 11 to 12 feet. Adjust graft union to 4 to 6 inches above soil level. Remove all feathers below 24 inches using a flush cut. Do not head the leader or the feathers. Remove any feathers that are larger than two-thirds the diameter of the leader.
- At 3 to 4 inches of growth: Rub off the second and third shoots below the new leader shoot to eliminate competitors to the leader shoot.
- May: Install a 3- to 4-wire tree support system that will allow the tree to be supported to 3 meters. Attach the trees to the support system with a permanent tree tie above the first tier of feathers, leaving a 2-inch-diameter loop to allow for trunk growth.
- Early June: Tie down each feather that is longer than 10 inches to a pendant position below horizontal.

Second leaf

- Dormant: Do not head leader or prune trees unless there are scaffolds that are more than half the diameter of the central axis.
- Make sure the leader is securely fastened to the support wires or conduit.
- At 4 to 6 inches of growth: Pinch the lateral shoots in the top fourth of last year's leader growth, removing about 2 inches of growth (the terminal bud and 4 to 5 young leaves).
- Early June: Hand-thin the crop to single fruit 4 inches apart (target 15 to 20 fruit per tree if tree growth was good; otherwise, base crop load on tree trunk diameter and bearing habit).
- Mid-June: Re-pinch all lateral shoots in the top fourth of last year's growth. Tie the developing leader to the support system with a permanent tie.

Third leaf

- Dormant: Do not head the leader. Remove all broken branches by heading back or renewal cut to a spur. Remove overly vigorous limbs that are more than two-thirds the diameter of the leader using a bevel cut.
- Late May: Chemically thin according to crop load, tree strength, and weather conditions, and then follow up with hand-thinning to the appropriate levels to ensure regular annual cropping and adequate fruit size (target 50 to 60 fruit per tree).
- June: Tie the developing leader to the support system with a permanent tie.
- August: Lightly summer prune to encourage good light penetration and fruit color.

Fourth leaf

- Dormant: Do not head the leader. Remove overly vigorous limbs that are more than two-thirds the diameter of the leader using a bevel cut.
- Late May: Chemically thin and follow up with hand-thinning to the appropriate levels to ensure regular annual cropping and adequate fruit size (target 100 fruit per tree).
- June: Tie the developing leader to the support system with a permanent tie at the top of the wire.
- August: Lightly summer prune to encourage good light penetration and fruit color.

Mature tree pruning (fifth to twentieth leaf)

- Dormant: Limit the tree height to 90 percent of cross-row spacing by cutting the leader back to a fruitful side branch. For example, if the cross-row spacing is 11 feet, then $11 \times 0.9 = 9.9$ or 10 feet.
- Annually: Remove at least two limbs, including the lower-tier scaffolds that are more than two-thirds the diameter of the leader, using a bevel or Dutch cut. Columnarize the branches by removing any side branches that develop. Remove any limbs larger than 1 inch in diameter in the upper 2 feet of the tree. On varieties like Delicious, Gala, Golden Delicious, and McIntosh, if shoots start to taper down to smaller than pencil size in diameter, head them back to where they are pencil size, preferably to a slightly upright growing shoot or spur.

Central leader system

This is a popular system in Pennsylvania for free standing trees. With the range of rootstocks available, trees can vary from 7 to 20 feet tall. Trees can be kept smaller by periodically heading back the central leader into 2-year-old wood to stiffen the central axis. Size and vigor can also be controlled by selecting less-vigorous branches as the central leaders.

Trees are trained into a Christmas tree shape with the tops always narrower than the lower branches. Annual pruning is required for maximum sunlight penetration into the tree's interior and for greater production. In some instances, summer pruning is also beneficial.

The cost of establishing this system is relatively low because no tree supports are used and there are fewer trees per acre. In early years, efforts are focused on trying to invigorate trees to fill their allotted spaces. Early production years are then spent in slowing the trees down and getting them into an annual bearing habit. Later, as the planting grows older, it is necessary to maintain fruit spur quality by pruning annually and keeping tree tops from overshadowing lower branches.

The following is a "cookbook" method of how to prune and train trees to a central leader system.

At planting

- Remove all scaffolds below 18 inches flush to the trunk. Trees with fewer than three scaffold branches should be headed at 30 inches and all feathers removed with a bevel or Dutch cut. Trees with three or more branches offer three options depending on the vigor of the scion and rootstock. Always remove any scaffolds that are more than half the diameter of the central trunk. The options in order of low vigor to high vigor are as follows:
 1. Option 1: Head leader 10 to 12 inches above the uppermost branch and all branches by a third.
 2. Option 2: Head leader 10 to 12 inches above the uppermost branch and do not head the side branches.
 3. Option 3: Do not head leader or side branches.

