Virginia Cooperative Extension
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Publication 422-021

# Training and Pruning Apple Trees

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## Introduction

Proper training and pruning of trees is a major component of a profitable apple orchard operation. Successful pruning is an art based upon scientific principles of tree growth and physiology and an experienced understanding of tree response to various pruning cuts and practices. Each tree is an individual and should be treated accordingly. Varieties differ in growth characteristics and response to pruning cuts, rootstocks, soil, and growing conditions. It is important that orchard designs, objectives, and goals be clearly defined and that pruning principles are developed accordingly. Medium- to high-density plantings require greater commitment to detailed training and pruning than low-density orchards and should not be attempted unless such a commitment is made.

There are several training systems for apple. The training system discussed in this publication is the central leader, which is the most common system in commercial orchards and is easily adapted to non-commercial situations. The central leader system is used for freestanding trees on the relatively vigorous standard and semi-dwarf rootstocks.

## Objectives of Training and Pruning

The objectives of tree training and pruning are to develop and maintain small, conical shaped (Christmas tree shape) trees that are capable of early production of large crops of high quality fruit. Trees are pruned to help maintain a balance between vegetative and reproductive growth throughout the tree and to maintain desired tree shape and size with an open tree canopy that allows penetration of sunlight and pesticides. The practices of training and pruning are not easily separated because the training of a young tree will determine how the tree will be pruned as it matures. Too frequently, the pruning required in mature trees involves the correction of mistakes made while training them as young trees. Proper training of young trees will save time and expense in future pruning and produce earlier profitable crops. The greatest pruning skill is required during early tree development.

Maintaining suitable vigor of an apple tree is necessary to develop a balance between reproductive and vegetative growth throughout the life of the tree. Such vigor is established by thorough land preparation, proper selection of rootstock/variety combinations, weed control, adequate available moisture, effective pest control, and fertilization programs based on soil and foliar analyses. Protection against rodent and deer damage is also very important. Good initial tree vigor is necessary to establish adequate canopy volume for optimum profitable production as early as possible in the life of the orchard.

As trees come into production, it is necessary to encourage a transition from vegetative to reproductive growth. Continued excessive vegetative growth may delay fruiting and result in low yields of large but soft, poorly colored fruit with limited storage potential. Trees with low vigor, however, may produce small, firm, highly colored fruit. Pruning is one tool that can be used to regulate tree vigor.

## Apple Tree Growth and Physiology

### Sunlight Utilization

Sunlight is critical to tree growth and cropping. Pruning can alter light interception and its utilization by the tree. Sunlight is the sole source of energy for plant growth. Green leaves intercept light energy and convert it to chemical energy through the process of photosynthesis. Photosynthetic products (carbohydrates) are required for vegetative growth, fruit set, fruit growth, fruit color, and

www.ext.vt.edu
Produced by Communications and Marketing, College of Agriculture and Life Sciences, Virginia Polytechnic Institute and State University, 2014

VT/1214/HORT-94P

flower bud initiation and development. Tree size, shape, and density greatly influence the quantity of light intercepted by a tree and the distribution of light through the the tree canopy, which is heavily shaded, also increasestree canopy. As tree size increases, the proportion of Large, globular-shaped tree canopies can be divided into three distinct zones of light penetration. The peripheral layer (3-5 feet thick) of the canopy receives more than 60% full sun, which is in excess of the light required to produce quality fruit. The middle third of the canopy receives 30-60% full sun, which is adequate for fruit development. The interior portion of the tree receives less than 30% full sun. In general, at least 30% full sun is required to produce large well-colored fruit with high sugar levels and for flower bud development. A conical tree form (Christmas tree shape) has a smaller proportion of canopy volume receiving inadequate light (Fig. 1). It is important that adequate sunlight be available to as much of the total tree as possible to maximize per-acre yields of quality fruit.

