Common Mistakes in Planting and Establishing High-Density Apple Orchards

Terence L. Robinson

Department of Horticultural Sciences
New York State Agricultural Experiment Station, Cornell University
Geneva, NY 14456

This work was supported in part by the New York Apple Research and Development Program.

The yield potential over the first five years of a new Tall Spindle apple orchard in NY State is much higher than previously envisioned by most growers. To achieve this potential it is important that growers avoid the common mistakes that lead to too little or too much growth. This can be accomplished by planting high quality trees, managing limb angle at planting and applying fertigation soon after planting. If this is combined with minimal pruning and a precocious rootstock, significant production should be obtained in the second - fifth years.

Our research trials have shown that the Tall Spindle apple orchard system can have significant yield in the second year if growers plant highly feathered trees. Over the first five years the yield potential in NY State with the Tall Spindle is double or triple what most growers expect. However, the successful management of apple trees in these high-density planting systems depends on maintaining a balance between vegetative growth and fruiting (Figure 1). If vigor is too low, excessive fruiting results, fruit size declines, biennial bearing increases and trees fail to fill their allotted space soon enough to make the orchard profitable. If vegetative vigor is excessive, then flowering and fruiting are reduced and containment of the tree to the allotted space becomes problematic. Successfully balancing vegetative vigor and fruiting, results in 'calm' trees that produce heavy annual crops and require only a light annual pruning. Pruning and crop load management are the primary management tools, along with fertilization and irrigation, used to achieve a balance between vegetative growth and cropping throughout the orchards life. These management variables are affected by planting density, tree quality and tree training strategies.

Planting Density

Planting density is the single most important factor that determines the yield of an orchard for the first 5 years. However, tree quality also has a large impact on early yield per tree. We suggest for modern high-density orchards that in-row spacing range from three-five feet and the row spacings from 10-14 ft. (780-1450 trees/acre). Within this range, the decision of how close to plant a new orchard should be made with consideration of the vigor of the variety, vigor of the rootstock, and soil strength. With vigorous scion cultivars, growers should use a dwarfing clone of M.9, G,11 or B.9 rootstock and/or greater planting distances. With weak scion cultivars, a vigorous clone of M.9, G.41 or G.16 rootstock should be used and/or closer planting distances. Despite some latitude in planting distances, growers should remember that to obtain high early yields, high tree densities are essential. For weak and moderate vigor cultivars such as Honeycrisp, Delicious, Braeburn, Empire, Jonamac, Macoun, Idared, Gala, NY674, Golden Delicious, etc we suggest an in-row spacing of three feet. For vigorous cultivars

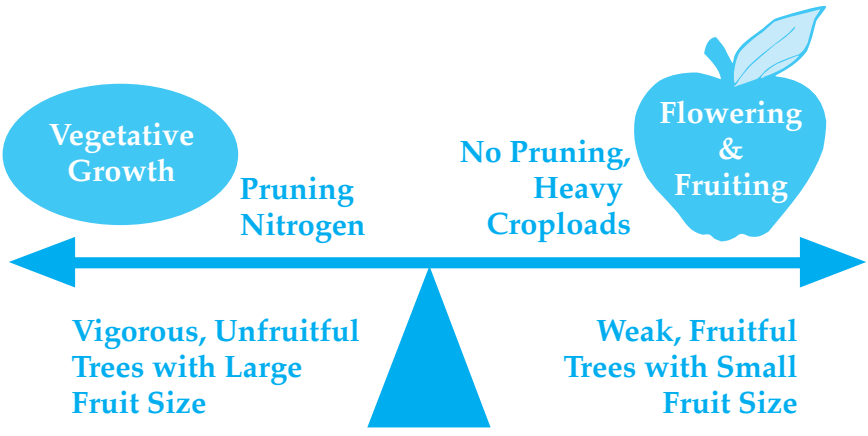

Figure 1. The balance between vegetative growth and cropping is heavily influenced by pruning, nitrogen and cropload.

such as McIntosh, Spartan, Fuji, Jonagold, Mutsu, etc. and tip bearing varieties such as Cortland, Rome, Granny Smith and Gingergold we suggest an in-row spacing of four feet. Between-row spacing should be 12 feet-13 feet on slopes and 10 feet-11 feet on level ground.