First growing season

- May: Remove two or three competing buds that broke and began to grow below the chosen leader if you headed the tree back at planting. Spread the scaffolds horizontally if you had left them on at planting.
- June: Clothespin new shoots to a horizontal position when they are as long as, or just longer than, the clothespin. (Remove the clothespins after 4 or 5 weeks.)

Second leaf

- Dormant: If additional scaffolds are needed, score above desired buds in the late dormant season (4 to 6 weeks before bud break) or apply Promalin mixed with latex paint.
- Do not head the central leader. Select three to five first-tier scaffold branches of moderate vigor with wide crotch angles and remove the rest. Care should be taken to attain good spacing of branches around the trunk, both radially and vertically. Scaffold branches that are evenly distributed around the tree will assure even light distribution and scaffolds that are spaced out vertically will assure that leader dominance is maintained.
- June: Position permanent scaffolds at a 50- to 75-degree angle from vertical using spreaders, weights, elastics, or string.

Third leaf

- Head the central leader, removing half to a third of previous year's growth. Thin out overly vigorous limbs that are of no use.
- June: Position permanent scaffolds at a 50- to 75-degree angle from vertical using spreaders, weights, elastics, or string. When 3 to 6 inches of new growth has developed in the top third of last year's central trunk growth, select shoots to be the second-tier scaffolds. Pinch out the most and least vigorous shoots, leaving three to four of moderate vigor. Clothespin these second tier scaffolds to obtain wide crotch angles.

Fourth leaf

- Do not head the leader. Prune out only overly vigorous limbs that are of no use.
- June/July: Position first-tier scaffolds at a 50- to 75-degree angle, and position second-tier scaffolds horizontally using spreaders, weights, elastics, or string. Position overly vigorous limbs below horizontal.

Fifth and succeeding years

- Do not head the leader until it has bent over with a crop. Maintain good light distribution by making a minimal number of thinning cuts. Continue to position scaffold limbs with spreaders until this function is replaced by the weight of a crop. Shorten bottom tier of scaffolds by pruning back to side branch. Shorten pendant branches back to a more horizontal position. Summer prune as needed in August to maintain light penetration.

Final leader height

- The ideal situation is that the leader will bend with a crop to restrict the tree height. This is termed the "crop and flop" method. However, in some cultivars the leader does not bend and the tree continues to grow upward. If this occurs you can cut the leader back to a lower, more horizontal branch, but only do so after the upper portion of the tree has fruited.

Trellis systems

A trellis system relies on the use of three to four wires to serve as support and training aids. Several ultimate tree forms or training patterns may be chosen in developing a trellis. Certain components critical to this system must be understood and avoided regardless of the tree form chosen:

1. Branches to be trained to the wires should always originate on the main trunk below the wire. Bending branches from the main trunk or axis down to the wire will encourage upright water sprouts at the point of the bend. Water sprouts are unproductive and lead to an overabundance of growth.
2. Do not keep every branch on the tree. Branches growing vigorously into the drive row should be removed. Do not try to bend every branch back into the wire.
3. It is not necessary to stop branches from extending into adjoining trees. The idea is to create an interwoven wall of bearing surface.

The following is a "cookbook" method for training trees to a Penn State low hedgerow four-wire trellis system.

- The goal is to train to an oblique palmette, which is a central-axis tree with four pairs of oblique scaffolds spaced approximately 18 inches apart in a narrow vertical plane. Scaffolds from adjacent trees cross each other, forming a lattice framework on which bearing wood is developed and managed as the fruiting mantle of the

trellis hedgerow.

Non-Feathered Trees:

At planting

- A one-year whip is planted vertically and headed at 18 inches, the height of the bottom wire. Usually, three shoots appear as a “crow’s foot.” The center one is selected to be the leader of the tree, and is tied to the bottom wire. At the same time, or a little later, two lateral shoots about 3 to 4 inches below the wire, one on each side of the tree, are selected to become a pair of scaffold limbs. When about a foot in length, these are inclined at a slope of approximately 60 degrees and secured to the bottom wire. When 2 to 3 feet in length, they are reset at a 45-degree slope. The leader is allowed to elongate and is secured to the second wire when its wood has matured sufficiently for tying. Other lateral growth is usually removed.
- Fall: The tree’s central axis, leader, and scaffolds are secured to the trellis wires for overwintering.

