storage. Sundance is moderately resistant to powdery mildew and highly resistant to cedar apple rust and fire blight. Full details on the cultivar can be viewed in *HortScience* volume 39 number 2.

Topaz was developed in the Czech Republic from a cross between the Czech apple cultivars Vanda and Rubin. Topaz is a medium to medium-large apple. The skin color is yellow overlain with a red and crimson flush. The flesh is crisp and cream colored. The trees are moderately vigorous and very precocious. Trees are resistant to apple scab and moderately resistant to powdery mildew. Fruit matures about 1 week after Golden Delicious.

Williams Pride was released in 1988, one of the earliest-ripening cultivars released. Matures approximately 1 week after Lodi; in our plantings has matured around the middle of August. The dark red fruits are large with a semitart flavor that is very good. May have uneven ripening requiring multiple pickings. Growth observations indicate that the tree is very willowy. Suggested for homeowner use and roadside markets. Shows a strong tendency toward bitter pit.

The Future of Scab-Resistant Cultivars

Many more cultivars are being developed and tested in Europe. The Czech Republic, Italy, France, and Latvia all have active breeding and testing programs. The limitations to obtaining these cultivars is the inability to import new plant materials without going through a lengthy screening process. The other limitation to the wide adoption of scab-resistant cultivars is that most of the cultivars only carry the Vf gene for resistance. Establishing solid plantings of Vf-resistant cultivars may cause a breakdown in resistance of scab protection. In Switzerland where they have been growing scab-resistant cultivars, it is recommended that even if the cultivar is scab resistant a minimum number of sulfur sprays be applied each year to prevent the buildup of apple scab populations that can overcome the Vf resistance.

The Basics of Pruning

Fruit growers are constantly manipulating tree canopies to maximize fruit production. This is done in two ways: by pruning to remove limbs or shoots or by bending limbs or shoots in specific orientations. Pruning and training are therefore horticultural manipulations done to modify naturally occurring growth patterns within plants. The primary processes being modified are apical dominance (see below) and the natural flowering and/or fruiting characteristics of the trees.

The first point to remember is that pruning is a dwarfing process. A pruned tree will always be smaller than a same-aged tree that was not pruned. For pruning to be effective, however, it must be practiced with an understanding of how trees respond to branch or shoot removal and of how those removals affect future tree growth.

The second point to remember is that training affects primarily tree form, while pruning affects mainly function. Training determines the general character and even the details of the plant's outline and its branching and framework. Pruning is meant to determine how and when the tree will fruit. Therefore, training and pruning are two different aspects of modifying naturally occurring growth patterns. Training involves tree development and form, whereas pruning involves tree function and size.

Training takes place in the first 4-5 years of the tree's life. Pruning is conducted for the entire life of the tree. In a tree's early productive years, the goal of pruning is to contain excessive vigor. During declining years, pruning's emphasis shifts to promoting vigor and allowing maximum sunlight to penetrate the tree canopy.

Types of pruning cuts

Regardless of the kind of fruit tree (or, for that matter, kind of plant), only two types of pruning cuts are made: heading back cuts and thinning out cuts. Every other cut you may hear discussed is a variation of these two. A heading back cut is the partial removal of a shoot, limb, or branch. In orchards this may range from the tipping of leaders or branches to the use of mechanical hedging machines. A thinning out cut is the removal of an entire shoot, limb, or branch at its point of origin. In orchards this can include the removal of a primary or secondary scaffold limb, removal of a spur system, or desuckering interior water sprouts arising from horizontal limbs.

Impact of flower position

The difference in how a tree or plant responds to these two cuts is the basis for the different training systems. Concurrent with knowing how a tree responds to these two cuts is knowing where the particular species produces flowers and fruits. Every bud on a tree is regarded as a potential flower bud; therefore, flowers can occur in many areas. In general, however, they occur (a) terminally on long or short growths, (b) laterally in the axils of the current or past season's leaves, and (c) adventitiously from any point on the exposed bark of limbs, trunks, or roots (rarely).

