

# Training and Pruning Apple Trees

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## Introduction

A quiet revolution is in progress in the Northeast apple industry. In the interests of efficiency, low-density orchards of large, old trees are being rapidly replaced by smaller trees at closer spacings. Though opinions may differ as to the optimum tree size and spacing, all agree that smaller trees are an economic necessity. Accepted cultural practices for the large trees of the past are no longer appropriate, and significant adjustments must be made for tree size and spacing. Training and pruning are conspicuous examples of practices that require major revision for adaptation to density plantings.

The advantages of density plantings have been widely publicized. Many growers expected such plantings to be early bearing, high yielding, and virtually work-free, but disappointment has been all too common. In a recent extensive survey of young plantings of varying density in Washington (Axford 1976), it was reported that the average yield of orchards 5-12 years old had not increased in the past 17 years. There was no correlation between yield and rootstock, and

density had only a minor impact on yield. Detailed questionnaires revealed that the effect of certain cultural practices on yield had been greater than the effect of either rootstock or density. The production potential was realized only in those high-density orchards where careful attention was devoted to cultural practices.

The advantages of high-density plantings are real and significant. However, their full benefits will be reserved for those growers who conscientiously pursue an appropriate cultural program. In the survey mentioned, one of the most important factors in early production was the training of the young trees. Training and pruning are inseparable because they are companion practices in the young tree, and the training of the young tree determines, in large part, the type of pruning required by the mature tree. These two practices affect both the amount and type of growth, and errors in either can negate efforts in other areas of the cultural program. Correct training and pruning are essential for early production, sustained high yields, optimum fruit quality, and efficient management.

The recommendations that follow are intended for the Northeast only. In other areas, growing conditions, particularly temperature and sunlight, may be significantly different. Such climatic differences influence both vigor and fruitfulness, and these are major considerations in the development of appropriate pruning programs. Therefore, these recommendations may be applicable to other areas only after some modification.

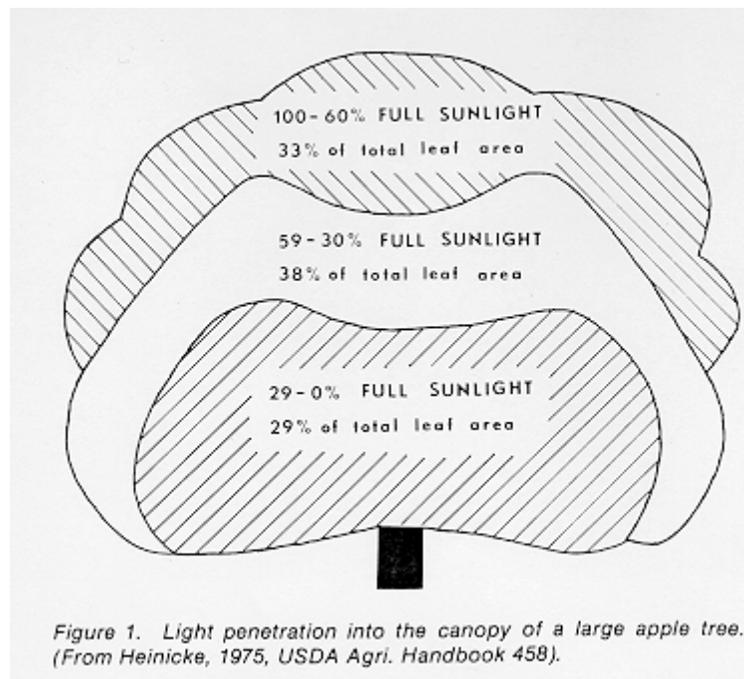
## **Objectives of Training and Pruning**

In the nonbearing years, some pruning will always be necessary, but the emphasis should be on training rather than pruning. Ideally, the growth of the young tree should be directed into branches that will be a permanent part of the mature tree, and an equal effort should be made to avoid superfluous growth that will be removed before it fruits. Training practices should encourage early production and the development of a strong structural framework capable of supporting heavy crops in future years. The framework should facilitate the development and maintenance of optimum tree shape. The training program should also produce trees that will be easy to manage in later years. In terms of future management, pruning is the cultural practice most affected by training. Much of the pruning of mature trees is merely the correction of earlier errors and omissions.

The amount and quality of fruit produced by an apple tree are determined by the relationship between vegetative and fruitful growth. The woody tissues of the tree compete with the fruits for the products of the leaves, and excessive vegetative growth is made at the expense of the fruits. Moderate vegetative growth is necessary for a large, functional leaf surface and for the development of new bearing wood. Inadequate vegetative growth results in a loss of fruitfulness and a reduction in fruit size. The relationship between vegetative and fruitful growth is influenced by many factors, such as fertilization, weather, and crop load, but pruning plays a major role. In essence, proper pruning removes unproductive wood, maintains optimum vigor in productive wood, and encourages the continuous development of new bearing wood to replace that removed by pruning. Wood may be unproductive because the vigor is either too high or too low. Excessively vigorous wood may develop in response to over fertilization, severe pruning, or loss of crop. Low vigor may be due to inadequate fertilization, insufficient (or no) pruning,

excessive cropping, or shading. Productive wood quickly becomes unfruitful if heavily shaded. The development of new bearing wood requires moderate, but not excessive, vigor and good light exposure.

In listing the above factors, the recurring reference to light exposure (or shading) is highly significant. It has frequently been stated that the limiting factor in the productivity of an apple tree is the shade it casts upon itself. Equally important in high-density plantings is the shade of adjacent trees. Intensive studies (Heinicke 1964, 1975) have shown that there are distinct light zones within an apple tree (fig. 1). To quote Heinicke, "A layer of fruit and foliage on the outside surface of the tree receives a high proportion of the available light far in excess of tree requirements. A second layer further down has adequate light, and a third layer or core in the center of the tree has insufficient light for the production of quality fruit. The solution to greater productivity lies in eliminating the unproductive area of inadequate light, which will improve the overall efficiency of that area of the orchard occupied by a tree."



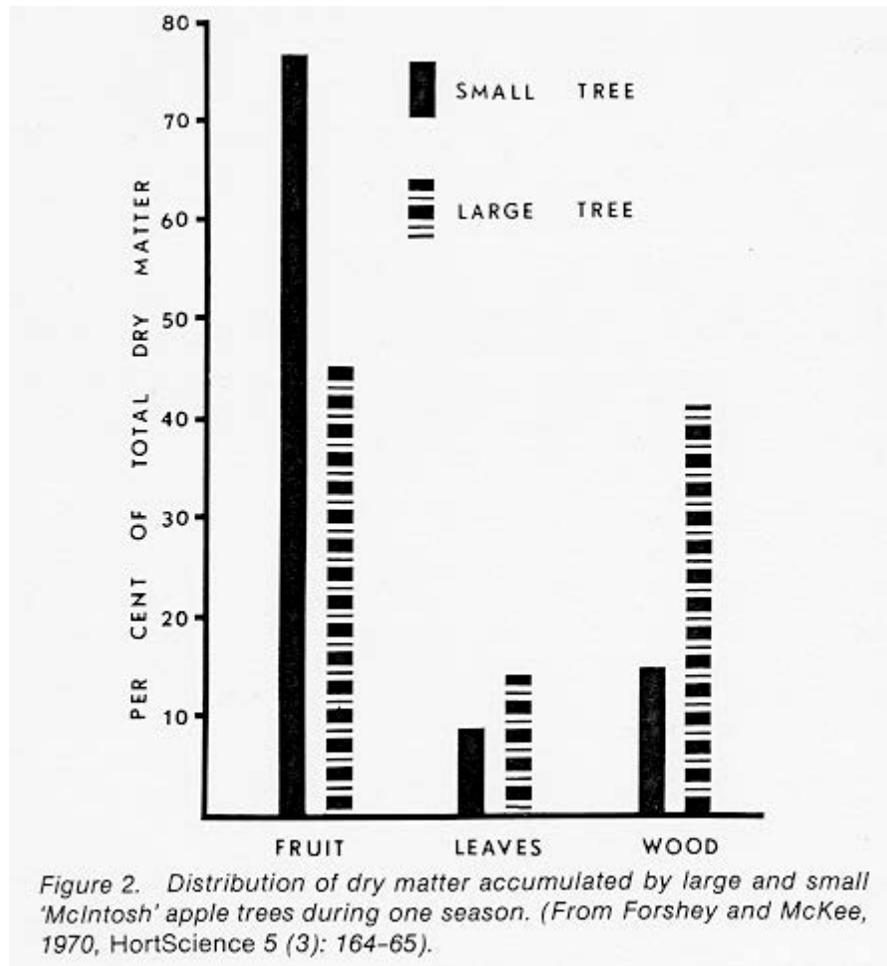
The zone that receives less than 30 percent full sunlight is less fruitful and produces smaller fruits of unsatisfactory color. In the past, the usual solution to this problem was the removal of all the bearing wood in the heavily shaded interior of the tree. This was effective in a way because it did eliminate some inferior fruit, but it did not increase efficiency. In addition, this approach continuously forced the bearing wood upward and outward and encouraged the development of very large trees. At wide spacings, this was tolerable, even though it was inefficient. At close spacings, this approach quickly leads to overlapping trees which heavily shade themselves and each other. This type of open-center pruning can rapidly transform a density planting into an unmanageable thicket.

The two most important factors in determining the percentage of the total leaf surface that receives inadequate sunlight are tree size and tree shape. In the light distribution studies

mentioned (Heinicke 1964, 1975), the shaded, unproductive area decreased as tree size decreased. The percentage of the total leaf area receiving less than 30% full sunlight increased from 8 percent in 8-foot dwarf trees, through 13-19 percent in 12-16-foot semi-dwarf trees, to 24 percent in 20 foot-high standard trees. Pruning is only one of many factors that affect tree size, and size can be controlled by pruning only within rather definite limits. The ultimate size of the tree will be determined by the interaction of rootstock, cultivar, soil, fertilization, cropping, and growth retardants as well as pruning, and the precise control of tree size requires an appropriate combination of all these variables. However, in closely spaced plantings, a major objective of the pruning program must be the restriction of the height of the tree and the spread of its branches to minimize the shade the tree casts on itself and on adjacent trees.

Open-center trees, such as the tree in figure 1, tend to be globular in shape with a dense canopy at the top which heavily shades the lower half of the tree. Not only is a large proportion of this type of tree unproductive, but also, the most productive part is at the top where the fruit is least accessible. A tree that is cone or pyramid shaped exposes a greater percentage of the total leaf surface to adequate sunlight and, as a result, has a smaller unproductive zone. In addition, most of the fruit develops in the lower part of the tree so that it is easier to care for and to harvest. The requirements for a conic tree are a central leader, an open framework that allows sunlight to penetrate to the interior of the tree, horizontal scaffold branches, and upper branches so positioned and restricted in size that the shade they cast on the lower branches is minimal. Training practices should be directed toward the establishment of this most efficient tree shape, and pruning practices should maintain it throughout the useful life of the planting.