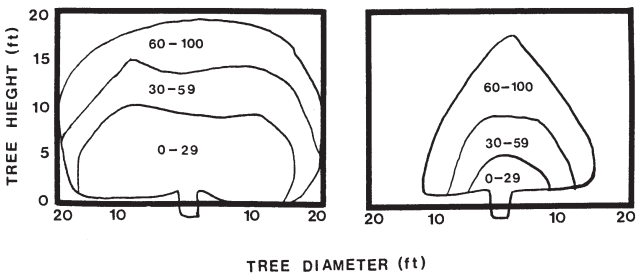


Figure 1. Light distribution in tree canopies is influenced by tree shape and size. Large, round trees (Left) have 3 relatively distinct zones of light levels, and about one third of the tree volume receives inadequate light (0-29% full sun) for production of quality fruit. Smaller conical-shaped trees (Right) have a greater portion of the tree volume receiving high light levels.

## Tree Growth

Trees increase in size in only two ways – primary growth and secondary growth. Primary growth, which is the elongation of shoots and roots, results from cell division that occurs in the apical meristem, a mass of cells in the shoot tip. These cells elongate in the region below the apical meristem and cell differentiation (formation of various tissues) occurs in the lower portion of this region. Secondary growth occurs in a second meristem region, the cambium, a cylindrical layer of cells beneath the bark, which is the site of cell division. The cambium produces xylem toward the inside and phloem toward the outside, which results in annual layers of wood (growth rings). Xylem cells transport water and nutrients from the roots to the shoots and provide structural support for the tree. Phloem cells primarily transport carbohydrates and other organic materials from the leaves to the fruit, trunk, and roots.

## Types of Buds

It is important that the orchardist be familiar with different types of buds because they directly influence the size and quality of the crop. A leaf bud is a compressed shoot possessing approximately six leaves. Only leafy shoots may develop from leaf buds. A fruit bud is a compressed modified shoot possessing modified leaves (flower parts). Only a flower or cluster of flowers may develop from a flower bud. Mixed buds can produce both leafy shoots and flowers.

A bud at the end of a long or short shoot (spur) is called a terminal bud; buds in the axles of leaves are called lateral buds. On apple trees, mixed buds usually develop terminally on spurs, but some varieties such as Rome Beauty produce mixed buds terminally on long shoots; these are referred to as “terminal bearers” or “tip bearers.” Buds produced laterally on current season’s shoots are usually leaf buds and produce only leafy shoots. Many lateral buds remain dormant and become trace buds covered by wood and bark. Each year, such buds elongate enough to keep their apical meristems at the surface just under a crack or opening. Some of these buds eventually develop into water sprouts. Adventitious buds are new growing points developed from positions where buds are not normally found. Adventitious buds may develop in callous tissue around pruning wounds and give rise to water sprouts. Some rootstocks produce root suckers from adventitious buds in underground roots. The nature of each terminal or lateral bud (flower, leaf, or mixed) is determined by late summer. Water sprouts are vigorous upright shoots developing from buds on the upper surface of limbs or buds near pruning cuts.

## Energy for Growth

Early-season growth depends on carbohydrates and nitrogenous compounds resulting from the previous season’s photosynthetic activity, which are stored in the roots and the trunk over winter. Adequate foliage is present on the tree by early summer to support continued growth of the tree and fruit and to replenish reserves

for initial growth the following spring.

Growing plant organs can mobilize photosynthates from the leaves toward themselves. Actively growing shoots, roots, trunks, and fruit compete for the limited supply of carbohydrates. Therefore, as fruit load increases, shoot, root, and trunk growth usually are suppressed. However, this relationship may depend on the variety/rootstock combination. Consistent annual cropping is usually considered important to prevent excessive shoot elongation.

## Limb Orientations

Limbs with narrow crotch angles (angle between limb and trunk) are weak and tend to break under the weight of a crop. As the trunk and limb increase in diameter, bark tissue fills the space between the trunk and limb, resulting in bark inclusion, which causes the weakness. Limbs with poor crotches should be either removed or spread to an orientation approaching the horizontal.

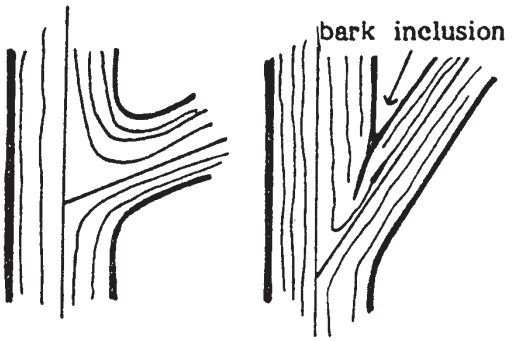


Figure 2. Wide crotch angles are strong.

