The Tall Spindle Apple Production System

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In the late 1990's a new planting system called the Tall Spindle system was developed from a combination of the Slender Spindle, the Vertical Axis and the Super Spindle systems. It uses high tree densities, highly feathered trees, bending of the feathers below horizontal at planting, and no permanent scaffold branches. It may be the most profitable system for NY growers.

There has been a steady increase in tree planting density over the last 50 years from 35 trees/acre to, in some cases, more than 2,500 trees/acre. Some experimental orchards have used densities up to 4,000 trees/acre. During the 1980's and 1990's the Slender Spindle training system (Wertheim, 1968) was the most common system in Northern Europe, while the Vertical Axis (Lespinasse, 1980) was more common in Southern Europe, North America, and New Zealand. In the 1990's a few growers planted the very high density Super Spindle system (Nuberlin, 1993) with greater than 2,000 trees/acre. By the late 1990's an amalgamation of these three systems gave rise to a new system we began calling the Tall Spindle system.

Development of the Tall Spindle System

This new planting system achieves the goals of very high early yields, high sustained yields and excellent fruit quality, while moderating the initial investment as compared to the Super Spindle system (Table 1). The important components of this system are:

1. High planting densities (~1,000-1,500 trees/acre).
2. The use of a fully dwarfing rootstock.
3. Highly feathered nursery trees (10-15 feathers).
4. Minimal pruning at planting.
5. Bending feathers and below horizontal at planting.
6. No permanent scaffold branches.
7. Limb renewal pruning to remove and renew branches as they get too large.

Each of the puzzle pieces is important and fruit growers must successfully integrate these puzzle pieces to be profitable. Ignoring one or more of the puzzle pieces has resulted in difficulty managing vigor with this planting system (Hoying and Robinson, 2000).

The Tall Spindle is based on the Slender Spindle tree developed by Bob Wertheim (1968), which was designed to improve early yields and management efficiency by planting higher tree densities and reducing tree height to allow all management to be done from the ground. However, the short stature of the Slender Spindle tree and moderate density often resulted in moderate yield and dense canopies. In the 1970's and 1980's, most Slender Spindle orchards had densities from 600-1000 trees/acre and had a tree height and diameter of about 6 ft.(1.8m). A significant trend in the late 1980's and 1990's was to increase tree planting density in Slender Spindle orchards to improve yields (Oberhofer, 1987). Some growers attempted to increase planting density by planting double and triple rows. However, the dense canopies were difficult to manage and vigor usually became a problem as the orchard matured. During the early 1990's, much higher tree densities, between 2,000 and 5,500 trees/acre, were tested in single rows and a more narrow and taller tree form was developed: the Super Spindle system. These trees had a tree diameter of 1.5-2 ft (45-60cm) and a tree height of 8 ft (2.5m). Through managing this system, growers and researchers learned that by never allowing permanent scaffold branches to develop the tree could be kept very compact for many years. However, the cost of the Super Spindle system was prohibitive for all except those who grew their own trees.

A second trend over the last 20 years has been greater emphasis on obtaining a significant yield in the second year after planting through the use of highly feathered trees. However, many of the

TABLE 1

Establishment Costs for 3' X 11' Tall Spindle Orchard System (10 rows X 400' long)

Item	Number/acre	Material Costs ($/acre)	Labor Costs ($/acre)	Total Cost ($/acre)
Trees	1320	$8,580	$100	$8,680
Anchor poles (6 ft)	20	$120	$100	$220
Inline poles (12 ft)	110	$1,100	$550	$1650
Wire	12,000 ft	$280	$100	$380
Staples, tightners and crimps		$50	$100	$150
Total		**$10,130**	**$950**	**$11,080**

trees used in the 1980's and 1990's had feathers that started at 20 inches (50cm) above the soil. The low height of the feathers required significant labor to tie the branches up when they began to fruit in order to prevent fruit from touching the ground. In the late 1990's, the minimum height of feathers was raised to 30-35 inches (Balkhoven-Baart et al., 2000). This allowed branches to hang in a pendant position when cropping and still not touch the ground, thus eliminating the need to tie up branches.