In addition to light distribution, and the resultant effects on the production of assimilates by the leaves, tree size and shape also influence the distribution of the assimilates. Large trees have more structural wood relative to bearing wood than do small trees. As a result, in large trees a greater proportion of the products of the leaves is diverted into wood growth (Forshey and McKee 1970; fig. 2). Because of the heavily shaded core area, the inner segments of the scaffold branches of open-center trees are unproductive structural elements even though the extremities are fruitful units. Conic trees of the same height and branch spread have fewer scaffold branches, shorter branches in the top, and the branches are productive all the way in to the trunk. Conic trees have significantly less structural wood per unit of bearing surface than open-center trees; consequently, a greater proportion of the products of the leaves is available for fruiting. Trees in high-density plantings should have the maximum fruiting wood and the minimum structural wood.



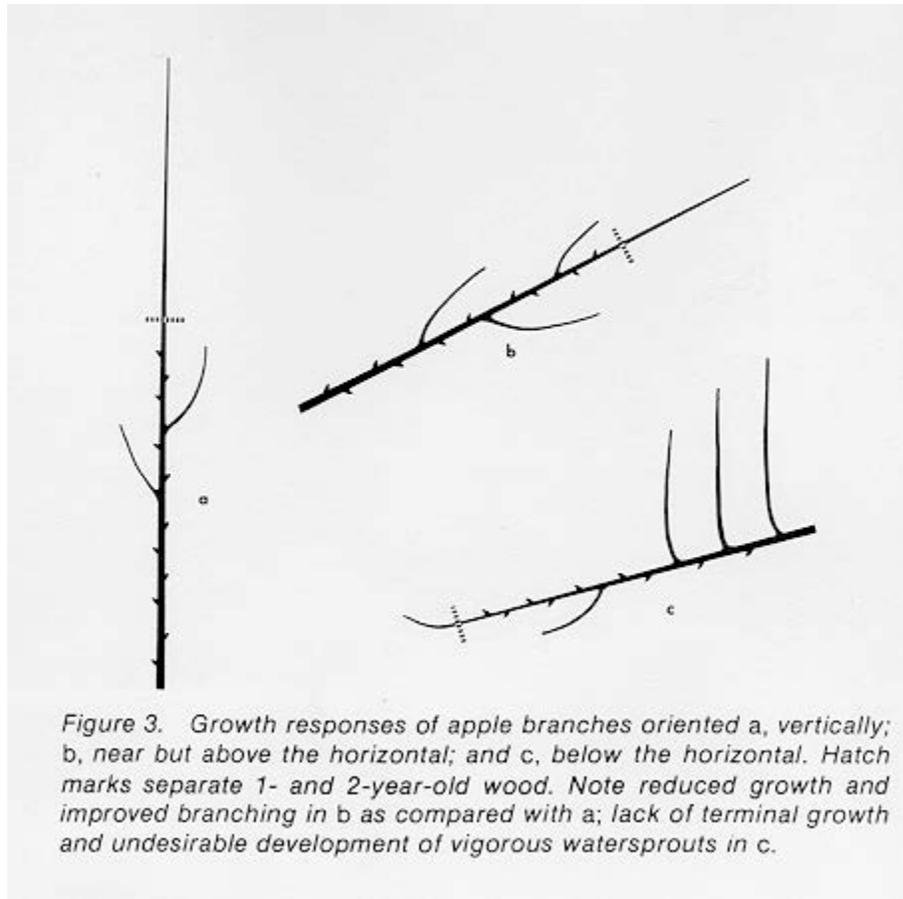
The objectives of training and pruning can be stated very simply: to develop and maintain a small, compact, efficient tree that can make maximum use of the sunlight available to it. The translation of broad objectives to specific pruning cuts is more complex. Successful pursuit of these objectives requires an understanding of (1) the physiology of tree growth, (2) the growth habits of commercially important apple cultivars, (3) the principles of training and pruning, (4) the responses to various types of pruning cuts, and (5) the influences of other factors, such as vigor and fruiting, on pruning responses. Detailed discussion of these factors and their interactions follows.

## Physiology of Tree Growth

Growth in an apple tree takes several forms. It includes the readily visible development of extension shoots, leaves, and fruits as well as the less conspicuous thickening of stems and the development of roots. All forms of growth require the assimilated materials manufactured by the leaves. Early-season growth is dependent on stored carbohydrate and nitrogenous reserves derived from photosynthetic activity the previous season. Later in the growing season current photosynthate is utilized to support growth of the tree and crop, and to restore reserves for the coming dormant period and the initial phases of growth the following spring. A healthy functional leaf surface is essential for these processes.

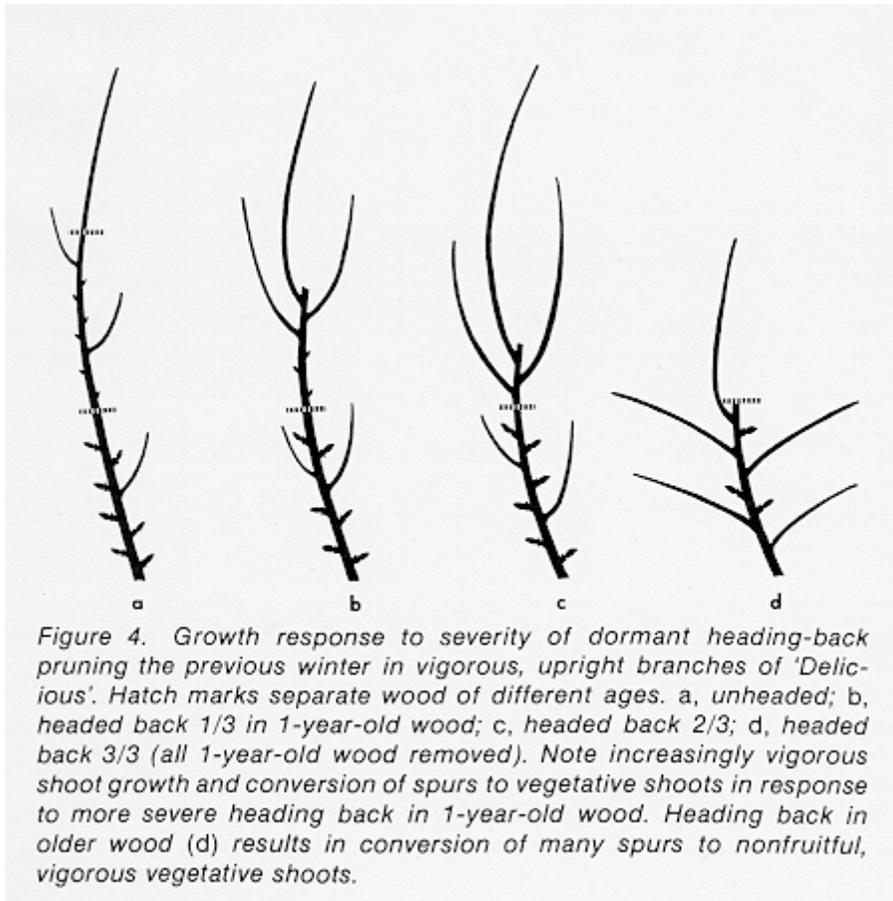
A growing point in an apple tree is any site in the tree that can direct the movement of manufactured food materials from the leaves toward itself. Actively growing shoots and fruits have this capability and compete among themselves and with other growing points, such as roots, for the products of the leaves. Because assimilate supply is limited, direction of assimilates to growing fruits decreases the supply available for shoot and root growth. An increased number of fruits invariably results in a compensating reduction in root growth and in number and vigor of shoots. It is in this way that fruiting helps to control tree vigor, shoot growth, and tree size. This mechanism of growth control becomes increasingly important at closer tree spacings. Reduced cropping in a high density orchard can lead to increased vegetative growth, which can quickly result in crowding and loss of bearing wood due to shading. For optimum growth control, crop load should be adjusted to the largest possible number of fruits consistent with good fruit size, quality, and repeat bloom.

The typical pattern of growth of an upright apple branch is shown in figure 3a. Most of the extension growth develops from the terminal bud itself. A few lateral buds may form shoots, but most of the buds become spurs or remain dormant. Production and downward movement of growth-regulating substances from the terminal growing shoot limit the development of shoots from lateral buds. These natural growth-regulating materials also tend to inhibit flower formation. The greater the vigor of vegetative growth, the greater the amounts of these flower formation inhibiting substances produced. When vegetative vigor becomes excessive, a large amount of shoot growth takes place, and few flower buds are formed. If an upright branch is bent to a near horizontal position, the pattern of growth-regulator movement is altered. Total vegetative growth is reduced, more lateral branch development occurs, and flower formation is stimulated (fig. 3b). If the branch is bent below the horizontal, terminal growth nearly ceases and is replaced by vigorous, upright watersprouts near the base of the branch (fig. 3c).



A pruned branch or tree always makes less total growth than it would have if left unpruned. Certain pruning cuts stimulate vegetative growth at the site of the cut and thereby create the illusion of increased growth, but that growth is always less than the sum of the part removed and the growth it would have made. Because pruning removes potential leaf surface for the following season as well as stored reserves in the wood, pruning severity is measured by the number of growing points, rather than the amount of wood, removed. Most pruning is done during the winter. At the end of each growing season, the top of the tree and the roots are in balance. Dormant pruning removes some growing points, and this increases the root resources of the remaining buds. The resultant invigoration partially compensates for the wood removed; and unless the pruning is carried to extremes, the net loss is minimal. In general, light pruning has a greater effect on growth distribution within the tree than on total growth. However, if a very large number of growing points is removed, the total growth the following season will be substantially reduced, and the growth from the remaining growing points will be excessive. Unlike dormant pruning, summer pruning is not invigorating. The early growth of shoots, leaves, and fruits is made at the expense of reserves stored in the woody tissues; late in the season the leaves replenish these reserves. If active leaf surface is removed in midsummer, before movement of assimilates from the leaves back to the wood has started, the net effect is a depletion of tree reserves that is reflected in reduced vigor the following season. The effect is directly proportional to the amount of leaf surface removed.

All pruning cuts can be classified in two major categories, termed heading back and thinning out. The differences in tree growth responses to heading back versus thinning out can be traced to their differential effects on the pattern of growth-regulator movement in the pruned branch. In thinning out, an entire shoot or branch is removed at its junction with a lateral or scaffold branch, or with the trunk. In contrast, heading back involves removing only a portion of a branch and interrupting the normal movement of growth regulators in the remaining branch section. Typical growth responses to heading-back pruning in vigorous, upright branches are illustrated in figure 4. The more severe the heading back in 1-year old wood, the stronger the vegetative growth response from buds just below the cut (fig. 4a-c). Heading back in older wood (fig. 4d) results in the conversion of potentially fruitful spurs to vigorous, non-fruitful vegetative shoots. The response to heading back can vary depending on several factors. Naturally vigorous cultivars with strong, upright growth, such as 'Delicious', exhibit a greater growth response to heading back than less vigorous cultivars. Trees of any cultivar in high vigor produce strong vegetative growth when headed back. Unlike upright branches, heading back comparable horizontal branches results in little increase in total vegetative growth over comparably oriented unpruned branches. However, the heading back cut stimulates more vigorous growth from buds near the cut, proportionately reducing branch development along the horizontal limb. The presence of a heavy crop can reduce or even eliminate the usual growth response to heading back. In contrast to heading back, thinning out cuts are not accompanied by the dramatic changes in growth pattern favoring development of vigorous vegetative growth. Because normal growth-regulator movement in the intact parts of the branch remains largely uninterrupted, shoot growth and stem thickening proceed normally.