Shoot growth can be altered by branch orientation. Most of the shoot growth on a vertically oriented branch develops from the terminal shoot bud. A plant hormone (auxin) is produced at the growing shoot's apex and moves down the shoot, preventing shoot development from lateral buds. Auxin also tends to inhibit flower bud formation (Fig. 3). Some lateral buds form short spurs or remain dormant. If a vertical shoot is bent to the horizontal, the pattern of hormone movement is altered. Auxin tends to accumulate on the underside of the shoot where it stimulates cell elongation, resulting in upward curvature of the shoot so that the top again grows vertically. Lateral buds along the upper side of the shoot are no longer inhibited and develop into upright water sprouts. Shoots oriented below the horizontal exhibit drastically suppressed terminal growth and upright water sprouts develop near the base of the branch. Limbs oriented 40-60 degrees from the vertical are most desirable because vegetative growth is adequate for production of future fruiting wood and fruiting is encouraged. Fruit also hangs below such branches with minimum limb rub.

## Dormant Pruning Response

A pruned tree is always smaller than a non-pruned tree. Certain pruning cuts stimulate shoot growth in the vicinity of the cut, creating the illusion of increased growth. However, such growth is less than the sum of the wood removed by pruning plus the growth it would have made. Trees tend to maintain equilibrium between the top of the tree and the roots. Pruning shifts this balance in favor of the remaining shoots so that more stored reserves are available per remaining bud. Therefore, a pruned tree produces more shoot growth than a non-pruned tree to maintain the characteristic top-root equilibrium. Shoot growth the season following pruning is proportional to pruning severity.

## Summer Pruning

Pruning during the summer had traditionally been thought to suppress tree vigor more than comparable pruning during the winter. The summer removal of leaves reduces the quantity of carbohydrate reserves in the trunks and roots, which, theoretically, should suppress shoot growth the following season. However, recent research results from Virginia and other regions of the U.S. indicate that shoot growth is not suppressed more by summer than by dormant pruning, and that summer pruning is not a viable method of suppressing tree vigor.

## Time of Pruning

The best time to prune fruit trees in Virginia is late winter after the threat of severe cold. However, fruit producers with large acreages must start early to prune all trees before bloom. Pruning should be delayed until most leaves have fallen, and trees should not be pruned during or just before extremely cold weather. Pruning should also be avoided during or just after exceptionally warm weather. Young trees should be pruned last because they grow vigorously and harden (develop low temperature tolerance) later in the fall than older trees.

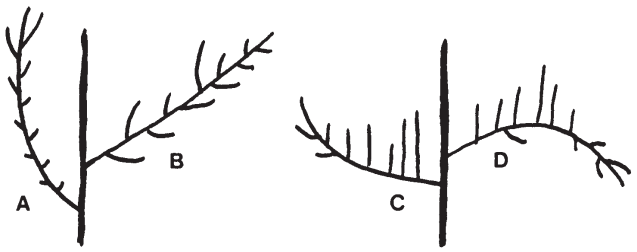


Figure 3. Branch orientation can affect shoot growth and flower bud development. A. Vertical shoots produce spurs, few side limbs. B. Limbs that are spread 60-45° produce side limbs of moderate vigor and spurs. C. Limbs that are spread below 45° may develop extensive upright growth that is non-fruitful. D. When the terminal is not the highest point on the limb, extension growth stops and new vigorous shoots develop from the highest point on the limb.