As a rule, the position of the flower or inflorescence on the shoot relative to the current season's growth is characteristic of the species or cultivar and does not change much. In apples fruit buds are borne terminally, unfolding to produce leafy shoots that terminate in flower clusters. Most of these terminal flowers are on short shoots called spurs. However, they can occur at the ends of long shoots, especially in the "terminal bearers" such as Rome Beauty. Flowers are infrequently also found as laterals arising on last year's wood. In most instances, in Pennsylvania and the Mid-Atlantic areas, these flowers do not set fruit. When the lateral flowers do set fruit, the resulting apples are usually small and of poor quality. The proportion of spur growth and flowering sites to terminal long shoot flowers is characteristic of a given cultivar and must be assessed when pruning in the field.

Apical dominance

Regardless of basic growth habit, all trees respond similarly to a given type of pruning cut. Heading cuts remove the growing point and developing leaves if applied during the summer and the terminal bud if applied during the winter. This operation severely changes the shoot's hormonal balance and forces the plant to react accordingly. The tendency for suppression of the lateral bud break is referred to as the apical dominance of the terminal bud.

This young growing point or terminal bud is the site of manufacture of the class of plant hormones known as auxins. Removing either the shoot tip or the young growing leaves stimulates the growth of lateral buds into side shoots because of the removal of that site of auxin manufacture. The lateral buds are inhibited

in growth by auxins produced in the young meristematic tissues contained in the shoot tip and transported back downward. This effect must occur when the leaves are very young because removing young, developing leaves can stimulate lateral bud break; but removing fully expanded leaves cannot stimulate growth.

There are two ways to overcome this apical dominance effect from shoot tips. One is to remove the shoot tip as in a heading cut and the other is to bend a shoot tip to a more horizontal position. The latter works because auxins generally move in response to gravity.

Research has suggested that the inhibition of flower bud formation can be explained by the alteration of three plant hormones: cytokinens, auxins, and gibberellins. All three occurred in higher concentrations in the conductive tissues of trees that were pruned. Cytokinenlike substances were doubled in the conductive tissues at the very beginning of growth in the spring. In mid-June, after a month of growth, auxin levels were much higher in pruned trees than in nonpruned trees. This was followed by higher levels of gibberellins from the middle of June to the end of July in the pruned trees, compared to controls.

Trees given no pruning

When growth begins, the terminal and subterminal buds are usually the first to start; in most deciduous trees and vines (less so in shrubs) they produce the longest and strongest shoots, although shoots may grow from many of the lower buds. However, seldom do all the lateral buds start, and as a rule the largest percentage of those remaining dormant are on the basal portion of the shoot.

Response to heading cuts

The result of a heading cut is the loss of apical dominance as mentioned above, with the removal of the inhibiting effect on the lateral buds. The net result is an increase in total shoot growth. Both shoot number and length are affected, but the impact is affected by shoot age, severity of cut, growth habit, and shoot orientation.

Shoot age

The stimulation of shoot growth is most pronounced when heading cuts are made into 1-year-old wood. Such cuts usually result in very vigorous shoots from the three to four buds immediately below the cut. These shoots can develop very narrow angles. Heading cuts made near the top of these shoots induce the top five to seven buds to grow, usually within 6 to 9 inches below the cut (although this will also vary by severity of cut and orientation of the branch).

Severity of cut

Severity can be long, medium, short, or very short (with a very short cut removing the most wood). Regrowth is related to the severity of cut in a bell curve response and time of season that pruning is done. Strong shoots have well-developed buds along the upper three-fourths of the shoot. At the shoot base, however, the buds normally are not as well developed. This difference may explain why the strongest regrowth usually occurs when shoots are headed by one-half to three-fourths their length. At the same time, heading back close to the annual ring (where growth began or very short will likely lead to less regrowth. The results of dormant shoot heading thus are influenced by the condition of the bud that becomes uppermost after heading. Heading cuts made in the dormant season stimulate the most regrowth, while those made late in the summer stimulate less regrowth.

Heading into older wood is not as invigorating as cuts made in 1-year-old wood. Nevertheless, it still increases total shoot growth.

