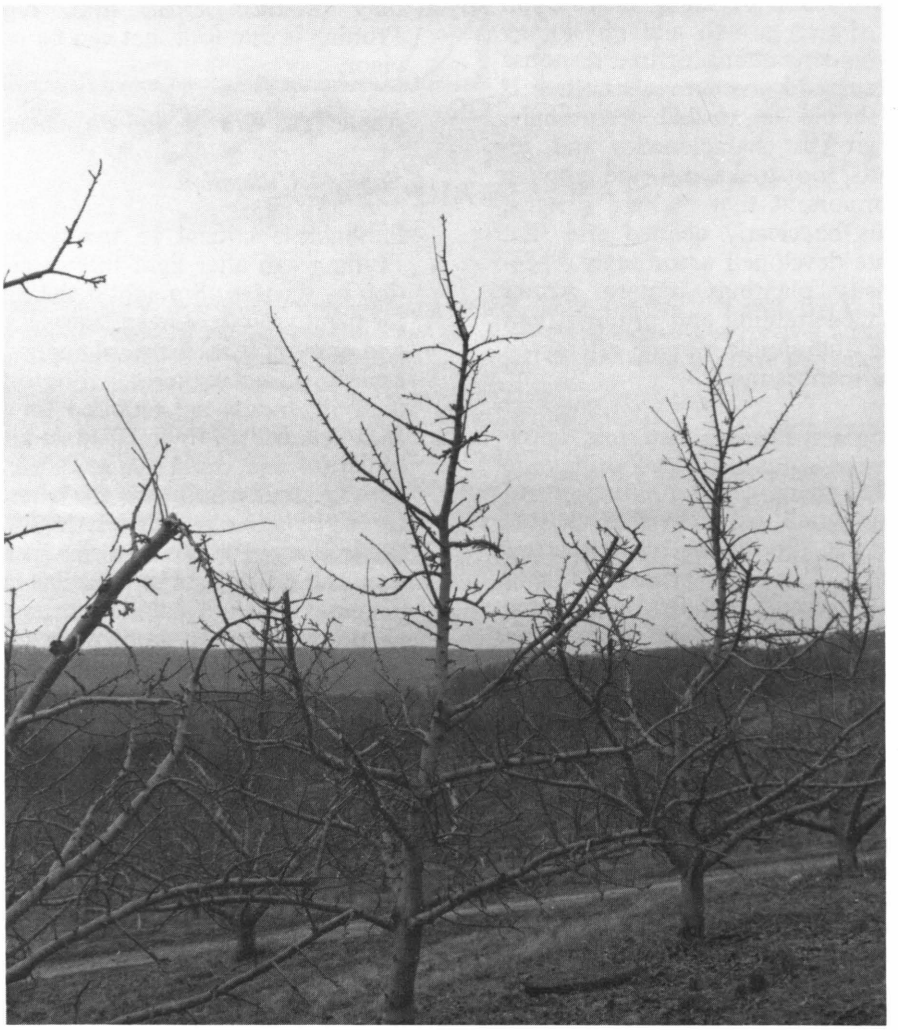
Virginia Cooperative Extension Service
Publication 422-021
Reprinted 1988



Training and Pruning Apple Trees

Virginia Tech and Virginia State
Virginia's Land-grant Universities

TRAINING AND PRUNING APPLE TREES

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Introduction

A major component in the management of a profitable orchard operation is the training and pruning of its trees. 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.

Objectives of Training and Pruning

The objectives of tree training and pruning are to develop and maintain small, conically-shaped 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. Detailed 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/scion 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 bearing surface for optimum profitable production as early as possible in the life of the orchard.

As the tree comes 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 and poorly-colored fruit that has 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 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 tree canopy. As tree size increases, the proportion of the tree canopy, which is heavily shaded, also increases. 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 for the development of large well-colored fruit that has 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.