A third trend was an increase in tree height from 6-8 ft.(11.8-2.4 m) to 9-10 ft. (2.7-3.0 m) to obtain higher mature tree yield (Robinson and Lakso, 1991). This resulted in greater light interception, which is directly related to yield, and a greater distance between fruiting branches spread along the trunk. In the 1990's, many growers began to avoid pruning Slender Spindle trees after planting or during the first few years. If the central leader was cut, as was typical with slender spindle trees, a vigorous frame developed, which needed a lot of summer pruning labor to maintain light distribution in the tree for good fruit quality. Without pruning of the leader and with feathers starting at 30 inches above the soil, the tree can be allowed to crop in the second year, which results in the natural bending of lateral branches to keep the canopy narrow. In the 1990's, as growers allowed Slender Spindle trees to grow taller, yields increased, and fruit quality often increased as well since there was more space between the branches along the axis. These trends led to the development of the Tall Spindle Tree with a tree diameter of 3-4 ft (90cm-1.2m), a tree height of 10 ft (3m) and a density between 1,000 and 1,500 trees/acre.

Figure 1. Tall Spindle orchards utilize highly-feathered trees planted at 3 ft. spacing.

Characteristics of the Tall Spindle System

Tree Density Tree density with Tall Spindle orchards can vary from a high of 1452 trees/acre (3' x 10') to a low of 838 trees/acre (4' x 13'). The proper density is decided by considering the vigor of the variety, vigor of the rootstock, and soil strength. With vigorous scion cultivars, growers should use a more dwarfing stock and greater planting distances. With weak scion cultivars, a more vigorous rootstock and/or closer planting distances should be used. Despite some latitude in planting distances, growers should remember that to obtain high early yields high tree densities are essential. For weak and moderate growing cultivars such as Honeycrisp, Delicious, Braeburn, Empire, Jonamac, Macoun, Idared, Gala, NY674, Golden Delicious, etc., we suggest an in-row spacing of 3ft (90cm) (Figure 1). For vigorous varieties 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 4ft (1.2m) Between-row spacing should be 12-13 ft (3.6-3.9m) on slopes and 10-11ft (3.0-3.3 m) on level ground.

Rootstock Although high tree density is the single most important factor affecting yield in the early years of an orchard's life, dwarfing rootstocks are the foundation for any successful Tall Spindle planting system. Most successful Tall Spindle plantings are planted with dwarfing rootstocks such as M.9 or B.9. In recent years in the U.S., the fire blight-resistant dwarf rootstocks from Geneva®™ (G.16, G.11 and G.41) have been used successfully in Tall Spindle plantings. Within the M.9 class of dwarfing rootstocks, there are significant differences in vigor between clones. The weaker clones (M.9NAKBT337, M.9Flueren56, B.9 and G.41) are especially useful with vigorous scion varieties on virgin soil. The more vigorous clones (M.9Pajam 2, M.9Nic29, M.9EMLA, G.16 and G.11) are much better when orchards are planted on replanted soil or when weak scion cultivars are used. Although M.9 is used around the world with great success in high density plantings, it is highly susceptible to fire blight and Woolly apple aphids. The new dwarfing rootstocks that are resistant to these problems, such as the Cornell Geneva series, should improve the worldwide performance of high-density orchards.

Tree Quality An essential component of the Tall Spindle system is a high branched (feathered) nursery trees. Several studies have shown that the greater the number of lateral branches or feathers, the greater the yield in the second and third year. The Tall Spindle system depends on significant second and third year yield for the economic success of the system. If growers use whips or small caliper trees which do not produce significant quantities of fruit until year four or five, often the carrying costs from the extremely high investment of the Tall Spindle orchard overwhelms the potential returns and negates the benefit of the high tree density on profitability. We recommend that the caliper of trees used in tall spindle plantings be a minimum of 5/8 in (16mm) and that they have 10-15 well positioned feathers with a maximum length of 1 ft (30cm) and starting at a minimum height to 30 in (80cm) on the tree (Figure 2). Generally, nursery trees in North America do not have this number of feathers. However, in the last two years a few nurseries have produced highly feathered trees. Many nursery trees have 3-5 long feathers instead of 10 short feathers. The tree with few long feathers requires more branch management than the tree with more short feathers.

Figure 2. A young Tall Spindle orchard with highly feathered trees (15+ feathers) planted in NY State at 3' x 12". Note tree height is 6' at planting.