Growth habit

Researchers have classified apple cultivars into four general growth and flowering habits. They use the terms acropetal or acrotonic to describe cultivars that we call tip bearers, such as Rome Beauty or Granny Smith. At the opposite end of the spectrum are basipetal or basitonic cultivars. These produce mostly spur growth and are typified in the extreme by Redchief, the Campbell strain of Delicious. Lightly heading back basitonic cultivars (spur Delicious types) does not generate as much vigorous shoot regrowth as heading back those that do not have a strong spur growth habit. Heading back the acrotonic (weeping) growth habit cultivars increases regrowth to a greater extent and also reduces flower bud formation.

Shoot orientation

Regrowth response is also affected by a shoot's orientation from the horizontal. The more upright the shoot, the greater the regrowth. Generally, heading cuts into upright shoots produces shoots that have a very narrow angle and that are very vigorous. These vigorous shoots create undesirable shade and have very low fruiting potential.

Not all heading cuts are detrimental to a tree, however. In some instances heading cuts are needed to stimulate growth to keep a tree in balance. They should be used to stimulate lateral growth and branching. Heading cuts should also be made to shorten and to stiffen branches. These cuts are necessary when a cultivar tends to produce too much fruit on the end of branches. In peaches, owing to the site of flower production, heading cuts are a necessity.

Response to thinning cuts

Thinning cuts primarily are used for two purposes: (1) to increase light penetration and (2) to remove competing or crowding shoots or limbs. Vigorous shoot growth may develop in the immediate vicinity of the pruning cut, but the effect on adjacent parts of the tree is minimal. Thinning cuts do not change the relationship of various parts of the shoot or branch to each other as heading cuts do, because either the entire shoot or the branch is removed or left intact. The ratio of terminal to lateral buds is largely undisturbed, and as a result, thinning cuts do not increase shoot growth as much as heading cuts. Thinning cuts also reduce flower formation less and can increase flowering when better light penetration is achieved. Yield is reduced only to the extent that the bearing surface is removed and is not reduced because of invigorating buds to form shoots rather than flowers.

Pruning and Training in Young Trees

During the first year or two of a tree's existence in an orchard, most time is spent on training the tree to develop a strong framework. The next period can be considered the "formative years"—when growth is directed and early intervention is performed to ensure that a proper structure develops. Intervention most frequently takes the form of limited pruning and training.

Scaffold selection occurs during the first one to two years. In most training systems the first scaffold should not be any lower than 18 to 20 inches above the ground. Thereafter, shoots should be selected so that they are spaced about 4 to 8 inches apart vertically and well distributed around the trunk.

The major mistake growers often make during the formative years is allowing the top of the tree to develop too soon. The result is that the tree forms a "sail" top and can be blown over, and the lower limbs do not develop sufficiently. Treetops naturally tend to develop sooner and to a greater extent because they are the most vigorous area of the tree and are exposed to the highest light levels. One rule of thumb for this area of the tree is the "one-half to two-thirds" rule. When branches on the central axis are between one-half and two-thirds the diameter of the central axis, they should be removed.

On the other hand, in some cultivars the dominance of the central leader is sometimes lost. This can result either from overcropping or from allowing too many limbs to develop from one area. It may then be necessary to rehead the leader back to invigorate it.

One exception to the rule of reduced pruning occurs with spur-type Delicious. It is not unusual for trees to fail to form sufficient numbers or quality of scaffold limbs the year of planting. In this case it is necessary to cut back the tree severely. This is accomplished by heading the central leader back to an inch or two above where you headed the tree last year. The side limbs that did grow are also cut back using what is commonly called a Dutch or bevel cut. By drastically reducing the top of the tree, you invigorate the tree and encourage greater growth. The Dutch cut is made to force new scaffolds to develop on the underside of the original shoot having a naturally wider angle. The disadvantage of this system is a delay in early bearing by one year.