Second year

- The tree’s leader and scaffolds are allowed to elongate. Lateral growth normally is retained unless too vigorous, showing dominance on a scaffold or on the central axis. Lowest scaffolds are allowed to elongate at a 30- to 45-degree slope.
- When the two low scaffolds from adjacent trees pass the second wire, they are crossed and tied together at the middle of the second wire. Some repositioning of the tie on the first wire may be necessary to develop an even slope in the scaffold.
- Any strong lateral growth from these scaffolds showing dominance is headed at approximately 6 inches to either a downward or lateral growing shoot. One-year wood over 12 inches in length is usually pruned in half.
- If a terminal in a scaffold sets fruit, the fruit is removed and the leader renewed.
- Lateral shoots usually develop naturally on the central leader. At each trellis wire, a pair of suitable laterals is selected to become scaffolds. These should arise approximately 3 to 4 inches below the wire. Laterals are inclined and attached to give about a 45-degree slope.
- Later in the season, these are repositioned at approximately 30 degrees. If a young scaffold is not sufficiently long to be positioned, it may be marked for later identification, which is easily done with a spring clothespin. Growth may be enhanced by tying to about 60 degrees. Any strong lateral growth below and/or immediately above a pair of selected shoots is removed.

This procedure for developing scaffolds is followed at each wire or level in the trellis. However, if suitable laterals fail to develop naturally, a heading cut may be made similar to that done at planting. The cut should be at or near a trellis wire for

laterals to arise about 3 to 4 inches below the wire.

Third and subsequent years

Training follows that outlined for the second leaf. If lateral shoots do not arise naturally at or near the desired location for scaffolds, the tree is headed at the wire to stimulate branching.

- When the central leader of the tree extends a foot or more above the top wire, it is bent to one side along the fourth wire to form half of the top tier. It is tied in a horizontal position. A suitable lateral, originating below the arch on the opposite side of the tree, is trained to form the other half of the fourth pair. However, it is usually inclined to the top wire before being trained horizontally.
- In future years, as scaffolds from the third tier reach the top wire, top scaffolds are headed back periodically to reduce their shading on those immediately below.
- Eventually, fourth-tier scaffolds may be no longer than 12 inches in length. All vertical shoots and wood are removed from the top of the trellis (fourth-scaffold tier). This is usually done in early August just prior to summer grooming of the bearing mantle.
- Scaffolds are arrested in further elongation when they reach the middle of an adjacent tree. This is usually accomplished by not tying up the terminal.
- Occasionally, tipping or cutting back to a downward-growing lateral may be needed.
- Annual pruning is both summer and dormant pruning. Summer pruning is in August, about three months after bloom, and is considered mainly a grooming operation. All vertical vigorous growth from the top of the trellis is removed, which reduces shading, aids in suppression of the vigor in the top scaffolds, and maintains a hedgerow height of 6 feet. In addition, all vertical growth within the hedgerow itself is removed, but this may be done at any time during the summer. Further, all lateral shoots 12 inches or longer are stubbed by heading back to three basal shoot leaves, or to about $\frac{1}{2}$ or $\frac{3}{4}$ inches. This August stubbing of shoots is the most important pruning of the year and is what distinguishes the Penn State system. Besides increasing the exposure of bearing wood and maturing fruits to sunlight, stubbing enhances the development of bearing wood by manipulating vigorous growth into short shoots and spurs.
- Dormant pruning is largely heading back of older bearing wood, making corrective cuts, thinning out spurs, and, where necessary, re-stubbing to continue the control of vigorous wood.

Feathered trees:

- A tree is planted vertically and oriented so that two feathers on opposite or nearly opposite sides of the tree occur approximately 14 to 15 inches from the ground (3 to 4 inches below the lowest trellis wire at 18 inches). These are inclined at a 45- to 60-degree slope, depending on length (vigor), and secured to the lowest trellis wire.

- If a suitable pair of feathers is located only above the bottom wire, training is possible for developing them into suitable scaffolds, provided they are located within 4 to 5 inches from the bottom wire. Training is a two-step operation. First, the basal part of a feather is bent horizontally or arched down to the wire. After tying, the remainder of the lateral is brought upward and fixed by dropping either a string or several ties attached together from the second wire. If of sufficient length, it is positioned at 45 to 60 degrees. Otherwise, it is just raised so that the terminal bud becomes the highest point. In a raised position, continued elongation of the young scaffold is assured. After sufficient growth, repositioning may be done. Thus, a high originating lateral may be made into a suitable scaffold. Its appearance would resemble that of a scaffold originating 3 to 4 inches below the bottom wire.

Vertical or French axe

Trees in the vertical axe system, developed in France, are allowed to grow 10 to 14 feet tall, depending on the cultivar. The simplest way to picture this system is to consider a pole with short fruiting spurs.

Trees are planted closer together than in the central leader system but not as close as the tall spindle. A critical point in establishing the French axe system is to immediately stake or tie the tree's central axis the first year. Trees can be headed at planting to a height of 28 to 30 inches, but thereafter they are never headed. To achieve the narrowest tree, only a single upright-growing branch is left to grow during the first year. Variations to produce a wider tree permit weak-growing horizontal branches to remain on the tree. Vigorous branches should be removed or tied down early in the season.