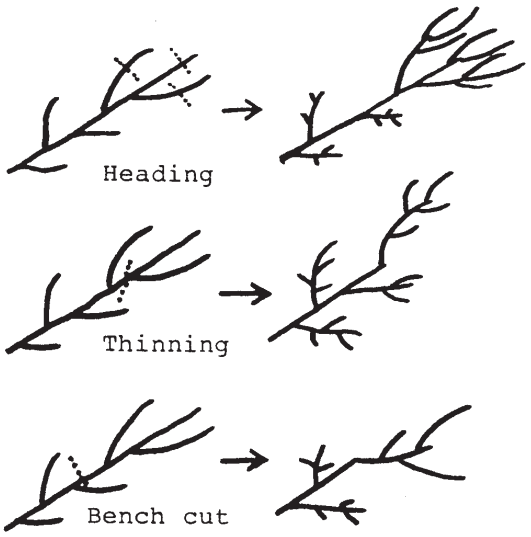


Figure 4. Heading cuts stimulate shoot development below the cut. Thinning cuts induce little vigorous shoot growth. Bench cuts may be used to produce a spreading growth habit, but the limb below the cut may be weak and may break.

## Types of Pruning Cuts

There are three basic types of pruning cuts: heading, thinning, and bench (Fig. 4). Heading cuts involve the removal of the terminal portion of a shoot. Since heading cuts remove the terminal growing point that is the source of auxin, lateral buds immediately below the cut are no longer inhibited and develop into shoots. Both the number and length of shoots developing below the cut increase, as heading of one-year-old shoots becomes more severe. Heading into older wood causes a conversion of potentially fruitful spurs to vigorous non-fruitful vegetative shoots. Shoot growth developing on horizontally oriented limbs will be less than on comparably pruned vertical shoots. Thinning cuts involve the removal of a branch at its point of origin. Thinning cuts do not induce dramatic changes in growth pattern because hormone production is not drastically altered.

Thinning cuts are preferable to heading cuts for maintaining tree size and shape because heading removes future fruiting wood. A bench cut is actually a special type of heading cut and involves removal of the terminal portion of a branch at a point just above a side branch. Bench cuts on young trees during the tree training and early fruiting years will tend to stiffen the portion of the branch below the cut and reduce the natural limb spreading caused by the weight of fruit. Bench cuts are often used to encourage outward growth of branches. However, limb spreading is preferable to bench cuts because water sprouts often develop at the site of a bench cut. In addition, the branch immediately below a bench cut is sometimes weak and may not support a heavy crop.

## Pruning Affects Fruiting

Any type of pruning always delays fruiting of young trees and always reduces yield on mature trees. Pruning tends to encourage vegetative growth, which is antagonistic towards flower bud formation. Additionally, pruning removes flower buds and wood on which future flower buds will be formed. Pruning usually improves fruit quality by improving light distribution throughout the tree and by reducing the number of fruits per tree. Fruits on pruned trees tend to be larger than on non-pruned trees because there are fewer fruits competing for carbohydrates. Therefore, to encourage fruiting, young trees should be pruned judiciously. To improve fruit quality and reduce overcropping, mature trees should be pruned annually.

# Principles of Training and Pruning Central-Leader Apple Trees

Trees on semi-dwarf and standard-size rootstocks can be trained as freestanding central leader trees. The root-

stocks best suited to this type of training are seedling, MM.111, MM.106, and interstems. M.7 can be grown without support with varieties that are fairly non-vigorous (Braeburn and spur Delicious), but will require support for most other varieties. Such trees are usually planted at densities of about 100 to 200 trees per acre. For more information about apple rootstocks, see VCE Publication 422-006, Apple Rootstock Characteristics. Trees on the dwarfing rootstocks, M.26 and M.9, can also be trained as central leaders, but the trunks should be supported with posts to a height of at least 3 feet above ground. Non-supported trees tend to lean, fall over, or break. Dwarf trees are typically planted at densities of 300 to 500 trees per acre.

The freestanding conical tree form is very efficient. Tree training and pruning should begin at planting. Tree form that results from an improperly trained 5-year-old tree cannot be corrected without loss of yield and fruit quality. Training should be continued until tree maturity. The specific training and pruning practices will vary with varietal vigor and growth habit, rootstock, fruitfulness, and desired tree size. However, certain principles must be followed to develop the conical tree form.

## Training and Pruning Non-bearing Trees

During the early years, emphasis should be on training rather than pruning because any pruning will tend to delay flowering. Pruning should be limited to removing branches that have unsuitable crotch angles and to branches that are in undesirable positions for proper tree development. Special attention must be given to the selection of properly spaced scaffold branches, spreading branches to the proper orientation, and maintenance of the central leader. The central leader should not be allowed to fruit because the weight of fruit will cause the leader to bend over, which causes a globular shaped canopy that receives poor light distribution. The early fruiting of lateral branches, however, can be regulated to assist in limb spreading, provided the weight of the fruit does not bend the branch to a position below the horizontal.