Figure 3. Highly feathered tree with all large feathers tied down below horizontal

Pruning at Planting Minimal pruning is practiced at planting. Highly feathered nursery trees having 10 to 15 small branches along the trunk require almost no pruning except to remove these large feathers having a branch diameter larger than one-half that of the main trunk immediately above where the feather originates. When nursery trees have fewer but bigger feathers, only those that are thicker than two-thirds of the trunk diameter are taken out. No heading is done except when the tips have been damaged or dehydrated during the packaging or manipulating prior to, or during planting. Although not recommended for Tall Spindle orchards, if whips or non-branched trees are used, they should be headed at 5ft (1.5m) at planting.

Branch Angle Manipulation The most important method of inducing early cropping is tying down of the larger feathers below horizontal right after planting (Figure 3). One of the most significant differences between the Tall Spindle and the more traditional Vertical Axis and Slender Spindle is that the Tall Spindle tree typically has no permanent lower tier of branches. With the Tall Spindle all of the larger feathers (more than 10" or 25cm long) are tied or weighted below the horizontal at planting to induce cropping and to prevent them from developing into substantial lower scaffolds. The pendant position results in a weak fruiting branch instead of a scaffold branch. Smaller, less vigorous feathers usually bend with cropload without any tying. With the Vertical Axis and Slender Spindle systems the feathers are allowed to be brought down to horizontal with fruit load in the third year or are tied down a little above horizontal, which allows them to grow into scaffolds over the first four years. 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. This situation 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 long-term cropping of many feathers and little invasive pruning for the first 5-8 years at the very close spacing of the Tall Spindle system.

After the initial tying or weighing down of feathers at planting, new lateral branches that arise along the leader do not need to be tied down. In most climates, if moderate vigor lateral shoots arising along the leader are not pruned, often cropload in the second or third year will 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 weighing down of the feathers at planting. On the other hand, in vigorous conditions and/or warmer climates where winter chilling is insufficient, often limbs become too large before they set sufficient croploads to bend the branches down. In these situations, tying down of all vigorous limbs must be done annually for the first 3-5 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.

Cropload Management As the tree begins to bear, management of cropping with the Tall Spindle during the first four years to avoid biennial bearing is critical to maintaining a proper balance between vegetative growth and cropping. With

Figure 4. A young Tall Spindle orchard has a supported trunk, a narrow cylindrical shape and no permanent branches. Vigorous branches are removed leaving only small diameter fruiting branches on the trunk.

precocious dwarfing rootstocks, young apple trees can often overset in the second or third year, resulting in biennial bearing as early as the fourth year. This then results in increased vigor in the fourth year, just as the trees have filled their allotted space and 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 15-20 apples/tree in the second year, 50-60 apples/tree in the third year, and 100 apples/tree in the fourth year. For slow growing and biennial bearing varieties like Honeycrisp, croploads should be half that used with Gala.

Mature Canopy Shape The Tall Spindle tree is essentially a 10 ft (3m) trunk with small fruiting branches inserted all along its length (Figure 4 and Figure 5). A simplified training recipe is given in Table 2. To achieve this tree in only three years, the central leader is not cut (headed) at planting. This results in a 5-6 ft tall tree at planting, which is already 50% of its final height (Figure 1). This relatively tall, thin tree needs support before the fully leafed-out canopy acts as a sail resulting in tree breakage during strong windstorms. Thus a 3-4 wire trellis must be installed by the time the tree leafs out. A 3-4 wire trellis is preferred to a individual tree stake and a single wire trellis since the tree density makes cost of an individual tree stake (conduit pipe) prohibitive. Some growers of the Tall Spindle system use an inexpensive bamboo tree

Figure 5. A mature Tall Spindle tree has a dominant trunk, but no permanent branches. Vigorous branches are removed leaving only small diameter fruiting branches on the trunk.

TABLE 2

Simplified pruning and training plan for the Tall Spindle system.