Once the initial lower framework and tree structure is established, then pruning during the early bearing years is a matter of repeated intervention to ensure good sunlight exposure and to develop a series of tiers of branching structures. As you move progressively up in the tree, each tier should get shorter and weaker.

Summer Pruning of Apples and Peaches

Rising costs have forced tree fruit growers to turn to more intensive planting systems to increase production per acre and per man-hour. As a consequence, tree crowding with a loss of productivity and fruit quality has occurred in some plantings. Traditional dormant pruning restricts root growth and reduces tree trunk enlargement, while it stimulates growth near the cuts. Such growth can worsen tree crowding and reduce light penetration. Fruit growers are therefore turning to summer pruning as a means of controlling growth. Summer pruning also offers a way to balance the workload by reducing the time spent on dormant pruning.

Pruning fruit trees during the summer has been of interest for well over 100 years. A few researchers in this country evaluated summer pruning between 1900 and 1920, concluding that responses were too variable to recommend its widespread adoption. Little was said or written about summer pruning in the United States between 1930 and 1975, when further research was begun in Virginia and Ohio. Since 1975, research has focused on the effects of summer pruning on apples and peaches. Misunderstandings about summer pruning have arisen and should be cleared up.

First, what is summer pruning? It is removing any vegetative growth when there are leaves or flowers on the tree. This includes desuckering the interior of trees, selecting scaffolds on young trees, tipping terminal growth, summer topping of peaches, and dormant-style pruning conducted during the growing season. With all pruning, be it dormant or summer, the ultimate effect is to control tree size.

Effects on growth

Probably the most mistaken idea is that summer pruning restricts growth more than winter pruning. Work in Virginia and Ohio on apples and in New Jersey on peaches has shown that summer pruning causes more vigorous vegetative growth the following year than traditional dormant pruning. Summer pruning does restrict increases in trunk enlargement, branch diameter, and root growth. However, tree crowding in intensive plantings is the result of shoot growth, and summer pruning does not suppress shoot growth as much as dormant pruning.

In assessing tree response to summer pruning, it is important to compare that response with the effects of comparable dormant pruning. For example, at the growing season's end, a tree pruned in summer will obviously look much different from a dormant-pruned tree. After comparable dormant pruning, however, both trees look very similar.

The later you summer prune the less likely the chance of regrowth during the season of pruning. Pruning in mid- to late August can be beneficial to open the canopy up and to allow better sunlight penetration for enhanced color development of fruit.

Effects on flowering and fruiting

Research conducted on the effect of summer pruning on flowering and fruiting has had mixed results. In studies on apple trees pruned in late July or August, no increase in flowering took place the following year. Summer pruning done earlier, in June or early July, was shown to increase flowering in apples. Pruning Redhaven peaches on July 1 or August 1 reduced the number of flower buds proportional to the length of shoots removed; however, the August 1 pruning increased the number of flower buds per node.

In peaches, summer topping was shown to reduce the cold hardiness of flower buds on two out of four sampling dates. Flowering of summer-topped Sunqueen peach trees also appeared advanced, compared to that of dormant-pruned trees.

Effects on overall yield have been variable. In the Virginia apple studies, total fruit weight and numbers per tree did not consistently increase. In Ohio, fruit yield per tree was reduced, but yield per canopy volume was unaffected. Sunqueen peaches mechanically topped over a two-year period had a yield 9 percent lower than yields of dormant-pruned or normal summer-pruned trees. Overall, in individual cases, responses to flowering and fruiting probably depend on variety, timing, and severity of pruning.

Effects on fruit quality

The influence of summer pruning on fruit quality depends on variety and overall tree vigor. Summer pruning has been shown to increase fruit color, especially in crowded plantings where light levels are low. Severely summer-pruned trees tend to produce smaller fruit and lower soluble solids when pruning is done earlier in the season. On the favorable side, summer pruning tends to

reduce bitter pit and enhance color in apples. Flesh firmness of Loring peaches was increased by summer topping. Summer desuckering of peaches has been shown to be beneficial in improving fruit color without the side effects on fruit size. Desuckering consists of removing only the large vigorous upright shoots in the center of the tree.