## First Year

At planting, the unbranched 1-year-whip should be headed at 30 inches above ground. Lower heading results in a few vigorous shoots developing below the heading cut, but most may be too low. Higher heading results in the development of shorter shoots. Head the central leader to a bud on the windward side of the whip. The wind will maintain the shoot in a vertical position.

Most U.S. nurseries sell unbranched whips and feathered or branched trees. Feathered trees are easier to produce with varieties that are more vigorous than spur-type strains of 'Delicious'. One advantage of feathered trees is that the grower receives trees that have scaffold branches with wide crotch angles. In addition, feathered trees usually become productive sooner than unbranched whips.

To produce the freestanding central leader tree, feathered trees should be pruned similar to a tree that has grown for one season in the orchard. At planting, remove low branches and branches with poor crotch angles. The height of the lowest branch should vary depending on the height of mowing equipment to be used. Most commercial orchardists prefer branches 24 to 26 inches above ground, but when trees are grown in the yard, branches should be 30 to 36 inches above ground. Sometimes all the branches are too high or too low. In such cases remove all branches and treat it as a non-branched whip. Head the central leader 10 inches above the highest usable branch. If there are only one or two branches on the tree, remove the branches and treat the tree as an unbranched whip. If trees are planted further apart than 6 feet in the row, scaffold branches should be headed by about 1/3 to stiffen the branch. Heading scaffolds will delay fruiting, but it allows one to fill the space between the trees to maximize yields as trees mature. Non-headed branches remain limber and bend under the weight of a crop during the first few years after planting. Drooping branches must be shortened to more upright shoots, so such trees never attain diameters of much more than 8 feet.

Sometimes branches are not at the right location. The desired height of branches on new trees is 24 to 40 inches above ground. Branches that are higher or lower should be removed. If all branches are too low or too high, all branches should be removed and the tree should be treated as a non-branched whip. Making a whip out of such trees will delay fruiting by a year, but will ultimately produce a better tree.

The buds within 4 to 8 inches below the heading cut

will develop into shoots of nearly equal size and vigor. The more vertical of these (usually the top shoot) should be selected as the leader. Competing branches with poor crotch angles should be removed when they are 3 to 6 inches long and while they are still succulent during the first growing season. Also, remove shoots that develop below 18 inches on the main trunk. Removing these shoots can easily be done by hand (stripping) and the wounds heal rapidly (Fig. 5). Shoots that develop further down on the leader are usually less vigorous and have better crotch angles. The crotch angles of these shoots can be improved by spreading the shoots to the horizontal with spring-type clothespins or toothpicks (Fig. 6). These practices will help reduce the need for pruning dormant trees, which delays fruiting.

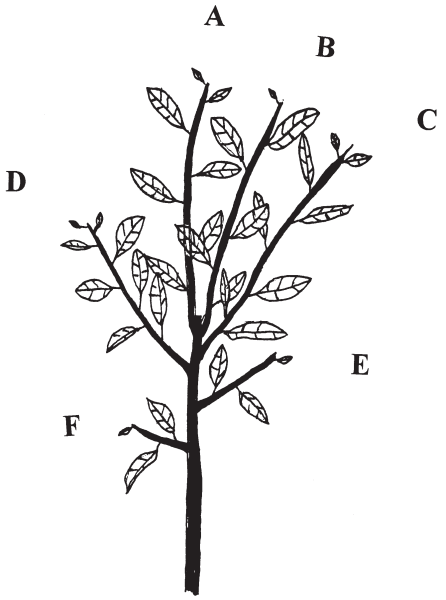


Figure 5. Several shoots will develop below a heading cut. Retain the longest straightest shoot (A) and remove shoots with narrow crotch angles (B and C). Shoots arising lower on the leader (D, E, and F) are usually shorter and have wider crotch angles, and should be retained. Undesirable shoots can be removed during the early summer when shoots are 6 to 8 inches long or they can be removed while dormant pruning.