## Principles of Training and Pruning the Young Apple Tree

Training and pruning the young apple tree begin at planting time, and the training program should be continued until the tree reaches maturity. An intelligently applied program of training and pruning the young tree eliminates the need for costly corrective pruning later, develops good tree structure, and encourages early fruit production. The specific, year-by-year program will vary depending on several factors, including varietal vigor, tree growth habit, precocity, final tree size, and whether the tree is freestanding or supported. Trees intended for mechanical harvesting should be trained appropriately from the start.

### The freestanding tree

With young trees the emphasis should be on training procedures rather than pruning. Since most pruning cuts on young trees stimulate vegetative growth and delay flowering, pruning should be limited strictly to those cuts necessary for proper tree development. Scaffold limbs on young trees seldom develop in the most favorable positions for maximum strength and proper light exposure. Scaffold limb selection and spreading alleviate these problems and aid in control of growth and stimulation of early fruiting. The approaches to training and pruning young trees vary depending on the growth habit of the cultivar. Cultivars with a spreading habit, such as

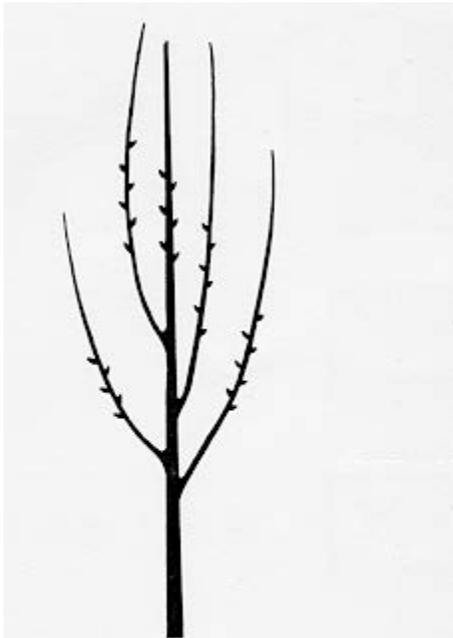
'Golden Delicious' or 'Idared', can be trained to a conic shape with little effort (fig. 5). With vigorous, upright-growing cultivars such as 'Delicious', careful attention must be paid to scaffold selection and limb spreading to obtain the desired tree structure (figs. 6-8). Improper scaffold selection can lead to restriction of central-leader growth due to development of too many scaffolds from one point on the trunk (fig. 9). The loss of leader dominance results in the formation of an unfavorable globular canopy shape. During the first years of tree training, careful attention must be paid to training the central leader. Loss of dominance of the central leader can lead to the formation of an open-center, globular canopy with poor light distribution. Fruit forming on the leader shoot must be removed; if not, their weight causes the leader to bend over or "fruit out" (fig. 10). Fruit growth further weakens the leader, and it usually encroaches on a scaffold limb, resulting in shading and loss of bearing wood.



*Figure 5. Growth habit of 'Golden Delicious'. Note the well-defined central leader, wide-angled crotches, and moderate extension growth.*



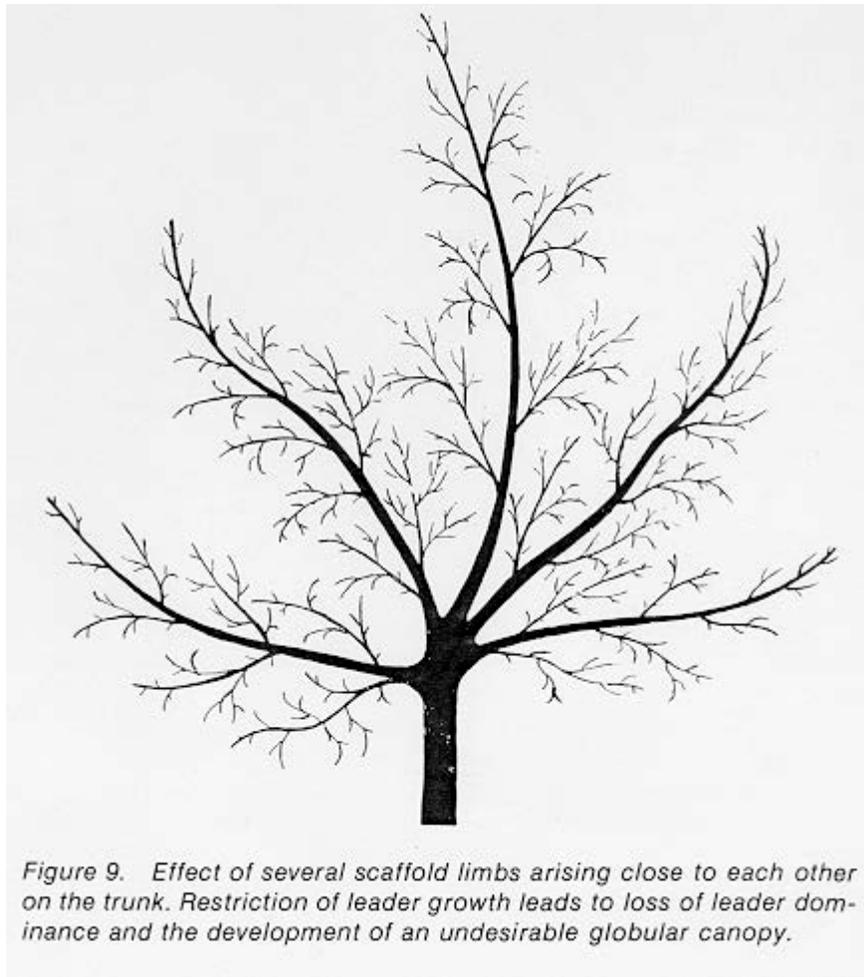
*Figure 6. Growth habit of 'Delicious'. Note vigorous, upright growth competing with the central leader, excessive number of scaffold limbs and narrow crotch angles.*



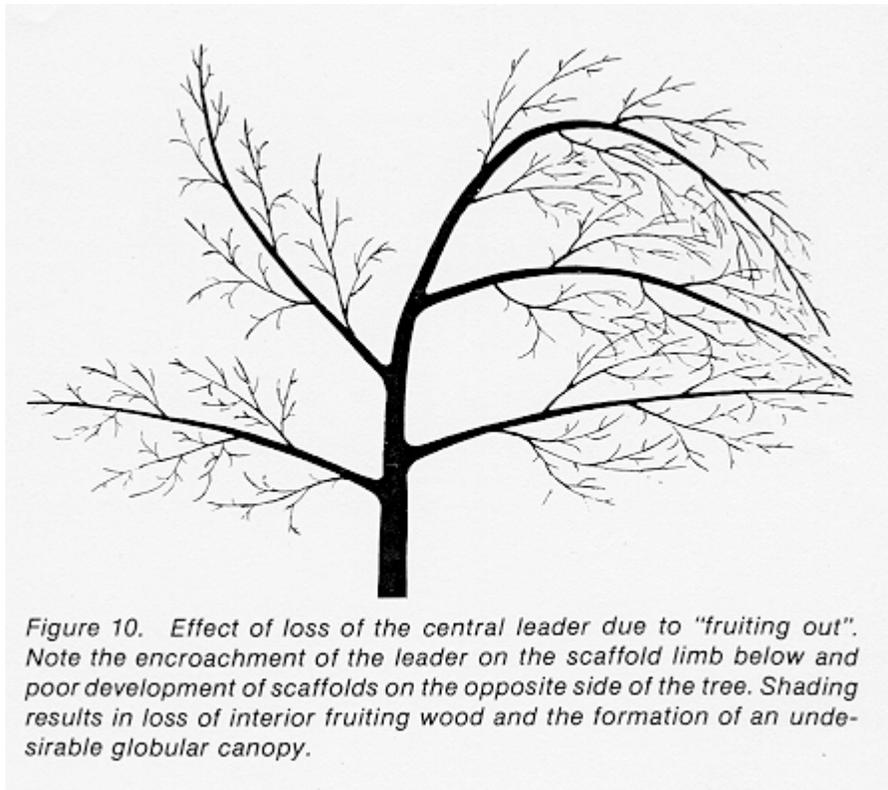
*Figure 7. The same tree as shown in figure 6 after scaffold selection and heading back the central-leader shoot. Note spacing of scaffolds along the main trunk.*



*Figure 8. The same tree as shown in figure 7 after insertion of limb spreaders. Spreading improves the crotch angle, reduces scaffold vigor, favors flower bud formation, reduces competition with the leader, and eliminates interference of lower scaffolds with the growth of scaffolds originating higher on the trunk.*



*Figure 9. Effect of several scaffold limbs arising close to each other on the trunk. Restriction of leader growth leads to loss of leader dominance and the development of an undesirable globular canopy.*



## **Central-leader development**

During the first growing season, most trees will produce a cluster of vigorous shoots near the heading cut. These develop from the uppermost 2-4 buds. The shoots are usually approximately equal in size and vigor with unacceptable narrow crotch angles. One such shoot, usually the uppermost, should be selected as the leader, and competition with it eliminated by pinching out competing shoots while they are still succulent (fig. 11). In subsequent years, the effort required to maintain a strong, dominant leader will vary with cultivar and vigor. In the less vigorous cultivars that grow naturally to a central leader, such as 'Golden Delicious' and 'Idared', all that may be required is the pinching out of an occasional competing shoot early in the growing season. In other cases, sustained effort will be necessary. With some cultivars, particularly 'Delicious', numerous competing shoots may develop and the leader may make excessive extension growth. When extension growth exceeds 18 inches (45 cm), the leader is often structurally weak, and lateral development so limited that there are insufficient suitable branches for the main scaffolds. In this situation, the leader should be headed back by about one fourth.

This both strengthens the leader and stimulates lateral growth which can be developed into scaffold branches. A cluster of shoots usually develops near the pruning cut in much the same manner that they develop in response to the original heading cut. These should be summer pruned as illustrated in figure 11. At the same time, other new shoots that are challenging the dominance of the leader can be removed or repositioned by spreading. Regular heading back of the leader, and the accompanying summer selection of the most desirable leader shoot, may be

necessary every year until the tree comes into bearing.



Figure 11. Summer pruning to ensure dominance of the leader. The unbranched whip is headed back at planting (a). Vigorous shoots develop from the uppermost buds (b). Shoots that compete with the leader are removed while still succulent (c). The removal of competing shoots is continued in subsequent years.