The easiest way to control vigorous branches at the top is to allow the leader to bend over with fruit. Later, the drooping portion of the central leader cut back to a weak growing side branch. Dormant pruning each year consists of removing vigorous, upright-growing shoots. Vigorous top branches can also be controlled with timely summer pruning. If performed properly, summer pruning can encourage a greater fruiting surface. If a branch has fruited and needs to be replaced, make an angled stub (Dutch) cut. A new branch will emerge from adventitious buds.

The following is a "cookbook" method of how to train and prune trees to a vertical axe system.

At planting

- Remove all scaffolds below 18 inches, flush to the trunk. Trees with fewer than three branches should be headed at 30 inches. Attach trees to the support system as soon as possible. Trees with three or more branches offer two options depending on the vigor of the scion and rootstock. Always remove any scaffolds that are more than one-half the diameter of the central trunk. The alternatives in order of low vigor to high vigor are:

Option 1: Head leader 10 to 12 inches above the uppermost branch and do not head the side branches. Bend the side branches to horizontal by using weight string or elastics.

Option 2: Do not head leader or side branches. This last option is best used when there are three to five good feathers (branches).

First growing season

- May: Remove the two or three buds that began to grow below the chosen leader if you headed the tree back at planting. Bend the side branches to horizontal by using weight string or elastics.
- June: Clothespin new shoots when they are as long as, or just longer than, the clothespin.

Second leaf

- If additional scaffolds are needed, score above desired buds in the late dormant season (4 to 6 weeks before bud break) or apply Promalin mixed with latex paint.
- Do not head the leader. If additional scaffolds are needed, notch above desired buds in the late dormant season (4 to 6 weeks before bud break) or apply Promalin mixed with latex paint.
- June: When 3 to 6 inches of new growth develops on shoots in the top half of the leader, pinch the new growth back by one-third their length. Position permanent scaffolds horizontally by using weights, elastics, or string. Position vigorous shoots below horizontal by means of weights, elastics, or string.
- July: Re-pinch all laterals as outlined above, as needed. If tree is vigorous, pinching the shoots a third time in August may be necessary.

Third leaf

- Do not head the leader. Tie down vigorous upright limbs below horizontal. Remove any side branches above the main scaffolds that are more than one-half the diameter of the central axis with a Dutch cut.
- June: When 3 to 6 inches of new growth has developed on shoots in the top third of last year's central leader, pinch them back by one-third to one-half their length.

Fourth leaf

- Do not head the leader. Prune out overly vigorous limbs that are of no use.
- June/July: Position excessively vigorous limbs slightly below horizontal.
- ~OR~
- August: Summer prune, removing vigorous limbs, to maintain pyramid shape and improve light interception.

Fifth and succeeding years

- Do not head the leader. Shorten bottom tier scaffolds by pruning back to a side branch. If desired begin removing/renewing scaffolds by thinning out the one most vigorous limb in the bottom middle and top of the tree.
- Remove any side branches above the main scaffolds that are more than one-half the diameter of the central axis with a Dutch cut. Leave all weak fruiting wood. Shorten pendant branches back to a more horizontal position. Summer prune as needed in August to maintain light interception.

Final leader height

- The ideal situation is that the leader will bend with a crop to restrict the tree height. This is termed the “crop and flop” method. However, in some cultivars the leader does not bend, and the tree continues to grow upward. If this occurs, you can cut the leader back to a lower more horizontal branch, but only do so after the upper portion of the tree has fruited.

Tree Support Systems

As apple growers move to higher-density production systems using more dwarfing rootstocks, tree support becomes more of a concern. Most of the very dwarfing rootstocks require support, but there are somewhat more vigorous rootstocks that can perform well without support under certain conditions. Depending on cultivar, soil type, slope, vigor, and cropping conditions, support may be necessary for semi-dwarf stocks.

Support systems should be installed soon after planting. Tall spindle and vertical axe training systems depend upon installing the system shortly after planting to keep the leader upright and growing vigorously.

The cost of tree support systems varies widely. One system commonly used is a single wire set at 9–10 feet off the ground and a 12-foot piece of conduit driven into the ground and then attached to the wire. In recent years the cost of conduit has risen to the point that growers are now looking at using 4 or 5 wires spaced 1.5–2.0 feet apart as the support system. Penn State has developed an [Orchard Support System Component Costs Calculator as an Excel spreadsheet](#) that will help with the decision-making process. The spreadsheet also has a calculator that will estimate how many end posts and line posts will be needed.

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