After the first growing season, the tree has a new terminal shoot (1-year-old section), several 1-year-old limbs, and the original whip (2-year-old trunk section). The central leader (1-year-old section) should be headed to a bud on the windward side by removing 1/4 to 1/3 of the past season's growth. Heading will encourage branching 18 to 24 inches above the first set of limbs and will keep the leader vigorous and stiff. It is handled exactly as heading the newly planted whip. Several shoots may have developed on the whip below the original heading cut. The top 2 or 3 shoots will have narrow crotch angles and will compete with the leader. They should be removed if they were not removed during the summer. Retain all branches with wide crotches. When the tree is 5 to 7 years old, some of these branches will be removed. Maximum yearly yields are obtained by retaining all branches until they have fruited for a year or two.

Figure 6. Crotch angles of shoots developing below heading cuts are usually narrow. Crotch angles can be improved by mechanically spreading newly developing shoots in the spring or with toothpicks or pieces of wire as shown in the figure.

Sometimes trees may produce few shoots the first season. If less than three shoots develop, the shoots should be removed because they will become dominant. If all shoots develop on one side of the tree, they should all be removed to maintain a balanced tree.

During the first winter, there are usually 3 to 6 branches on the original trunk (2-year-old section). These branches should be spread with pieces of sharpened wire to an angle of 40 to 60º from vertical. Do not head the branches because yield will be reduced. Researchers in Ontario found that yield was reduced for several years when branches on young trees were headed once. In Virginia, we found that annual heading of branches reduced yield 15% during the first seven years after planting (Table 1).

If trees fail to develop properly during the first and second years, trunk renewal is a method of promoting

**Table 1.** The effect of heading or removing scaffold branches for six years on tree size and yield on 8-year-old Redchief Delicious apple tree.

| Pruning Treatment | | | | |
|---|---|---|---|---|
| Annual heading | Scaffold limb removal | Tree ht (ft) | Tree spread (ft). | Cum. yield (lbs/ tree) |
| No | No | 15.1 | 16.0 | 750 |
| Yes | No | 14.6 | 14.5 | 618 |
| No | Yes | 15.1 | 15.8 | 612 |
| Yes | Yes | 15.2 | 15.4 | 546 |

good tree growth. This involves cutting the central leader back to a few buds to develop strong new shoots. Spur-type trees often produce little growth the first year. If leaf size and color are adequate, do not use trunk renewal; these trees usually grow well during the second season.

## Second Year

The central leader will develop vigorous terminal shoots below the heading cut. Only one terminal shoot is needed. Usually the competing leaders are removed during the dormant season. However, it is better to remove these excess shoots early in the season when they are 4 to 8 inches long. Growth is then directed into the most desirable shoots. Excess shoots that are developing on the leader and vertical shoots that are developing on the upper sides of scaffold branches can also be removed at this time. The shoots remaining on the leader can be spread with clothespins or toothpicks.

Figure 7. One-year-old tree before (Left) and after (Right) dormant pruning. Note the removal of branches with narrow crotch angles, spreading of branches, and heading the leader and scaffold branches.

At the conclusion of the second season, the tree consists of a 1-year-old leader, a 2-year-old trunk section with 1-year-old limbs, and the original whip with 2-year-old branches. To encourage early fruiting, young trees should be pruned as little as possible in the previous year. Spread but do not head all branches with wide crotches. All branches with narrow crotches should be removed and the central leader should be headed by 1/4 to 1/3.

## Third Year

After three growing seasons, the tree is composed of sections of 1-, 2-, 3-, and 4-year-old wood. The tree should be pruned the same as in the previous winter.

Sometimes watersprouts will develop from the upper sides of scaffold limbs that have been spread, especially if they were spread too flat. These watersprouts can be removed during the early summer while they are still succulent. Removal of these upright shoots during the

Figure 8. Two-year-old tree before (Left) and after (Right) dormant-season pruning. Young trees often have too many branches and branches may grow upright. Note the removal of low branches, heading of the leader and scaffolds, and spreading of branches. Two layers have been developed in this tree.

dormant season requires large pruning cuts that heal slowly. Removing sprouts during the dormant season usually induces several more sprouts to develop from buds around the pruning cut. This proliferation of waterspouts results in increased pruning costs. Stripping out waterspouts in the early summer greatly reduces the number of sprouts developing at that location in the future. The summer stripping of narrow-crotched, vigorous, competing shoots on each headed shoot and the central leader, and the spreading of new branches on the central leader, should be continued as in the previous growing season. Defruit the central leader to prevent it from bending.