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 issues from a second meristem region, the

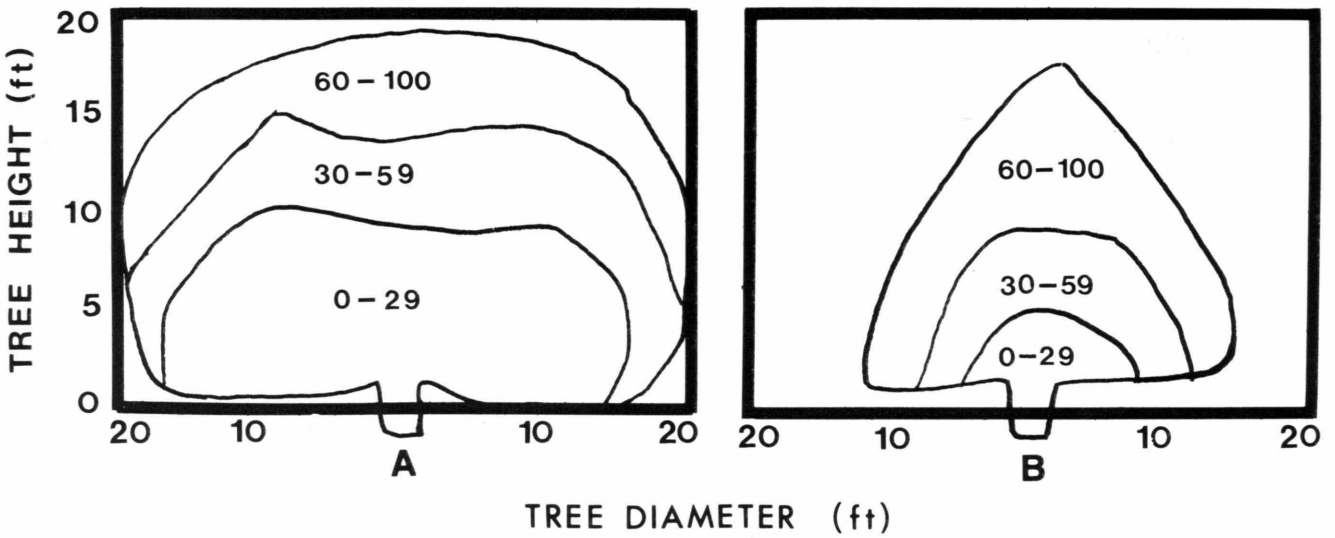

Figure 1. Light distribution in tree canopies is influenced by tree shape and size. Large, round trees (A) have 3 relatively distinct zones of light levels, and about one third of the tree volume receives inadequate light (0-29% full sun) for production of quality fruit. Smaller conical-shaped trees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

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; if it's in the axle of a leaf, it's called a *lateral* bud. 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". 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.

Energy for Growth

Early-season growth is dependent on carbohydrates and nitrogenous materials that result from the previous season's photosynthetic activity and 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 for the prevention of 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 (Fig. 2).

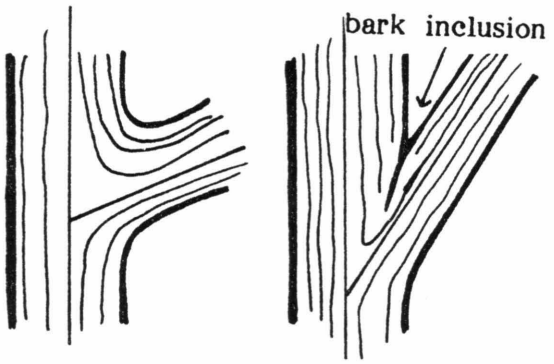

Figure 2. Wide crotch angles are strong.

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 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 an 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 an unpruned 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 has 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 prior to extremely severe 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.