## Selection and training of scaffold limbs

Probably the most important procedure in the development of a well-trained, highly productive orchard is the proper selection and training of the scaffold branches. The future productivity of the orchard is directly correlated with the attention devoted to scaffold training during the first few years in the orchard. The objectives of scaffold selection and training are to develop a series of well-spaced, properly positioned branches which can take advantage of high light exposure to produce and carry heavy crops of fruit. The first scaffold limb should be at least 18 inches (45 cm) from the ground to allow sufficient clearance for the movement of orchard equipment (fig. 12a). If mechanical harvesting is planned, the first scaffold should be 30 inches (75 cm) from the ground to provide access for the fruit-catching platform. In this case it is better to start scaffold development at this height initially, rather than to remove a major scaffold at a lower height later. Additional scaffold limbs should be separated along the trunk by at least 8 inches (20 cm) and should be well distributed around the trunk so that their development will not interfere with nearby scaffolds (fig. 12a, b). Development of a tier of properly positioned scaffolds as shown in figure 12 will normally require more than one year. With the young tree the temptation exists to select an entire tier of well-distributed branches within a short distance of each other on the trunk. Though this structure may appear satisfactory at that time, as the limbs grow and spread out, they encroach upon and shade one another. The enlargement of the scaffold branch bases can lead to the choking off of the central leader, resulting after several years in the development of an undesirable globular canopy (fig. 9).

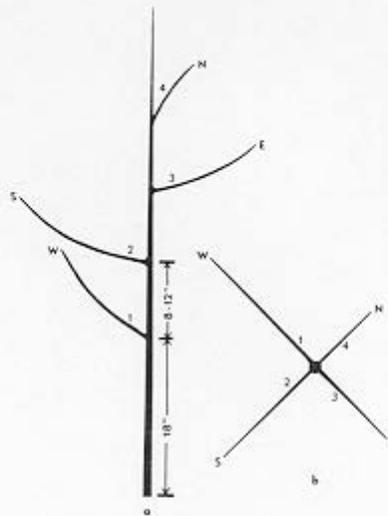


Figure 12. Principles of scaffold selection and training. (a) A tier of scaffold limbs should be well spaced along the trunk, with no more than one scaffold arising from any point on the trunk. The first scaffold should arise at least 18 inches (45 cm) from the ground. (b) The tree as viewed from above. Note the good distribution of scaffolds. Upper scaffolds must be kept smaller than lower scaffolds to maintain proper light exposure of lower scaffolds.

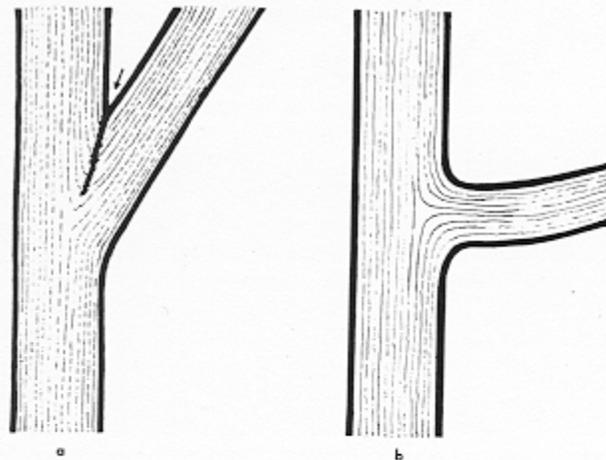
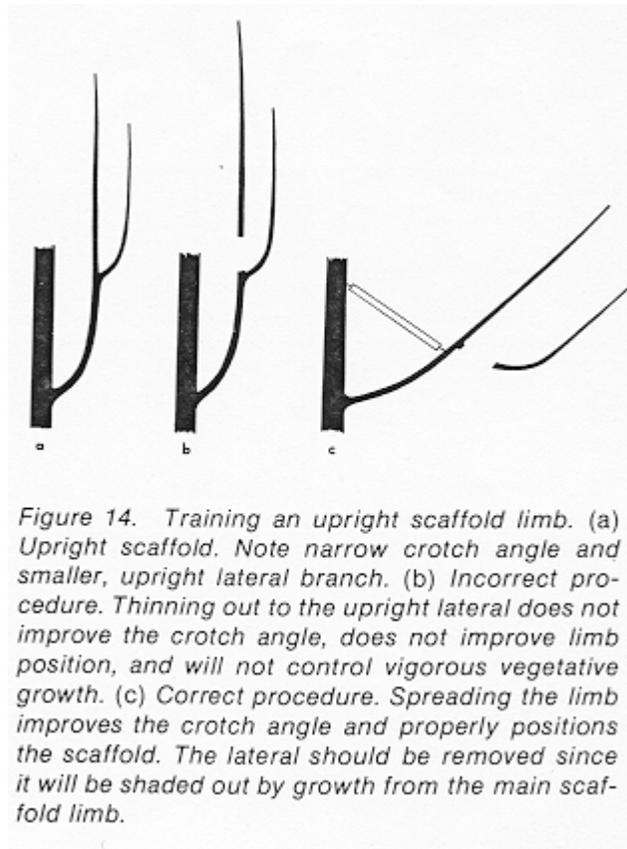


Figure 13. Structure of narrow and wide crotches. (a) Narrow crotch. Note the development of a bark inclusion (arrow) where bark of the trunk and branch have been pressed together. This structure weakens the crotch and serves as an entry point for decay organisms and pathogens. (b) Wide crotch. Annual rings of wood are deposited all around the junction of the scaffold and trunk, increasing crotch strength as the scaffold increases in size and fruit-bearing capacity.

For maximum strength and fruit-carrying capacity, a scaffold limb should develop with a wide crotch angle at the trunk (fig. 13b). A narrow crotch angle usually contains a bark inclusion (fig. 13a), which makes the crotch much weaker and is a potential site of decay and entry of pathogens. Some cultivars naturally develop wide crotch angles. Upright cultivars such as 'Delicious' will usually develop narrow crotch angles unless correctly handled. Widening narrow crotch angles must be started early; usually by 3-4 years of age, a limb is too stiff for the crotch angle to be influenced by any treatment.

The value of scaffold limb spreading cannot be overemphasized. Spreading positions the scaffold to take maximum advantage of light exposure along its entire length. Spreading the scaffold limb reduces the vigor of its vegetative growth and favors the development of flower buds. Reducing scaffold limb vigor favors the growth and dominance of the central leader. Spreading encourages branching along the length of the scaffold rather than near the terminal, as is the case with upright branches. Finally, spreading lower scaffolds allows upper scaffolds to develop without interference. Thinning out an upright branch to an outside lateral does not improve the original narrow crotch angle, nor will it result in an improved position for the scaffold (fig. 14a, b). The upright lateral will continue to grow vigorously and will interfere with scaffold development farther up on the trunk. Instead of the former approach, the limb should be spread (fig. 14c). In this case the lateral should be removed since its lower position would otherwise result in its being shaded out. Scaffold limbs should be spread to an angle of about 60° to the trunk, and care should be taken to avoid spreading scaffolds below the horizontal. This angle will give them sufficient flexibility so that subsequent heavy crops will not bend the scaffold below the horizontal. The results of proper scaffold training are greater strength, reduced vegetative vigor, increased flower formation, and proper positioning for further development.



## The supported tree

Trees that may be supported for a period of time but that are intended to be freestanding, as is often the case with trees on M.7 or M.26 rootstocks, should be trained in the same manner as freestanding trees. Training the wholly supported tree differs in some respects from that of the freestanding tree. Because the major support for the tree is provided by a trellis or pole, the need for a strong central leader is minimized. Scaffold selection is based more on distribution around the tree than on vertical spacing since these trees are usually small enough for no part of the canopy to be excessively shaded. The emphasis with supported trees should be on controlling growth and developing early, heavy fruit production by tying limbs to the trellis or spreading limbs, if necessary, and removing vigorous growth during winter pruning. These precautions are particularly important with vigorous, upright cultivars, which otherwise may remain vegetative and rapidly outgrow their allocated space.

Leader training for the supported tree should emphasize thinning-out cuts to modify the leader and reduce vigor in the top of the tree (figs. 15, 16). During the dormant period a thinning-out cut should be used to remove vigorous, upright growth. A weaker lateral is then tied up in the position of the leader and left intact (fig. 15). Since no heading-back cut is made, the growth from this weaker leader shoot will be less vigorous but will prevent the development of vigorous watersprouts from below. Scaffolds are not spaced along the trunk as for the freestanding tree but are selected primarily for their distribution around the trunk. Because the modified leader practices utilized in training supported trees result in weaker leader growth, careful attention

must be paid to scaffold limb spreading where needed to control vigor lower in the tree. This is especially important with vigorous or upright cultivars not adapted to these planting systems. Heading-back cuts which could result in invigoration of vegetative growth should be avoided at all costs. Development of early, heavy fruiting is vital if growth is to be checked and final tree size maintained within bounds.

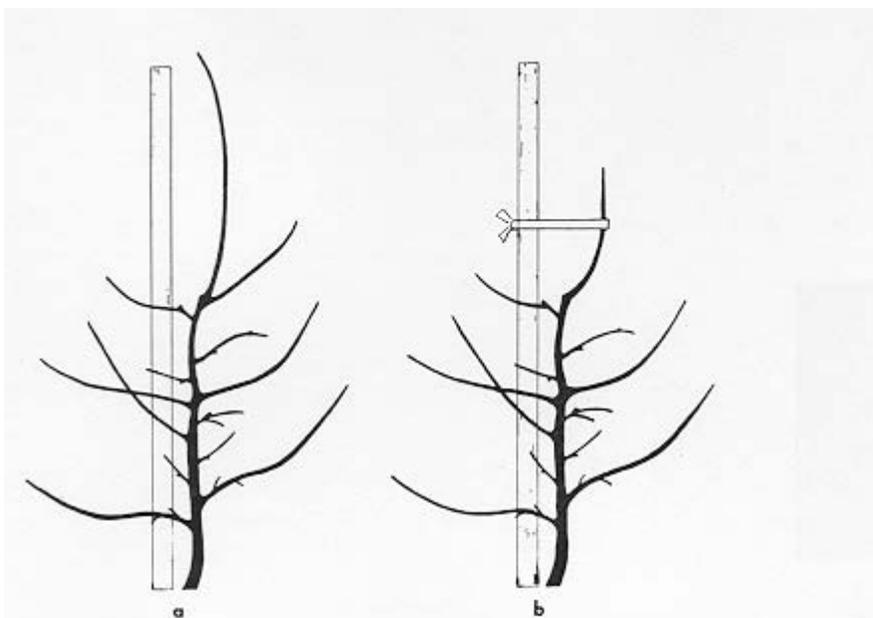


Figure 15. Leader training and scaffold selection in the spindle-bush tree. The objective is to control vigor by weakening, but not eliminating, the leader and developing rapid, heavy fruiting on scaffolds. (a) Vigorous growth is removed by thinning out to a weaker lateral. (b) This lateral is tied up into the position of the leader and left intact. Heading-back cuts are avoided. Scaffolds are selected primarily for their orientation around the trunk. Vigorous scaffold limbs should be spread or removed.