Depending on the rootstock and variety, trees may start to fruit the third or fourth year. Older branches should be allowed to fruit, but fruit should be removed from the leader to prevent the leader from bending.

## Fourth Year

In general, trees should be treated as in the third season. Defruit the central leader and young lateral branches in the upper part of the tree to avoid limb drooping. Remove vigorous watersprouts and strip and spread competing shoots on the central leader and scaffold limbs.

Less vigorous watersprouts, those less than pencil thick at the base or less than 18 inches long, can be retained. If these watersprouts are growing vertically, they can be reoriented to less than 45˚ from vertical to retard vegetative growth and induce fruiting. These watersprouts will become fruiting systems and can be removed after fruiting for 2 or 3 years.

Before dormant-season pruning, spread the scaffold branches; this may require spreaders 3 to 4 feet long. Trees that have been spread look different and usually require less pruning than was apparent before spreading. Continue to remove shoots or branches with narrow crotches. Try to do as little pruning as possible to encourage fruiting.

## Beyond the Fourth Year

Apple growers often do a good job of training trees for the first few years, but pay less attention to the central leader and treetop after about 5 or 6 years. Be sure to continue training the tree top until the tree has attained the desired height. Treat the top as a new tree each year.

The same principles can be used as in previous years. The conical tree shape should be maintained to allow

Figure 9. A six-year-old 'Delicious' tree (Left) before spreading, (Middle) after spreading, and (Right) after pruning. The weight of a crop will pull the scaffold branches down to form the conical tree shape. Note the removal of many limbs in the top half of the tree to allow light penetration.

light penetration throughout the canopy. Tree height will depend on the vigor of the rootstock/variety combination and soil fertility. Trees can usually be maintained at the desired height by cutting into 2-year-old wood on the central leader just above a moderately vigorous lateral shoot. Maintain a narrow top by removing vigorous branches in the top half of the tree. Branches with a diameter half the size of the trunk at the point of attachment should be removed by cutting at an angle to leave a short stub that is shorter on top than on the bottom. Buds just below the stub will develop into shoots with wide angles and can be spread to produce a new branch. This type of limb rotation will maintain a small tree top.

Unlike branches in the tree top, the 4 or 5 lowest branches are permanent and should be retained for the life of the tree. The ends of the branches will eventually droop under the weight of a crop. This will result in branches extending into the row middle making it difficult to drive equipment between the rows. Fruit on the ends of drooping branches will hand in the grass and may rot. Cutting the end off the branch to a more upright limb can shorten such branches.

## Pruning Mature Trees

For various reasons, trees sometimes become too large or overly vigorous in the top. Fruit growers often wish to reduce the height and spread of large older trees. Before pruning, tree vigor should be carefully considered. Nitrogen fertilization, light cropping, and pruning enhance tree vigor. Tree size should be reduced without overly invigorating the tree in order to avoid drastic crop losses and production of low-quality fruit. Therefore, tree vigor and pruning must be balanced. The season before severe pruning, nitrogen fertilization should be reduced or eliminated and annual cropping is essential.

Limb orientation is also important for controlling tree vigor. Upright limbs can often be tied down or positioned to the horizontal rather than pruned out; this will suppress vegetative growth and encourage fruiting. If a large upright limb cannot be reoriented, it must be removed.

Proper limb positioning can greatly reduce pruning, which stimulates growth. If there are excess limbs, they can be removed over a 2- or 3-year period to avoid throwing the tree into a vegetative stage. Remove old spurs that hang down on the undersides of large branches, remove watersprouts, and use heading cuts only in areas where increased vigor is desired. Older spur systems that have branched repeatedly become weak and unproductive. Such spurs may be invigorated by thinning-out and heading to remove a portion of the spur system.