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 results in 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 somewhat of a compromise between heading and thinning cuts and involves the removal of the terminal portion of a branch at a point just above a side branch. Bench cuts on young trees

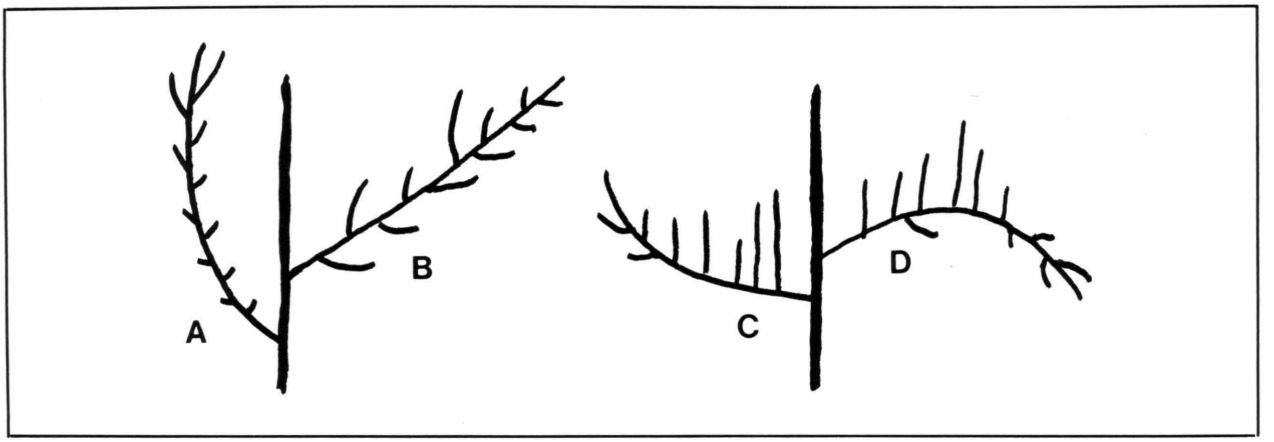

Figure 3. Branch orientation can affect shoot growth and flower bud development. A. Vertical shoots produce spurs, few side limbs. B. Limbs that are spread 60-45° produce side limbs of moderate vigor and spurs. C. Limbs that are spread below 45° may develop extensive upright growth that is nonfruitful. 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.

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.

Principles of Training and Pruning Central-leader Apple Trees

The free-standing 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 Nonbearing 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″ above ground. Lower heading results

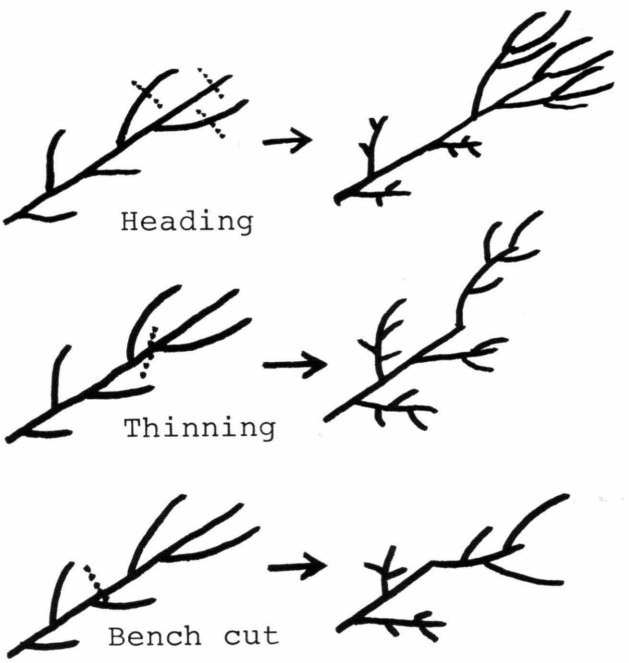

Figure 4. Heading cuts stimulate shoot development below the cut.: Thinning cuts induce little vigorous shoot growth. Bench cuts may be used to produce a spreading growth habit, but the limb below the cut may be weak and may break.

in a few vigorous shoots developing below the heading cut, but most may be too low. Higher heading results in the development of more shorter shoots. Head 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. However, some nurseries are experimenting with the concept of "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 free-standing central leader tree, feathered trees should be pruned similar to a tree that has grown for one season in the orchard. After planting, remove low branches and select up to 5 branches that are symmetrically spaced around the trunk. Head the central leader to 36 inches above ground. With the supported slender spindle training system, which requires feathered trees, the scaffold branches are not headed to induce early fruiting which helps control tree size. However, most of our orchard trees are being trained as free-standing trees, and the scaffold branches should be headed by 1/3 to stiffen them and to induce branching.