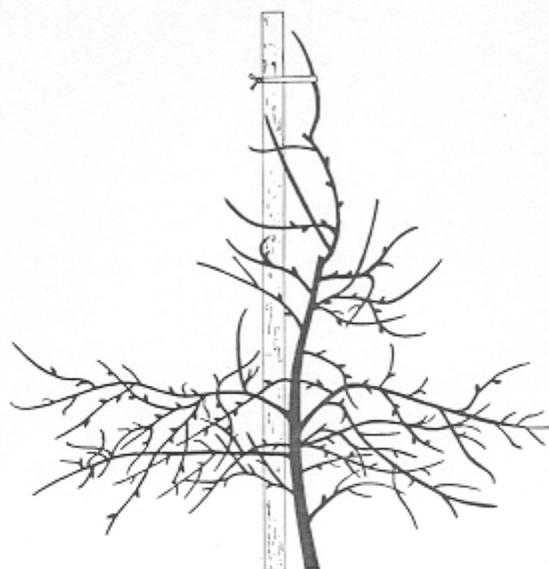


Figure 16. Mature spindle-bush tree. Note repeated modification of the leader to control vigor in the top of the tree and horizontal position of scaffolds.

## **Other practices**

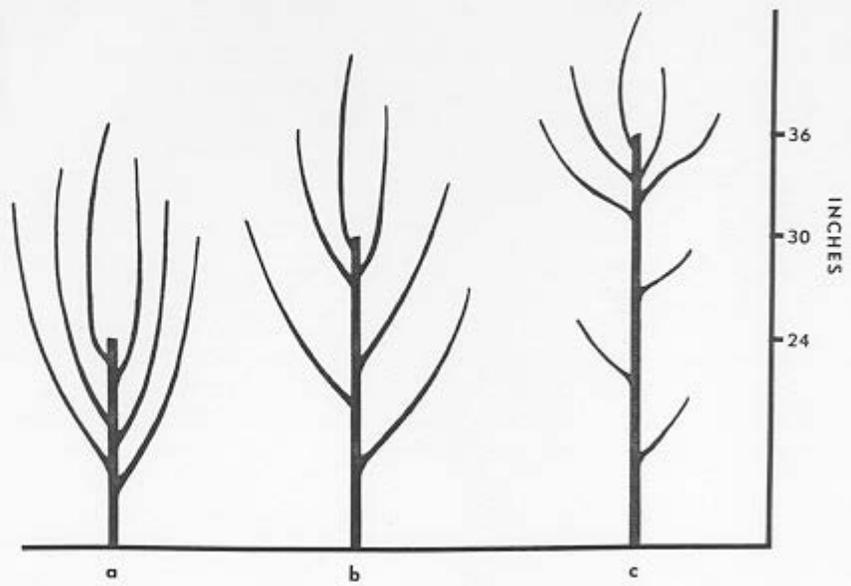
Summer pruning on young trees should be limited primarily to central-leader training and tipping undesirable shoots in midsummer to restrict their growth. If vigorous watersprouts have begun to grow, they can be removed at this time. Generally, summer tipping should be delayed until after mid-July to minimize the tendency for regrowth to develop. If young trees remain excessively vigorous for several years with little indication of developing fruitfulness, a spray of Alar and ethephon can be used to induce flower-bud formation. For most cultivars a spray of 1000 ppm Alar and 300 ppm ethephon applied 2 to 3 weeks after full bloom will provide some vegetative growth control and will induce flower buds for the following year. For very vigorous

trees or cultivars such as 'Delicious', the Alar concentration should be increased to 1500 to 2000 ppm. Though this treatment may result in some decrease in fruit size the following year, it is the number of fruits per tree, and not their size, which has the primary influence on tree growth. Normally, this treatment would not be repeated the following year since ethephon at this concentration and timing would thin off most or all of the fruit.

## **Training and pruning the young tree**

At planting time the young tree should be headed back to stimulate branch development (fig. 17). If well-developed 1-year whips are planted, they should be headed at about 30 inches (75 cm) from the ground unless mechanical harvesting is planned. In this case the trees should be headed at around 36 inches (90 cm) to allow for the development of suitably located scaffold limbs. Low heading results in excessive growth from the remaining buds (fig. 17a) whereas heading back much higher leads to the development of a whorl of weaker shoots near the cut, with little growth lower on the trunk (fig. 17c). If older, feathered trees are planted, they should be headed back to a strong spur or bud to stimulate vegetative growth and bring the shoot-root ratio more nearly into balance. Feathers not to be retained as scaffolds should be removed, and long feathers headed back at planting.

Figure 17. Heading back young trees at planting. (a) Heading back too low. Note excessive growth from all growing points. (b) Correct height. Note vigorous development of the central leader and good growth from shoots in the zone where the first scaffolds will be selected. (c) Heading back too high. Note whorl of weak growth at the top and poor growth farther down on the trunk.



During the first growing season leader selection should be made in early summer (fig. 11). All shoots developing below 18 inches (45 cm) or below the first permanent scaffold should be removed in midsummer. This procedure reduces the dormant pruning workload the following winter and encourages growth of scaffold shoots. Any shoots with narrow crotch angles that are to be retained can be spread at this time with hardwood toothpicks or short wire spreaders to develop wide crotch angles. Dormant pruning the first year should be limited to the removal of vigorous shoots that are not to become scaffolds and heading back the leader if this seems desirable. If an upper scaffold is much more vigorous than one below, it can be headed back to reduce its size. In general, heading back scaffold limbs does not result in improved growth and should be avoided.

Early in the second growing season scaffold limb spreading can be started. It is easier to spread scaffolds after bud-break since the wood becomes more flexible, reducing the risk of limb breakage. Spreading should be carried out as early as possible to derive maximum benefit from the altered growth responses of spreading limbs. Summer pruning of shoots competing with the leader should be continued, and any fruit forming on the leader removed. Shoots developing from the lower portion of the previous season's leader shoot can be selected to complete the first tier of scaffolds, and their initial training begun. Undesirable watersprouts or shoots developing with narrow crotch angles can be pinched out while succulent or pruned out later, in midsummer.

Training and pruning during succeeding years should continue the processes of central-leader development and scaffold selection and training. Often a scaffold that is spread while young will resume vertical growth. It should be respread the following season to maintain its proper development and avoid its encroaching on new scaffolds above. To maintain the correct conic tree shape, lower scaffolds should be larger and extend further from the trunk than the next scaffold above. If upper scaffolds are allowed to become too large, bearing wood on lower scaffolds will be lost, and the canopy will assume a globular, or umbrella-like, shape. Starting in

the third year some thinningout cuts may be necessary to control scaffold growth and development and maintain the desired tree shape. During the period of tree training, pruning should be minimal. As tree development proceeds, unnecessary branches which may have been retained can be removed. After the basic framework of the tree is established and fruit production has begun, the pruning program should be gradually changed to the maintenance of good light exposure and control of vigor throughout the tree.

## **Pruning Bearing Trees**

Since pruning both affects and is affected by tree vigor, careful attention to other cultural practices is absolutely essential for a successful pruning program. Fertilizer must be regulated to support consistent, moderate vegetative growth. Since crop load markedly affects vigor, uniform, annual production must be encouraged by judicious fruit thinning. On susceptible sites, frost control practices should be employed to avoid the disastrous invigoration of a complete crop loss. The pesticide program should maintain a healthy, functional leaf surface throughout the growing season. Where vigor remains too high in spite of conscientious efforts to reduce it, the cultural program should be supplemented with early-season applications of Alar.

### **When to prune**

Most of the pruning of bearing trees is done during the dormant period. In some cases, trees are pruned during the growing season, but summer pruning is generally reserved for special problems and will be considered separately. In the following discussion, unless specifically stated otherwise, all comments will refer to dormant pruning.

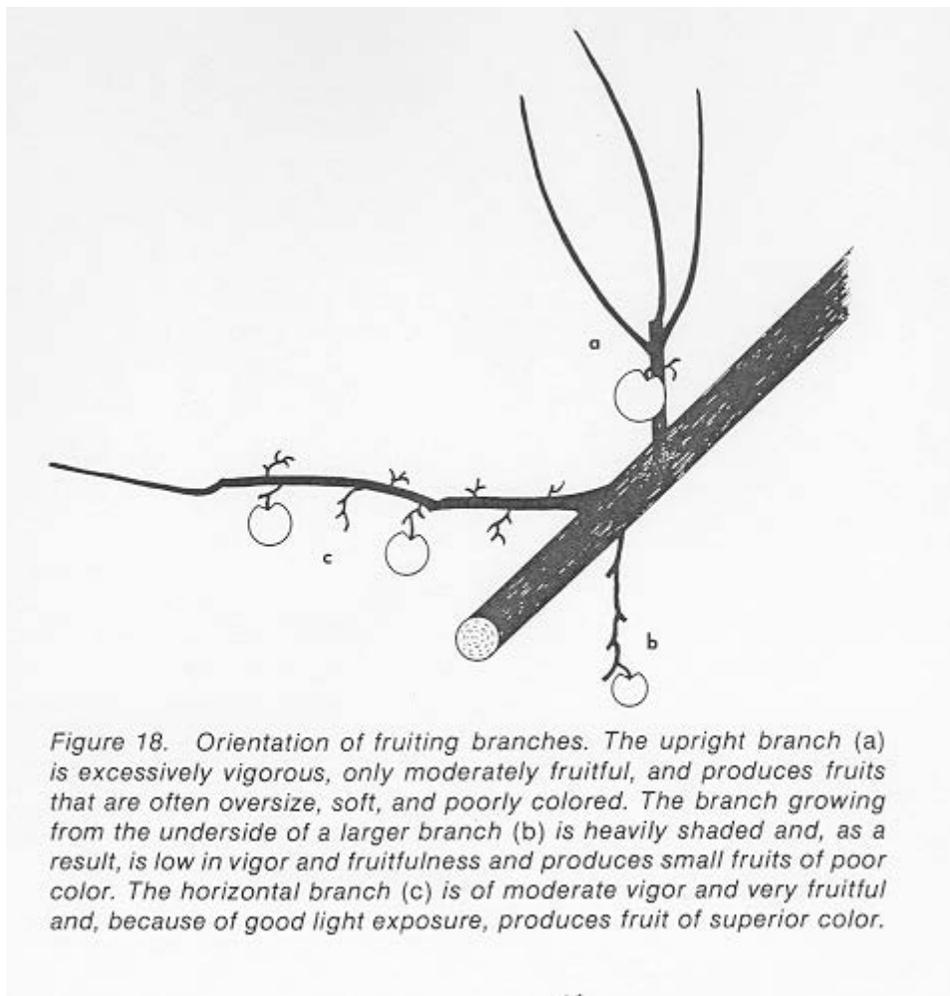
The trees can be pruned at any time during the winter months, but in the Northeast it is best to delay pruning until midwinter. Earlier pruning, before maximum hardiness has developed, greatly increases susceptibility to low temperature injury. This is particularly important if large cuts are required. Low-temperature injury at pruning cuts is often the forerunner of various cankers and wood rot diseases. Sometimes unfavorable weather significantly delays pruning, and growth starts before it is completed. In general, bearing trees in good vigor will not be adversely affected by late pruning if it is completed before bloom, but later pruning will reduce vigor. In orchards with a black rot problem, pruning after growth starts may increase the spread of this disease. With late pruning, the brush on the orchard floor may interfere with other late winter and early spring operations such as fertilization and the application of the first pesticide sprays. Differences in weather might permit earlier or later pruning in some years, but in general, most of the pruning of bearing trees in New York State should be confined to the months of January through March.