TABLE 1

Effect of irrigation and fertigation on growth and yield of Delicious/M.26 trees

Treatment	Shoot growth years 1-3 (% of Unirrigated)	Shoot growth years 4-6 (% of Unirrigated)	Yield/ tree years 2-4 (% of Unirrigated)	Yield/ tree years 5-7 (% of Unirrigated)	Av. Fruit Size (% of Unirrigated)
Unirrigated	100 c	100 b	100 b	100 b	100 b
Trickle Irrigation	137 b	131 a	98 b	115 ab	101 b
Fertigation	171 a	140 a	124 a	127 a	104 a

Tree Quality

Several studies have shown that the greater the number of lateral branches or feathers the greater the yield in the second and third year. Modern high-density orchards can have significant 2nd and 3rd year yield if highly feathered trees are planted and if trees grow well the first year. If growers use whips or small caliper trees these do not produce significant quantities of fruit until year four or five. We recommend that nursery trees have 10-15 well-positioned feathers with a maximum length of one ft (30cm) and starting at a height to 30 inches (80cm) above the soil. Generally nursery trees in North America have not had this number of feathers until the last two years. Many nursery trees have three-five long feathers instead of 10 short feathers. The tree with few long feathers requires more branch angle management than the tree with many short feathers. Fruit growers should insist that nurseries supply trees with the feathers that are high enough to tie down after planting.

Branch Angle Manipulation and Tree Density

An important method of shifting the balance between vegetative growth and cropping in young trees is to tie down branches below horizontal to induce cropping. In the vertical position, a shoot grows more vigorously than in a horizontal or pendant position and tends to remain non-fruitful. A horizontal or pendant limb grows less vigorously, and the apical growing point produces less auxin. This allows the lateral buds on the shoot to be released from dormancy and grow. Such horizontal growing branches then flower heavily the next year and bend under the weight of the fruit. The fruits are also strong competitors for resources, and they limit the growth of the branch even more. If a vertical limb is manually bent horizontal, lateral buds are released from dormancy and if the vigor of the branch is excessive, these buds may grow into vigorous upright shoots themselves and remain unfruitful. However, if the branch has more moderate vigor, the lateral buds grow into short shoots, which become fruitful. Branch angle also influences the response to heading cuts. On vertical shoots, heading cuts significantly stimulate vigor and reduce flowering. However on horizontal or pendant shoots, heading cuts have very little effect. This is because the terminal bud of vertical shoots exerts a dominant control on the rest of the shoot but in a horizontal shoot the terminal bud has much less influence.

At moderate or low tree densities, trees must be grown rapidly to fill the allotted space while with modern high-density orchards, which are spaced three-five ft between trees, only moderate growth is desired. If trees are highly feathered at planting almost no lateral growth is needed but vertical leader growth is necessary to achieve proper tree height. This requires that feathers be managed by manipulating the angle of the feathers soon after planting to limit extension growth. The extent to which the angle of feathers must be managed to limit growth is a function of the in-row plant spacing. With three-four ft in-row spacings (the Tall Spindle), feathers must be tied below horizontal in a pendant position at planting so that they produce almost no extension growth and begin cropping in the second year. This also prevents them from developing into substantial lower scaffolds. The pendant position results in a weak fruiting branch instead of a scaffold branch. In contrast, the wider spacings of the Vertical Axis system (five-six ft) require some extension growth before cropping bends the lower limbs below horizontal, thus feathers should not be tied down at planting. This allows them to grow into scaffolds over the first four years. However, any original feathers that are not horizontal at the end of the third year must be tied down or they will become too vigorous for the spacing. Growers who attempt to plant feathered trees at the Tall Spindle spacing but do not tie the feathers down often end up with limbs in the lower part of the tree that are too strong which requires severe limb removal pruning at an early age which invigorates the tree and makes long term canopy containment problematic. This simple change in tree management allows for long-term cropping of many feathers and little invasive pruning for the first five-eight years at the very close spacing of the Tall Spindle system. In contrast, whips require significant lateral extension growth even at 3-4 ft spacings. However, as with feathered trees, the new lateral branches should be managed according to their in-row spacing as described for feathered trees but generally one year later.