The buds within 4 to 8" below the heading cut will develop into shoots of nearly equal size and vigor. The most 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" long and while they are still succulent during the first growing season. Also remove shoots that develop below 18" 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 clothes pins or toothpicks (Fig. 6). These practices will help reduce the need for pruning dormant trees, which delays fruiting.

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" 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. Select 2 to 5 lateral shoots with good crotch angles that are symmetrically spaced along the 2-year-old whip. Shoots should be spaced vertically 6 to 8" apart. As limbs enlarge in diameter, they will appear closer together. Selection of more than one shoot at the same position on the 2-year-old whip will result in a whirl of shoots that may devitalize the leader. Avoid having branches develop on top of each other because the lower branch will be shaded.

Trees often produce less than 5 shoots the first season, so use the shoots that are available. Developing a layer of desirable branches often requires more than one year. If only a single shoot develops, it should be removed because it will become dominant. If several shoots develop on the same side of the tree, they should all be removed to maintain a balanced tree. The retained shoots should be headed by removing 1/4 to 1/3 of each shoot; this will stiffen the shoots and encourage branching. Head each shoot just above a side bud rather than a top or bottom bud; this encourages outward shoot growth. Prior to heading, shoots should be spread with pieces of sharpened wire to an angle of 20 to 40° from the vertical (Fig. 7).

If trees fail to develop properly during the first and second years, trunk renewal is a method of promoting 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 and each lateral shoot will develop several vigorous terminal shoots below the heading cuts. Only one terminal shoot is needed on each. 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" 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 clothes pins or toothpicks.

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. Two to 4 of the second set of branches on the 2-year-old trunk section, if available, should be selected as permanent scaffold

Figure 5. Shoots developing below a heading cut with narrow crotch angles and competing with the central leader (A) can be removed during the summer or (B) preferably when shoots are 6 to 8 inches long.

limbs. These branches should be 24 to 30″ above the top-most limb that is developing on the 3-year-old trunk section, and they should be spaced vertically 6″ apart around the tree. Branches on the 2-year-old trunk section should be spread and headed. Excess branches on the 3-year-old section should be removed and desirable branches should be spread. Lateral branches that are developing on the sides of limbs should be retained, and branches that are growing up or down should be removed. Keep scaffold branches uniform in length. The 2-year-old branches can be headed if branch stiffening or additional branching is desired. Although heading cuts delay fruiting, they are usually needed on spur-type 'Delicious' to stiffen branches and induce branching (Fig. 8). Vigorous varieties such as 'Stayman' or 'York' may not need heading. Each scaffold branch can be treated as a central leader.

Third Year

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 dormant season requires large pruning cuts that heal slowly. 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.

After three growing seasons, the tree is composed of sections of 1-, 2-, 3-, and 4-year-old wood. The 1-, 2-, and 3-year-old sections are pruned as described previously. Since the 4-year-old portion of the tree will probably produce some fruit during the fifth growing season, it will require some detailed pruning. Before pruning, spread the scaffold limbs so they are oriented 40 to 60° from the vertical. A tree looks different after spreading and usually reduces the amount of pruning that is needed. Next, remove all upright and overvigorous shoots, head some of those with moderate vigor, and leave those with moderate to weak vigor unheaded. Shoots that were headed the previous year will have side shoots and some will need to be removed to prevent crowding. Where necessary, thin-out these shoots

by cutting to a nonheaded side shoot. Head shoots in the tree top to maintain the conical form.

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 new watersprouts and strip and spread competing shoots on the central leader and scaffold limbs.