### **How to prune**

The pruning program should be planned well in advance of the actual work. Observations during the previous growing season should indicate where changes in the pruning program are required. Failure to satisfactorily control insects or diseases may indicate that the trees are too high or too thick for good spray coverage. Poor fruit color may be due to shading or excessive vigor. Low vigor may be responsible for undersize fruit, whereas oversize fruit may be associated with high

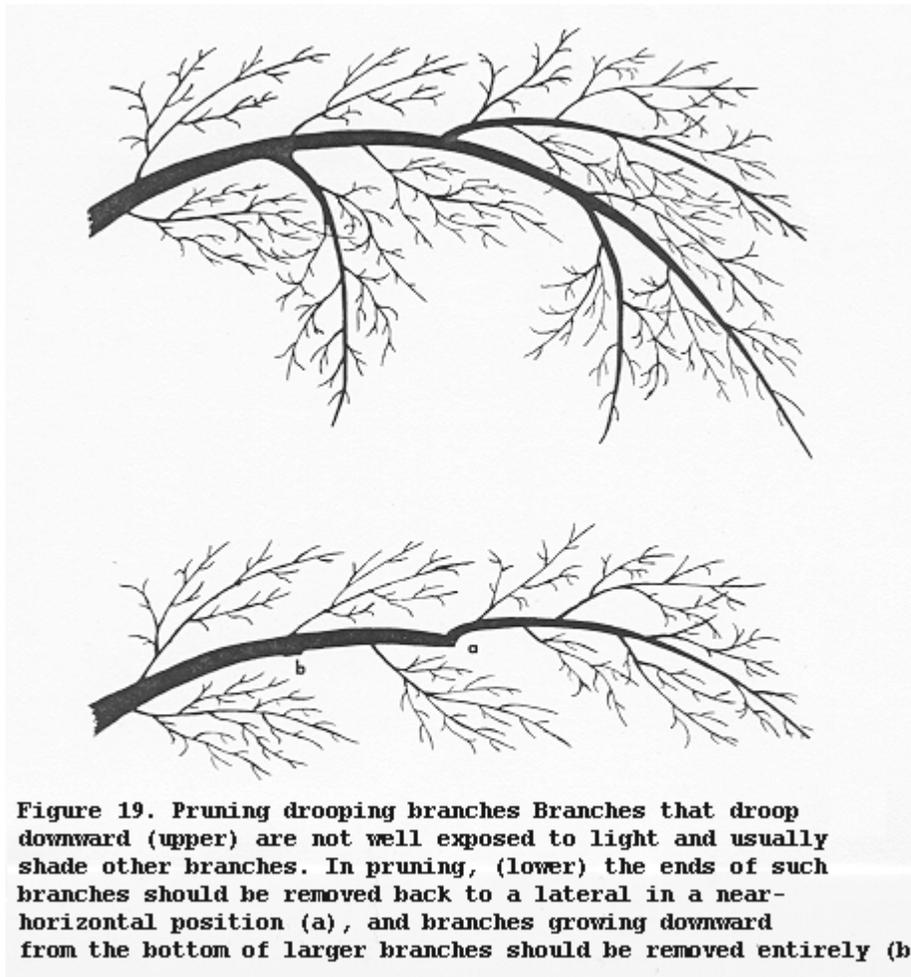
vigor which is often a response to over pruning. Trees that are too tall or too thick may provoke harvesting problems. Uneven responses to growth regulators, such as thinning chemicals and Alar, may indicate unacceptable differences in vigor between the top and the bottom of the tree. All of these are symptoms of unsatisfactory pruning and suggest that adjustments are required in the type and/or amount of pruning.

Ideally, vigor should be uniform throughout the tree, but this is seldom the case. In most trees, there are three different states of vigor as summarized in figure 18. The upright growth (a), which is often characteristic of the top of the tree, is excessively vigorous, only moderately fruitful; the fruits that develop are often oversize, soft, inadequately colored, and are subject to limb rubs. The branches that hang down (b) are low in vigor and are typical of heavily shaded wood. These branches are unfruitful, and the fruit that does develop on them is small and poorly colored. The horizontal branches (c) are moderately vigorous and very fruitful. The fruits are well exposed to light and are of good size and color. Because the fruits hang freely, they are not subject to limb rub. Since all three conditions are common in most trees, pruning cannot be uniform throughout the tree. Most of the time, pruning cuts that invigorate are to be avoided in the vigorous tops of the trees and are to be encouraged on the less vigorous lower branches and the interior of the tree.



*Figure 18. Orientation of fruiting branches. The upright branch (a) is excessively vigorous, only moderately fruitful, and produces fruits that are often oversize, soft, and poorly colored. The branch growing from the underside of a larger branch (b) is heavily shaded and, as a result, is low in vigor and fruitfulness and produces small fruits of poor color. The horizontal branch (c) is of moderate vigor and very fruitful and, because of good light exposure, produces fruit of superior color.*

The secret to uniform vigor throughout the tree is uniform light exposure of all the bearing wood. The importance of the conic shape has been previously emphasized. Even though this shape may be fairly easy to establish in the young tree, it is sometimes difficult to maintain in the mature tree. The branches of adjacent trees should not be permitted to overlap because this leads to heavy shading. In freestanding trees, the height of the tree should not exceed the spread of the branches. Once this height is attained, considerable effort is required to restrict the top of the tree so that it does not shade the lower branches without further invigorating the top. In this respect, two points are of paramount importance. First of all, the removal of one large branch is less invigorating than the removal of several small branches. It is therefore more effective to remove entire branches or major parts of branches back to strong, fruitful laterals than to do extensive detailed pruning in the vigorous tops of trees. Older branches of many cultivars, such as 'Delicious', tend to become droopy, and the size of the branch (and the shade it casts) can be significantly reduced by removing the ends of such branches as illustrated in figure 19. In some cases, it may be necessary to practice a regular program of branch renewal. In this approach, the terminal segments of the upper branches are regularly removed, and a strong lateral is trained to occupy the desired space. In anticipation of the removal of a branch, a lateral branch or a vigorous shoot or watersprout can sometimes be tied in the approximate position it is to assume a year or two before the terminal segment of the branch is removed. All too often, it is difficult for a grower schooled in the philosophy of open-center trees to make the cuts in the top of the tree that are necessary to insure adequate light exposure of the lower branches. It may seem that the most productive wood is being sacrificed. Though it is true that potential production is being removed, the productivity of a larger area on the lower branches is being maintained. Since the fruit on the lower branches is the easiest to care for and to harvest, this is the more important consideration.



The second factor to be considered is the response to heading back cuts in 1-year-old wood (fig. 4). Such cuts stimulate vegetative growth and are, therefore, to be avoided in the tops of most trees. The emphasis should be on the remove/ of the most vigorous wood and the retention, without heading back, of less vigorous wood (fig. 20). Excessively vigorous, upright shoots should be headed back only if the cut can be made at a wide-angled lateral of moderate vigor; otherwise, they should be removed entirely. The only exception would be in those rare cases where removal of all excessively vigorous upright shoots would leave a large area of a branch (more than 1 ½ linear feet) without any growing points. This might leave the branch vulnerable to sunscald. A single watersprout or shoot headed back to 4-6 buds should provide adequate protection.

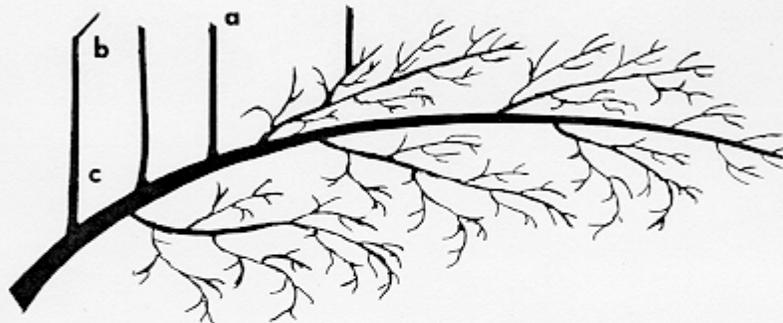
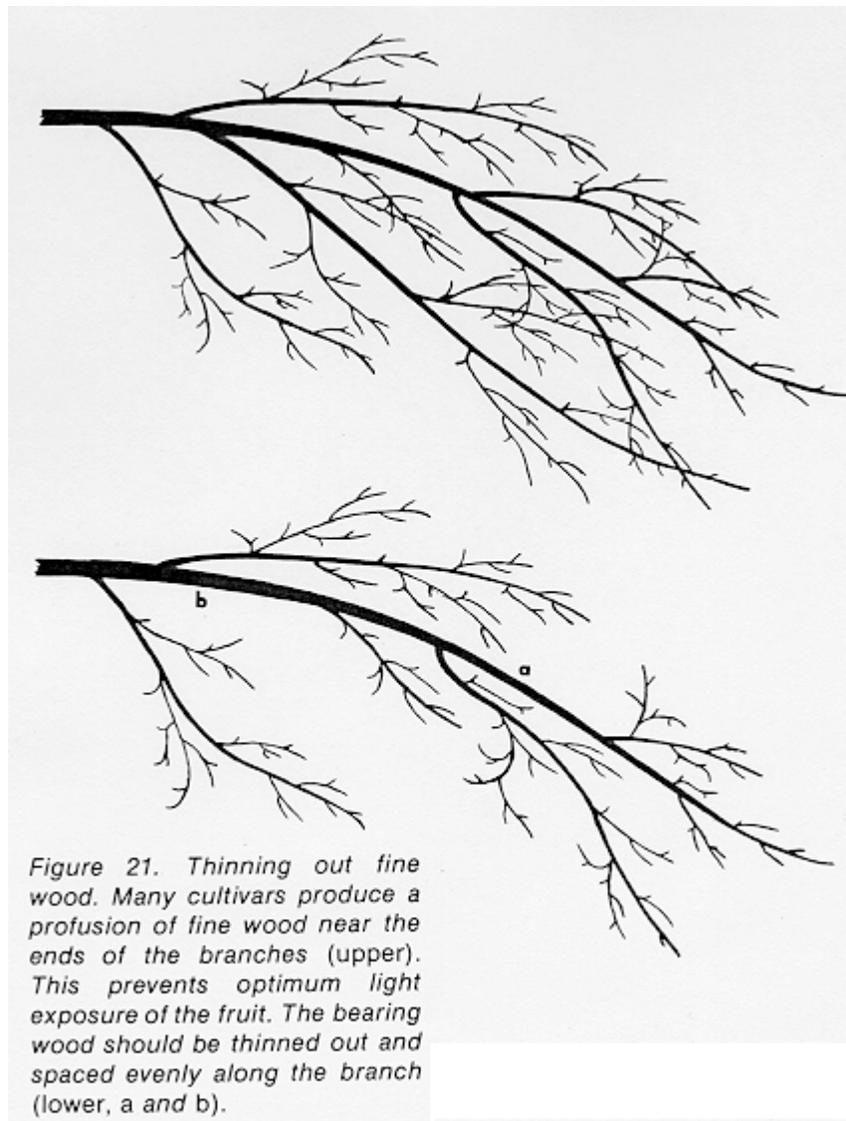


Figure 20. Pruning vigorous, upright growth. Trees in high vigor often produce numerous watersprouts and vigorous upright shoots (upper). In this situation, the emphasis in pruning should be on the elimination of excessively vigorous wood and the retention of wood of moderate vigor. Improper pruning (center) includes heading back all upright growth (a), heading a vigorous shoot to a very small, weak lateral or spur (b), and removal of all fine wood (c). These pruning cuts stimulate further vegetative growth. Proper pruning (lower) requires thinning out of some upright growth (d), complete removal of a vigorous shoot developing from fruiting wood (e), heading back a vigorous watersprout to a horizontal branch of moderate vigor (f), and removing an excessively vigorous shoot and leaving one of moderate vigor (g). This type of pruning favors fruitfulness.