After the initial tying or weighting down of feathers at planting, new lateral branches that arise along the leader do not need to be tied down. In most climates, moderate vigor shoots if not pruned will have enough cropload in the third year to bend branches down below horizontal and a natural balance between vigor and cropping will be established without additional limb positioning. Thus with the Tall Spindle, no additional limb tying is needed after the initial tying or weighting down of the feathers at planting. However, in vigorous and/or warmer climates where winter chilling is insufficient, limbs often become too large before they set sufficient crop loads to bend the branches down. In these climates, tying down of all vigorous limbs must be done annually for the first three-five years until the tree settles down and begins to crop heavily. However, in most traditional apple growing areas, growers often invest too much money in limb tying which should be limited to only the feathers at planting. Thereafter, the precocity of the rootstock induces heavy cropping and a natural balance is established.

Irrigation and Fertigation

Large, highly feathered trees often undergo water stress shortly after planting despite adequate soil moisture levels. This is due to the damaged root system of a transplanted tree, which cannot adequately support the large top without frequent irrigation. Large, highly feathered trees produce much more leaf area shortly after planting

TABLE 2

Effect of fertigation on growth and yield of Empire/9/106, Mutsu/9/106 and Delicious/M.26 Trees

Treatment	Shoot growth years 1-3 (% of Unirrigated)	Shoot growth years 4-6 (% of Unirrigated)	Yield/ tree years 2-4 (% of Unirrigated)	Yield/ tree years 5-7 (% of Unirrigated)	Av. Fruit Size (% of Unirrigated)
Unirrigated	100 b	100 b	100 b	100 b	100 b
Fertigation	153 a	134 a	140 a	135 a	108 a

than unfeathered trees. This creates a high water demand before the root system can re-grow sufficiently to support the trees. In addition, many years have periods of dry weather following planting which result in water stress of newly planted trees which can limit tree growth. Frequent and early trickle irrigation can help these trees produce good growth in the first year. In humid areas, growers are unaccustomed to installing irrigation immediately after planting and delay its installation until mid summer. We recommend that growers install trickle irrigation soon after planting with high- density orchards that use feathered trees to prevent water stress and maximize first year tree growth.

Frequent low doses of nitrogen fertilizer delivered at least twice weekly through the trickle system (fertigation) for the first 12 weeks of the season will greatly improve tree growth during the first two years to speed development of the canopy (Tables 1 and 2). Ground fertilization with dry fertilizers is often ineffective since too much time elapses between applying the fertilizer and uptake by the tree. With high tree densities, as with the Tall Spindle system and highly feathered trees, almost no lateral tree growth is required and only leader extension is needed. In this case fertigation for the first two years is essential both for the water to avoid water stress and for the nitrogen, which is rapidly moved with the water to the root zone and is readily available to the tree as soon as it starts growing. The application of immediate fertigation to highly feathered trees by NY growers will considerably improve tree growth and vastly improve yield potential in the 2nd and 3rd year (Tables 1 and 2, Figure 2). For moderate tree densities such as with the vertical axis, slender pyramid or Y-trellis, trees must be grown vigorously for several years to fill the allotted space with canopy and relatively high nitrogen fertilization is desirable for two to three years after planting. However, with the Tall Spindle, excessive fertilization, especially nitrogen, can cause too much growth, which results in delayed flowering, reduced yields, poor fruit quality and greater pruning.