Before dormant-season pruning, spread the scaffold branches; this may require spreaders 3 to 4′ long. The tree should be filling its space and the tree should be pruned to facilitate a transition from vegetative growth to fruiting. It is important to maintain a strong central leader. Head the leader as in previous years. If the leader becomes too tall or there was poor branch development in the tree top, then heading into 2-year-old wood may be necessary to induce vigor and branch development. Fewer heading cuts should be made, even in the tree top, to encourage cropping. Use thinning cuts to shorten branches by pruning to a weaker side shoot and leaving it unheaded.

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 tree top 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 (Fig. 9). Be sure to keep the tree top smaller than the bottom to maintain the conical tree form. The mature tree requires only 10 to 12 scaffold limbs to produce acceptable crops of high-quality fruit. The scaffold system should be arranged as 3 or 4 layers of 2 to 5 limbs. The layers of limbs should be spaced vertically 24 to 30″ apart on the central leader and should be arranged symmetrically around the tree to avoid mutual shading of branches. As trees mature, several scaffold limbs may need to be removed to improve light penetration. The terminal shoot on the central leader should be maintained as vegetative. This will require annual heading into 1-year-old and sometimes 2-year-old wood. Thinning cuts should be used to maintain tree spread and reduce limb crowding. Heading cuts should be used only to induce vigorous growth, usually in the lower part of the tree. If branches spread below the horizontal under the weight of a crop, they may have to be tied up or propped to prevent limb breakage and to maintain the balance between vegetative and reproductive growth. Thinning cuts should be used to maintain ladder bays in the trees to faciliate harvest and improve light penetration. When the tree reaches the desired height (probably 12 to 18′), use a thinning cut to remove the more vigorous narrow-angled branches formed on the leader below the dormant heading

Figure 6. Crotch angles of shoots developing below heading cuts are usually narrow. Crotch angles can be improved by mechanically spreading young shoots with toothpicks or pieces of wire.

A B

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

cut. Leave the weakest upright shoot and head it to 2 buds. Repeat this procedure each year, removing the strong shoots and heading back to the weakest upright shoot. If older limbs lose vigor and produce small, poor-quality fruit, it is easier to develop a new limb than to rejuvenate the older limbs. Remove these limbs where they originate from the trunk; then spread one of the resulting watersprouts to develop new fruiting wood. Branch renewal may also be necessary; the terminal segments of the upper branches are regularly removed, and a strong lateral or watersprout is trained to occupy the desired space.

Pruning Mature Trees

Fruit growers often wish to reduce the height and spread of large umbrella-shaped trees. Before pruning, tree vigor should be carefully considered. Nitrogen fertilization, light cropping, and pruning all 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 may be handled as a central leader. The lateral limbs on the upright branch can be spread to the horizontal to reduce growth and encourage fruiting. Orient limbs in positions where they will receive light and where they can carry a crop without limb rub. 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.

A B

Figure 8. Two-year-old tree before (A) and after (B) 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.

Long, drooping branches in the tree top that contribute to the umbrella shape can be thinned to vertical shoots to reduce shading and to narrow the tree top. Watersprouts are best removed in June to improve light penetration.

Mechanical Hedging and Topping

As skilled pruners become more expensive, and sometimes unavailable, growers have considered mowing the tops and sides of trees. Although this practice is relatively inexpensive, it is a poor horticultural practice. The nonselective cutting of wood often removes prime fruiting shoots while leaving nonproductive shoots. In addition, mowing results in many headed shoots at the tree periphery which produce additional shoots that shade the tree interior. Mowing can be used to effectively reduce tree size, but mowing should *always* be followed by detailed pruning to thin out the undesirable headed shoots.