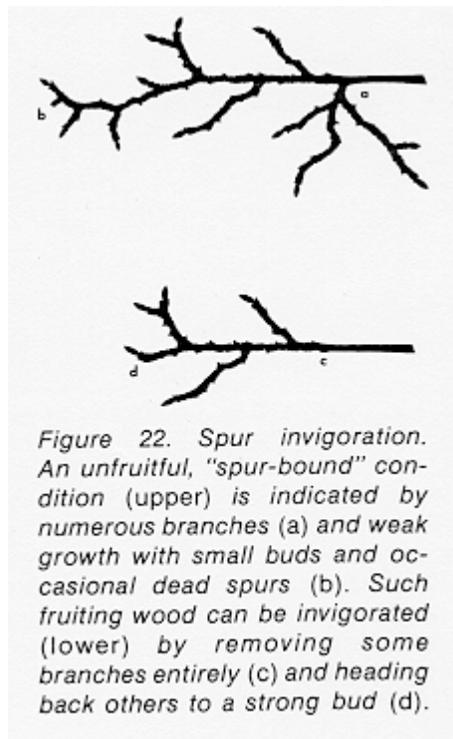
In the lower part of the tree, where vigor may be inadequate, detailed pruning is most desirable because this is more invigorating than large cuts. Headingback cuts in 1-year-old wood (fig. 3) are appropriate in these circumstances. Some cultivars, particularly 'Cortland' and 'Rome Beauty', produce a profusion of fine wood, and this should be systematically thinned out (fig. 21). Older spurs that have branched repeatedly often become weak and unproductive, and these should be invigorated by thinning-out and heading-back cuts as illustrated in figure 22. Some such spurs, particularly those that droop and hang under the main part of the branch, should be removed entirely.



In parts of the tree where vigor is moderate and productivity and light exposure are satisfactory, both invigorating cuts (thinning out and spur renewal) and the removal of upright growth may be necessary; the most appropriate pruning is usually a combination of the two extremes.

The actual pruning should proceed according to a regular routine. It is best done in three steps as follows: the large cuts are made first, undesirable smaller branches and shoots are removed next, and detailed pruning completes the job.

Larger cuts can be made to remove broken branches, to thin out or to restrict the top to minimize shading of the lower branches (fig. 19), or to prevent the lower branches of adjacent trees from overlapping. The latter problem is all too prevalent because many density orchards have been planted too close for the rootstock-cultivar-soil combination, and the trees begin to encroach on each other's territory at an early age. Where this problem exists, repeated, small heading-back cuts only stimulate vegetative growth and promote unfruitfulness. The most effective approach is to remove the offending branches entirely or to head them back to a strong lateral that can be trained to fill that area (fig. 23). A regular program of branch renewal may be necessary in extreme cases.



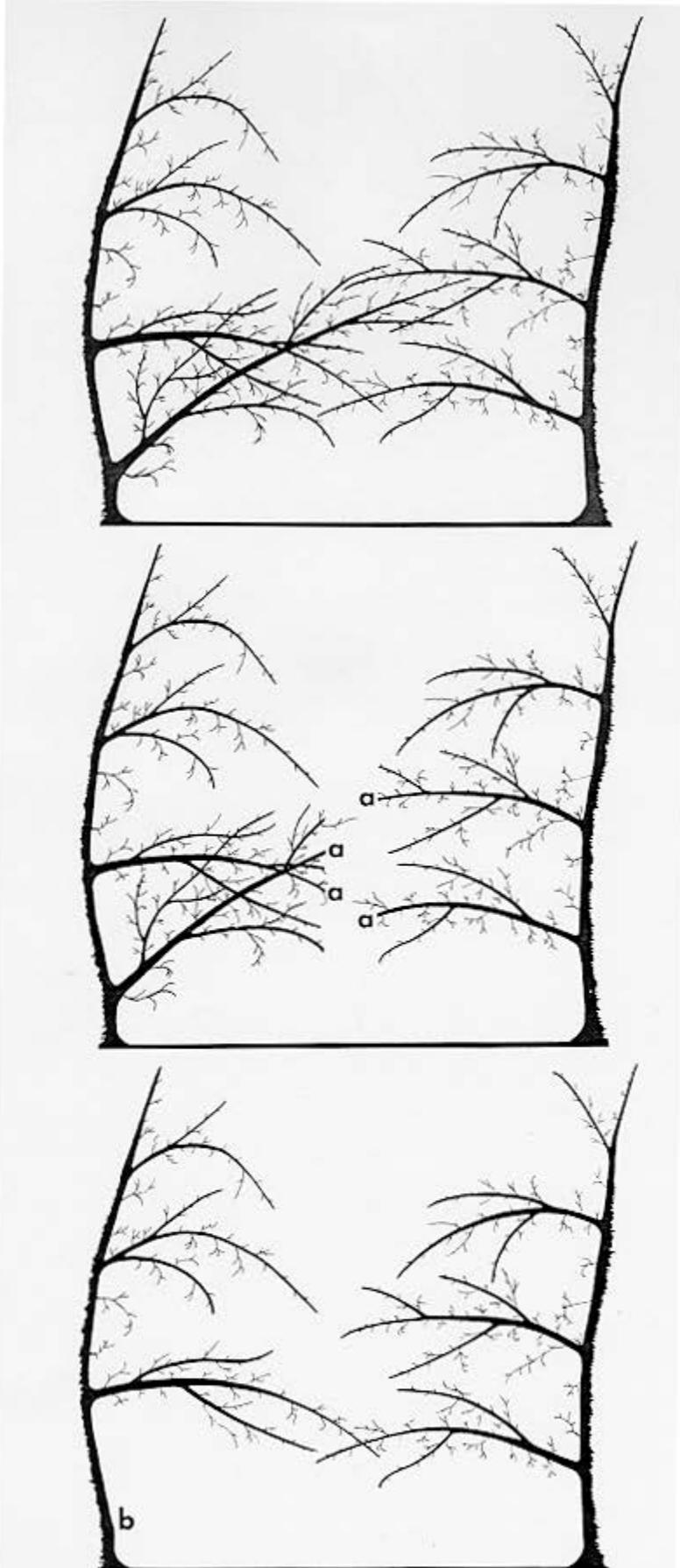


Figure 23. Overlapping branches of adjacent trees. Top: typical crowding in the row in higher density plantings. Center: incorrect pruning. The numerous heading-back cuts (a) will stimulate undesirable

In the second step, unproductive wood is removed. This includes both excessively vigorous wood, such as watersprouts and upright shoots (fig. 20), and weak branches that hang down and are always in shade (fig. 19).

The remaining wood is the effective bearing surface, and the detailed pruning is done to maintain optimum vigor, uniformly space the bearing wood along the branches, and maximize light exposure of the fruit. This pruning involves both thinning-out cuts and spur invigoration. (figs. 21 and 22). It must be emphasized, however, that if such wood has been shaded, a completely satisfactory response is possible only if light exposure is also improved.

In all pruning involving the removal of watersprouts, shoots, or branches, the cuts should be smooth and flush with the branch or trunk. Stubs or snags heal slowly, die back, and serve as points of entry for wood rot diseases. It is sometimes advantageous to apply a wound dressing, such as an asphalt emulsion, to large cuts.

In trees in good vigor, a cluster of very vigorous watersprouts usually develops around large pruning cuts. These watersprouts produce heavy shade, compete strongly with the developing fruits, and have little productive potential. Where numerous large cuts are made, watersprout growth greatly complicates pruning the following year. This undesirable growth can be controlled by treating the pruning cuts with Naphthaleneacetic acid (NAA) 1% in latex paint. The NAA-paint mixture can be applied any time after a pruning cut is made, but before growth starts in the spring. It is important to thoroughly coat the cut edges of the bark around the pruning cut as well as the exposed wood.

The reward for careful attention to all the details of training and pruning is small, compact, efficient, productive trees that are easy to manage (fig. 24). A major investment in time and money is not required to correct mistakes of the past. The penalty for neglect is large, inefficient, unmanageable trees such as the tree illustrated in figure 25. In density plantings, untrained trees do not develop the characteristic globular shape because the crowding "shades out" the lower branches. The result is often a conic shape but, unfortunately, an inverted one. This structure is completely incompatible with the concept of density plantings.