After the first few years, low nitrogen fertilization is desirable to keep the trees calm with a balance between fruiting and cropping. Many mature high density orchards receive excessive nitrogen fertilizer which cause severe canopy management problems. "Soil strength" or fertility must be considered when calculating the amount of nitrogen to apply to mature high-density orchards especially with vigorous and poor coloring varieties. Many soils in New York produce 30-60 lbs/acre of nitrogen annually through nitrification. This is often close to the amount needed by mature high-density orchards.

Fumigation and Weed Control

In many cases, tree growth of new orchards planted on old orchard land can be improved significantly with soil fumigation. However, the apple replant problem is variable with some sites showing no benefit from fumigation and other sites showing significant benefits. Ideally, growers should conduct a bioassay before replanting an old orchard site to assess the severity of replant problem and determine the value of soil fumigation. Even with fumigation almost all old orchard sites produce less tree growth than virgin sites. Thus, tree-planting density should be increased on old orchard sites compared to virgin sites by 20-30%.

Weed competition can drastically reduce tree growth during the first few years and can cause a failure of the orchard to fill it's allotted space which always results in diminished yield and profitability. Good weed control during the first three-four months of the growing season is the most critical time period of the season. In later summer months if weed control is poorer it is not detrimental to the trees. Thus we recommend that growers provide excellent weed control for the first three-four months of the season during the developmental years of the orchard.

Cropload Management

Management of cropping with high-density orchards during the first 4 years to avoid biennial bearing is critical to maintaining a proper balance between vegetative growth and cropping as the trees begin to bear. With precocious dwarfing rootstocks, young apple trees can often overset in the 2nd or 3rd year resulting in biennial bearing as early as the 4th year. A low crop in the 4th year results in increased vigor just when the trees have filled their allotted space and when reduced vigor is needed. Varieties differ in their biennial bearing tendency and this must be incorporated into the croploads allowed on young trees. For annual cropping varieties like Gala, we recommend croploads of 6 fruits/cm^2 trunk cross-sectional area (25-40 apples/tree in the second year, 40-60 apples/tree in the third year, and 100-120 apples/tree in the fourth year). For slow growing and biennial bearing varieties like Honeycrisp we recommend croploads of four fruits/cm^2 trunk cross-sectional area (15-20 apples/tree in the second year, 25-40 apples/tree in the third year, and 50-70 apples per tree in the fourth year). Within each year, the low end of the range should be used for low vigor trees and the high end of the range for high vigor trees.

Pruning During The Early Years

During the developmental years of an orchards life the trees have a juvenile character and the balance between vegetative growth and cropping is shifted toward vegetative growth (Figure 1). With high density systems such as the Tall Spindle, the goal is to get the trees into cropping as soon as possible. This is best accomplished by minimizing pruning during the first four years. No heading cuts should be done to the leader or lateral branches at planting or for the next four years since the maximum growth and earliest cropping is achieved with no pruning. For the first four years pruning should be limited to the complete removal of unsuitable branches such as those lateral branches larger than 2/3 the diameter of the leader. Of much greater importance during the first four years is limb angle manipulation to change a young vigorous tree from a vegetative state into a reproductive state. With the Tall Spindle and Vertical Axis systems the artificial bending of limbs is limited to the 1st tier of branches while with the Solaxe even upper branches are tied down. With the

Tall Spindle and the Vertical Axis systems the bending of upper branches is achieved naturally by cropload.