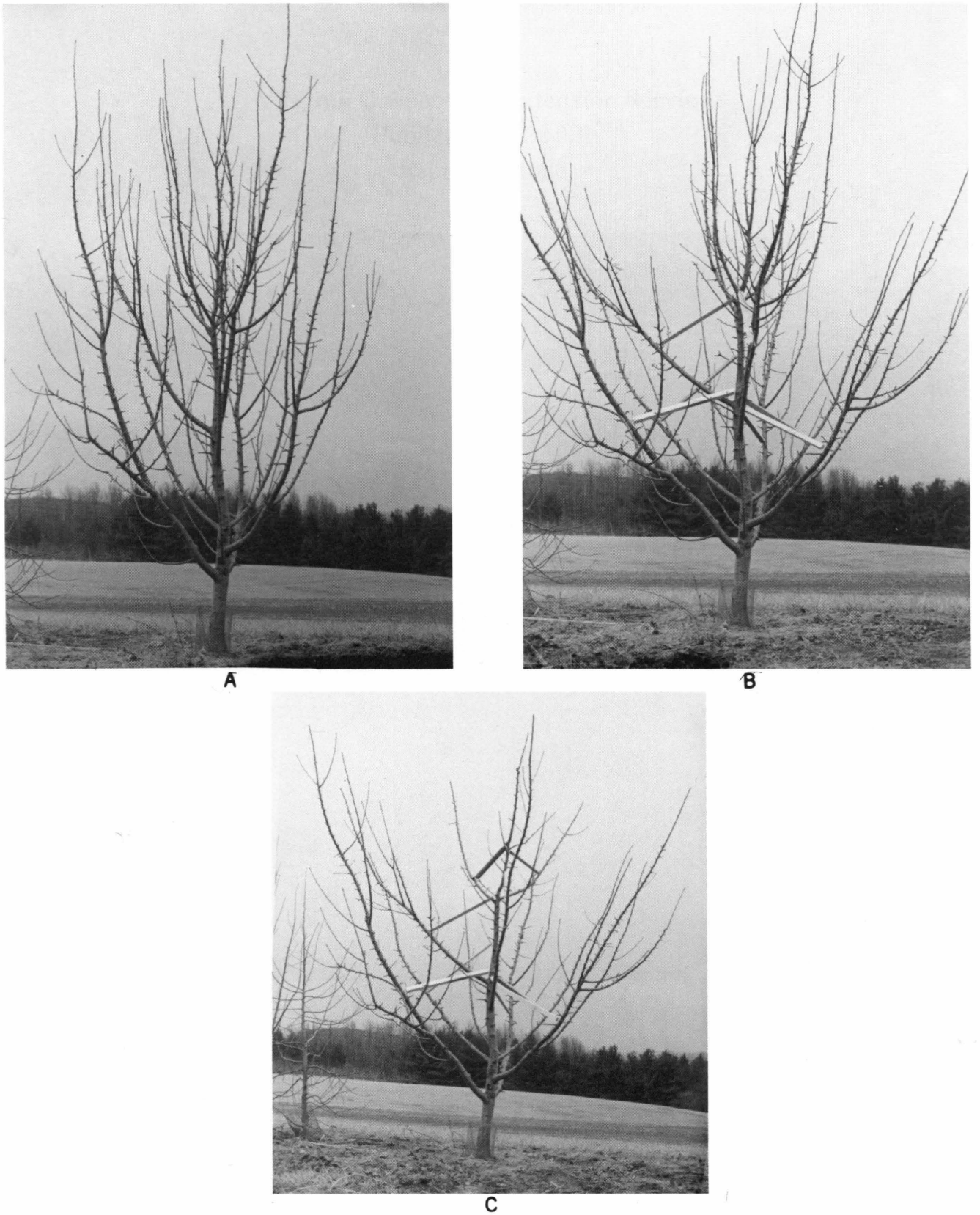

Figure 9. A six-year-old 'Delicious' tree (A) before spreading, (B) after spreading, and (C) after pruning. The weight of a crop will pull the scaffold branches down to form the conical tree shape. Note the removal of many limbs in the top half of the tree to allow light penetration.

Issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, and September 30, 1977, in cooperation with the U.S. Department of Agriculture. Mitchell R. Geasler, Director, Virginia Cooperative Extension Service, and Vice Provost for Extension, Virginia Polytechnic Institute and State University, Blacksburg, Virginia; Clinton V. Turner, Administrator, 1890 Extension Program, Virginia State University, Petersburg, Virginia.