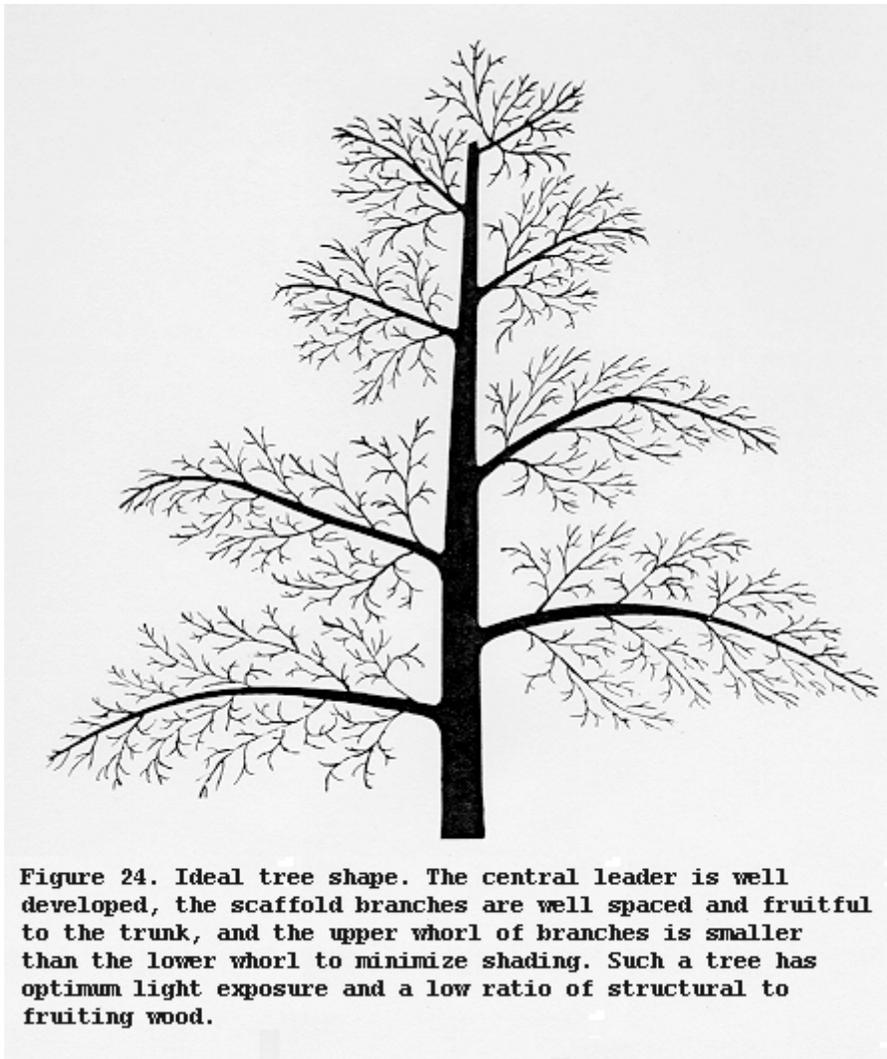


Figure 24. Ideal tree shape. The central leader is well developed, the scaffold branches are well spaced and fruitful to the trunk, and the upper whorl of branches is smaller than the lower whorl to minimize shading. Such a tree has optimum light exposure and a low ratio of structural to fruiting wood.



Figure 25. The results of improper training and pruning. In high-density plantings, neglect will invariably produce a tree with poor light exposure, a high ratio of structural to fruiting wood, little fruiting wood in the lower part of the tree, and most of the bearing wood upright rather than horizontal.

## Summer pruning

All pruning is dwarfing, but summer pruning reduces growth much more than equivalent pruning during the dormant period. The removal of active leaf surface during the growing season reduces the late-season accumulation of assimilates in the woody tissues. This lower level of reserves is reflected in reduced vigor the following season. Properly used, summer pruning can be an effective supplement to other cultural practices in controlling vigor. Summer pruning can also significantly improve fruit color in trees that are too vegetative.



*Figure 26. Summer pruning. Top: section of the top of a typical vigorous tree. Note the upright growth and the shading of the fruits. Bottom: proper summer pruning. The vigorous watersprouts have been removed (a); the current season's growth has been removed from the upright branches (b); the undesirable upright, but fruiting branch has been headed back just above the cluster of fruit (c) and will be removed in the dormant pruning; and the upturned branch has been headed back to a weak lateral (d).*

Obviously, trees in low vigor should not be summer pruned. This approach is reserved for trees in good to high vigor and, even here, should be practiced in moderation. The objective should be the removal of undesirable, excessively vigorous, upright growth, with the emphasis on the tops of the trees where most of this type of growth occurs. Pruning should be limited to removal of the current season's growth (fig. 26). Regular removal of 2 and 3-year-old wood will quickly result in a substantial reduction in bearing surface. Pruning in early summer may stimulate undesirable vegetative regrowth and significantly reduce flowering for the succeeding crop. The recommended time for summer pruning is August. This is the most effective time for vigor control, and it is late enough to avoid regrowth and reduced flowering. At the same time, summer pruning in August is early enough to provide a good fruit color response to the removal of heavily shading, vigorous "weed growth" from the tops of the trees.

## **Mechanical pruning**

Several types of hedging and topping machines have been used in apple orchards with varying degrees of success. Their effectiveness depends on the type of machine, the size and structure of the trees, the hedging approach, and the pruning skill of the grower.

There is one basic objection to mechanical pruning--the lack of selectivity. The indiscriminate cuts stimulate vegetative growth where invigoration is unnecessary and undesirable, and objectionable stubs are left throughout the tree. Such an approach cannot replace hand pruning entirely, and some detailed work is always necessary to complete the job. Failure to do this results in the rapid development of an almost impenetrable canopy of unfruitful "crow's nests" and "witch's brooms". Where hedging is combined with appropriate hand pruning, the cost of pruning can be significantly reduced. However, the degree of success can be limited by other factors.

The size and structure of the trees are important considerations. Hedging, like many other orchard practices, is most efficient with small, central-leader trees with horizontal branches. As tree size increases, a progressively smaller percentage of the total pruning can be done by hedging. The hedging cuts induce more undesirable vegetative growth on the typically upright branches of open-center trees than on the more horizontal branches of central-leader trees.

Hedging and topping machines vary from simple mowing-machine cutter bars on a fork lift to large, self-propelled rotary-saw machines which can cut branches several inches in diameter. The most effective hedging is accomplished with the more maneuverable cutter bar. This limits the size of the cut that can be made and confines hedging to the removal of relatively young wood. The tendency with the larger machines is to severely head back the tops and sides of the trees. If the tree is trained to an open center, and most older trees are, this removes a large percentage of the bearing surface and stimulates a tremendous flush of vegetative growth.

In some cases, hedgers are used to make a flat topping cut. This represents the least effective use of the machine. The inevitable result is an unmanageable proliferation of unfruitful vegetative growth which spreads the top of the tree and creates a dense canopy, heavily shading the bottom of the tree. The emphasis in hedging should, instead, be on side cuts with the objective of developing and maintaining the correct conic shape.

The above factors all influence the response to mechanical pruning, but the pruning acumen of the grower determines the success or failure of this approach. Though it is possible to reduce pruning costs by mechanization, hedging is not for everyone. Hedging will not solve the problems of the inept pruner but rather will create other and more serious problems. As is often the case, the most talented pruner, and the one who needs help the least, will benefit the most from hedging.

The most effective use of the hedger has been with trees that are just approaching the desired optimum size. If the trees have been properly trained to this point, the combination of careful hedging and supplemental hand pruning can greatly facilitate the establishment and maintenance of the ideal shape. This generally requires 3-4 years; after that, hedging is of rather limited usefulness.

### **Renovating old trees**

In some cases it may seem desirable to attempt to reduce the size and improve the structure of trees that are large and old but otherwise in good condition. Though all the advantages of a density planting are obviously not possible, reducing the size of such trees should provide some of the benefits, such as easier management and harvesting and improved fruit quality. Very rarely are the results completely satisfactory. To be at all effective, such trees must be severely topped and headed back on the sides, with removal of an inordinate amount of the total bearing surface. This approach sacrifices the most vigorous and most productive part of the tree and retains the weaker spurs which were previously heavily shaded. The inevitable result is a substantial reduction in yield. Generally, the vegetative response to this severe heading back is also unsatisfactory. Successful renovation of large trees and their continued maintenance at a smaller size require the generation of new bearing wood in the area that was formerly the unproductive interior of the tree. This happens only to a limited extent. In open-center trees, the scaffold branches are more upright than horizontal. When upright branches are severely headed back, the usual response is a flush of very vigorous watersprout growth from the vicinity of the pruning cut and limited new lateral growth from the rest of the branch. The vigorous watersprout growth adversely affects fruit quality through shading and competition for the products of the leaves. This vegetative growth tends to be unfruitful and quickly becomes a special pruning problem. Frequently a dense, impenetrable canopy develops; it is unfruitful and shades so heavily that new bearing wood does not develop in the interior of the tree. Reductions in yield following the initial heading back are rarely regained, the management of the trees is not measurably easier, and the quality of the fruit is not improved. In addition to these disappointments, severe topping of large trees often increases the incidence and severity of sunscald, black rot, low-temperature injury, and associated disorders that lead to the early demise of the trees.

Though it is possible, within rather narrow limits, to reduce the size and improve the structure of some old trees, successful renovation requires exceptional pruning skill, extraordinary patience, and time--usually 3 to 5 years. In few cases will it be worth the effort because a producing tree can be grown as quickly. The most practical approach for the majority of old trees is to restrict pruning to the minimum consistent with normal orchard operations and the desired fruit quality and to plan for early replacement.

## Economics of Pruning

Pruning represents a major part of the cost of producing apples. Cost studies for eastern New York (Forshey 1972, 1973, 1974; Forshey and Lawrence 1975; Lawrence 1976, 1977, 1978; and Gerling 1980) indicate that pruning accounts for approximately 50 percent of all labor costs and from 10 to 15 percent of total growing costs. In most of the years included in these studies, the cost per bushel of fruit harvested was just under 20 cents.

The costs cited above are averages of several farms, each of which has blocks of trees of varying ages and densities. As the larger, older trees, with their myriad pruning problems, are gradually phased out, and the younger, higher density plantings come into production, a significant change in pruning costs is anticipated. Though the higher-density plantings require more intensive management, smaller trees greatly increase pruning efficiency. Markedly reducing or eliminating the need to climb dramatically increases pruning productivity. When greater pruning efficiency is combined with the anticipated higher yields of density plantings, a significant reduction in the cost per bushel should be realized. Progressive growers can measure their efficiency by comparing per bushel pruning costs with the given averages. Declining pruning costs would be indicative of efficient management of the density plantings.

Some growers object to current pruning costs and, in an effort to save money, seriously neglect this important area of the cultural program. Omission of pruning is a ready source of substantial savings because it represents a large part-of the total cost and is an out-of-pocket expense. Unlike omissions in the pest control program, failure to prune does not carry the risk of rendering the crop immediately unsalable. The effects of inadequate pruning are slow to develop and are often rather subtle in expression. Unfortunately, they are likely to be long lasting. Usually the first problem to develop when pruning is omitted is a decline in fruit quality which can only prolong the economic problem responsible for the initial lack of funds for pruning. After a year or two of neglect, pruning will cost significantly more, and the response is likely to be less satisfactory. In these situations an attempt is usually made to compensate for the years of neglect by heavier pruning. This will reduce the crop and stimulate unnecessary vegetative growth which may adversely affect fruit quality and seriously complicate future pruning. Three or four years may be required to restore productivity and fruit quality and to bring vigor under control. Once an acceptable relationship is established between vegetative and fruitful growth, regular, annual, consistent pruning is required to maintain this delicate balance; the cost of this pruning must be considered as an essential part of the production budget.

Pruning is a basic pomological practice that affects the response to other cultural practices. At the same time, other practices affect pruning requirements and responses. Efficient orchard management is not a collection of individual cultural practices but an integrated program of related practices. Recommendations for other cultural practices are based on the assumption that the trees are properly pruned, and failure to prune may limit the response. Pruning is the catalyst that makes other cultural practices work.

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