Economic effects

Dormant-type pruning of apples even done in the summer may not lower overall pruning costs, but it does allow a better distribution of the labor force. Summer pruning offers the grower the option of maintaining a constant number of employees by shifting some of the winter workload to the summer. In mature peach trees, summer topping can save a grower 20 to 25 percent in pruning costs, although there may be a loss in yield after topping.

Summer pruning is a useful tool in fruit production, with certain limitations. It should never be viewed as the sole method of pruning. The best practice is to combine selective summer pruning with yearly dormant pruning. Summer pruning can help improve fruit color, alter fruit quality, train trees, and allow a better distribution of labor.

Before embarking on a program of summer pruning, growers must know what effect they wish to achieve. The earlier in the season summer pruning is completed, the greater the flowering and vegetative regrowth. Conversely, the later in the season summer pruning is done, the less it will affect flowering and the less regrowth there will be. Late-season pruning enhances fruit color but can reduce soluble solids and final fruit size.

Deciding on a Production System

Cost

Generally, cost of trees in the long run is a small part of production costs. The big expense is in the labor required for early training and pruning. This expense should decrease over time, but the higher the density, the greater the labor requirements. A good rule of thumb is: "The more intensive, the more expensive."

Spacing

For optimal production, it is necessary to make best use of the surface area of available land. Spacing that is too wide makes for inefficient planting, while spacing that is too narrow means that excessive labor will be needed to contain trees in their allotted spaces. Once a production system is worked out, spacing is determined by cultivar to be planted, rootstock, soil vigor, and slope.

"Plantsmanship"

Any given production system will be only as good as the grower's ability to manipulate the trees. The more intensive the system, the more growers or their workers must be familiar with how trees grow. There is less room for error in high-density production.

Labor requirements

A high-density orchard requires greater management skills; it also requires that labor be spread over a longer time period. Pruning must be done in both winter and summer. Because tree size is smaller, production becomes more efficient. Brains and nimbleness replace the need for brute strength, allowing greater flexibility in the labor you can hire. High-density orchards also make it easier for fewer people to take care of more trees, but in a smaller area.

Common misconceptions clarified

- There is no perfect production system. You need to develop your own style and a production system that suits your abilities, growing conditions, and chosen cultivars.
- High density does not necessarily mean greater yields. It is very possible to achieve 1,000 bushels per acre on well-managed, standard trees. However, it takes more years to reach full production capacity with standard trees than with dwarf trees.
- Yields and dollar returns do not always occur more quickly in high-density production. Mismanaging a high-density system in the early years can delay fruiting and production. Since the purpose of high-density plantings is to have early production, anything that delays early production will delay returns.

Finally, do not pass judgment on a particular system without adjusting all the factors.

Too often, growers give up on a system because they have tried to handle it the way they handle all their other systems. Make allowances for different row spacings to accommodate smaller equipment.

Production Systems for Apples

As the Pennsylvania industry moves from conventional medium-density, freestanding orchards to high-density, supported orchards, many pruning and training modifications must be made. In the medium-density central leader system, portions of trees are cut back severely for several years to stimulate growth. Emphasis is placed on building a large, strong framework to support future crops.

Conversely, in high-density systems excessive growth is discouraged; and instead of a large, strong framework, a weak-framed tree is desirable. To achieve these ends in a system such as slender spindle, very little pruning is done in early years. The goal is to promote early fruiting, which itself will inhibit future growth. All high-density systems require a greater knowledge and understanding of plant growth and of how the tree will respond to cuts. In early years, more attention is paid to training and positioning limbs than to pruning them. As trees mature, most high-density systems will be more productive if trees are pruned in both winter and summer.

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

Central leader system

This is the most widely planted system in Pennsylvania. Trees are usually, but not always, freestanding. With the range of rootstocks available (see Apple Tree Spacing), trees can vary from 7 to 20 feet tall. Trees can be kept smaller by periodically heading back the central leader into 2-year-old wood to stiffen the central axis. Size and vigor can also be controlled by selecting less-vigorous branches as the central leaders.