Mature Tree Pruning

As the orchard reaches maturity, containment pruning of the canopy is essential to maintaining trees within the allotted space and to maintain adequate light exposure of the lower portion of the tree. Good light distribution and good fruit quality can be maintained if the top of the tree is kept more narrow than the bottom of the tree, and if there is a good balance between vegetative growth and cropping. Pruning strategies based on shortening or stubbing back permanent branches that outgrow their allotted space generally are not as successful as limb renewal pruning strategies. This is partially because the most productive fruiting wood is cut off when a branch is shortened. In addition, stubbing cuts stimulate localized vigor on the affected branches which results in shading of the lower canopy. In our studies on how to manage the canopies of high-density systems, treatments where branches were shortened to maintain the conic shape to the tree, resulted in unacceptable yield reductions, a dense canopy, excessive interior canopy shading, excessive vigor compared to an unpruned control and poor fruit quality.

A more successful approach has been to annually remove one-two large upper branches completely and develop younger replacement branches. The removal of entire branches in the upper portion of high-density apple trees opens channels for light penetration, which maintains fruit production and quality in the bottom of the canopy. This "limb renewal" pruning is the single most important pruning concept for mature high-density orchards to contain the canopy and maintain a conic tree shape. To assure the development of a replacement branch, the large branch should be removed with an angled or beveled cut so that a small stub of the branch remains. From this stub a flat weak replacement branch often grows. If these are left unheaded they will naturally bend down with crop. They are naturally shorter than the bottom branches thus maintaining the conic shape of the tree without stubbing cuts. This type of pruning does not stimulate vigorous regrowth. Our recommendation is to begin removing one - three whole limbs in the top of the tree once the tree is mature (years six-seven). This allows moderate pruning each year and a method to contain tree size. It also maintains good light distribution in the canopy without inducing excessive vigor. On trees with overgrown tops that need to be restructured, moderate renewal pruning (one-two large upper branches annually) for a four-five year period can eliminate all of the large branches in the top of the tree.

Figure 2. Effect of fertigation (left photo) on third year yield of Empire M.9 apple trees compared to an unirrigated tree (right photo).

Once branches have become horizontal or pendant under the weight of crop, they can be shortened by heading back to side branch or spur without adverse effects, since the terminal bud no longer exerts significant control over the branch. However, if the overall vigor of the mature tree remains high, leaving the pendant branches long will help increase cropping and reduce the vigor of the tree. After a number of years, if the pendant branches begin to shade the bottom half of the tree they should be removed with a renewal cut and a replacement branch developed.

The natural bending of branches under the weight of fruit without heading can be used to great horticultural advantage in the tops of vigorous trees when it is desired to limit tree height. Often growers want to limit tree height by heading the leader in the top of the tree. If heading cuts are made on vertical shoots in the top of trees, vigorous regrowth results. If lateral shoots or limbs are manually bent horizontal or allowed to bend naturally under the weight of the crop they set heavy crops the next year. The crop will also act as a strong sink for resources thereby further reducing the vegetative vigor in the top of the tree. Once the top of the tree is fruitful and the leader has bent under the weight of the crop it can be shortened to a weak side branch without a vigorous response.

Conclusions

The yield potential over the first five years in NY State is much higher than previously envisioned by most growers. As growers plant more high-density Tall Spindle orchards it is important that they avoid the common mistakes, which lead to too little or too much growth. Growers should try to obtain 50cm of leader shoot growth in the first year, 75-100cm of leader shoot growth in the second and third years and 50cm of leader shoot growth in the fourth year. This can be accomplished by planting high quality trees, managing limb angle by tying feathers down and applying fertigation soon after planting. If this is combined with minimal pruning and a precocious rootstock, significant production should be obtained in the 2nd – 5th years, which will limit vegetative growth in future years resulting in a "calm" tree. High mature yields and high fruit quality can be achieved with a high-density orchard when the orchard has a balance between vegetative growth and cropping. This can

best be accomplished by maintaining a narrow canopy shape and through regular limb renewal pruning and the development of pendant fruiting branches.

Terence Robinson is a research and extension professor at Cornell's Geneva Experiment Station who leads Cornell's program in high-density orchard systems.