FIRST LEAF	
At Planting	Plant highly feathered trees (10-15 feathers) at a spacing of 3-4' x 11-12' (90cm-1.2m x 3.3m-3.6m). Adjust graft union to 6" (15 cm) above soil level. Remove all feathers below 24" (60 cm) using a flush cut. Do not head leader or feathers. Remove any feathers that are larger than 2/3 the diameter of the leader
3-4" Growth	Rub off 2nd and 3rd shoots below the new leader shoot to eliminate competitors to the leader shoot.
May	Install a 3-4 wire tree support system that will allow tree to be supported to 3m. Attach trees to support system with a permanent tree tie above 1st tier of feathers leaving a 2 inch diameter loop to allow for trunk grow.
Early June	Tie down each feather that is longer than 10" (25 cm) to a pendant position below horizontal.
SECOND LEAF	
Dormant	Do not head leader or prune trees.
10-15 cm growth	Pinch lateral shoots in top 1/4 of last years leader growth removing about 5 cm of growth (the terminal bud and 4-5 young leaves).
Early June	Hand thin crop to single fruit four inches apart. (Target 15-20 fruits/tree)
Mid June	Re-pinch all lateral shoots in top 1/4 of last years growth. Tie developing leader to support system with permanent tie.
THIRD LEAF	
Dormant	Do not head leader. Remove overly vigorous limbs that are more than 2/3 the diameter of the leader using a bevel cut.
Late May	Chemically thin according to cropload, tree strength, and weather conditions, then follow up with hand thinning to appropriate levels to ensure regular annual cropping and adequate fruit size. (Target 50-60 fruits/tree).
June	Tie developing leader to support system with a permanent tie.
August	Lightly summer prune to encourage good light penetration and fruit color.
FOURTH LEAF	
Dormant	Do not head leader. Remove overly vigorous limbs that are more than 2/3 the diameter of the leader using a bevel cut.
Late May	Chemically thin and follow up with hand thinning to appropriate levels to ensure regular annual cropping and adequate fruit size.(Target 100 fruits/tree).
June	Tie developing leader to support system with a permanent tie at the top of the pole.
August	Lightly summer prune to encourage light penetration and fruit color.
MATURE TREE PRUNING (Fifth-Twentieth Leaf)	
Dormant	Limit tree height to 10' (3m) by cutting leader back to a fruitful side branch. Annually, remove al least 2 limbs including lower tier scaffolds that are more than 2/3 the diameter of the leader using a bevel cut. Shorten bottom tier scaffolds where needed back to side branch to facilitate movement of equipment and preserve fruit quality on lower limbs. Remove any limbs larger than 1" diameter in the upper 2ft (60cm) of the tree
Late May	Chemically thin and follow up with hand thinning to appropriate levels to ensure regular annual cropping and adequate fruit size. (Target 100-120 fruits/tree).
August	Lightly summer prune to encourage light penetration and maintain pyramidal tree shape.

stake at each tree tied between a lower and higher wire.

The feathers or lateral branches are tied below horizontal either at planting or early during the first summer to induce cropping and to limit the width of the canopy (Figure 3). The leader's shoot is supported with the trellis and is not headed in succeeding years until year four or five, when mature tree height has been achieved and heavy cropping has begun. The upper part of the tree is composed of small fruitful branches that bend with crop below horizontal. The narrow, slender shape of the Tall Spindle canopy helps ensure that most of the canopy is well exposed to light resulting in excellent fruit quality.

Renewal Pruning Good light distribution and good fruit quality can be maintained as trees age if the top of the tree is kept more narrow than the bottom and there is a good balance between vegetative growth and cropping. For the Tall Spindle system, maintaining a conic shape as the trees age is critical to maintaining good light exposure, fruiting and fruit quality in the bottom of the tree. (Figure 6) In our experience, the best way to maintain good light distribution within the canopy as the tree ages is to remove whole limbs in the top of the tree once they grow too long, rather than shortening them back. A successful approach to managing the tops of trees has been to annually remove one to two upper branches completely. 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 lower portion 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. When this style of pruning is repeated annually, the top of the tree can be composed completely of young fruitful branches. The younger branches do not result in as much shade as larger older branches and are naturally shorter than the bottom branches thus maintaining the conic shape of the tree. When this strategy, termed limb renewal pruning, is employed with the Tall Spindle system, good light distribution can be maintained over the life of the tree.

Performance of the Tall Spindle in NY State

We began testing the Tall Spindle system (3' x 11') in 1997 at Geneva in a planting of both higher and lower densities (Robinson, 2005). In our report published last year in *the New York Fruit Quarterly*, the Tall Spindle system was the second highest yielding system, exceeded only by the much higher density Super Spindle system. Unfortunately, when the trial was planted we could not obtain the highly feathered trees here in the U.S., which are essential to the optimum performance of the Tall Spindle. Our trees had 3-5 feathers instead of 10-

Figure 6. A mature Tall Spindle Gala orchard in NY State

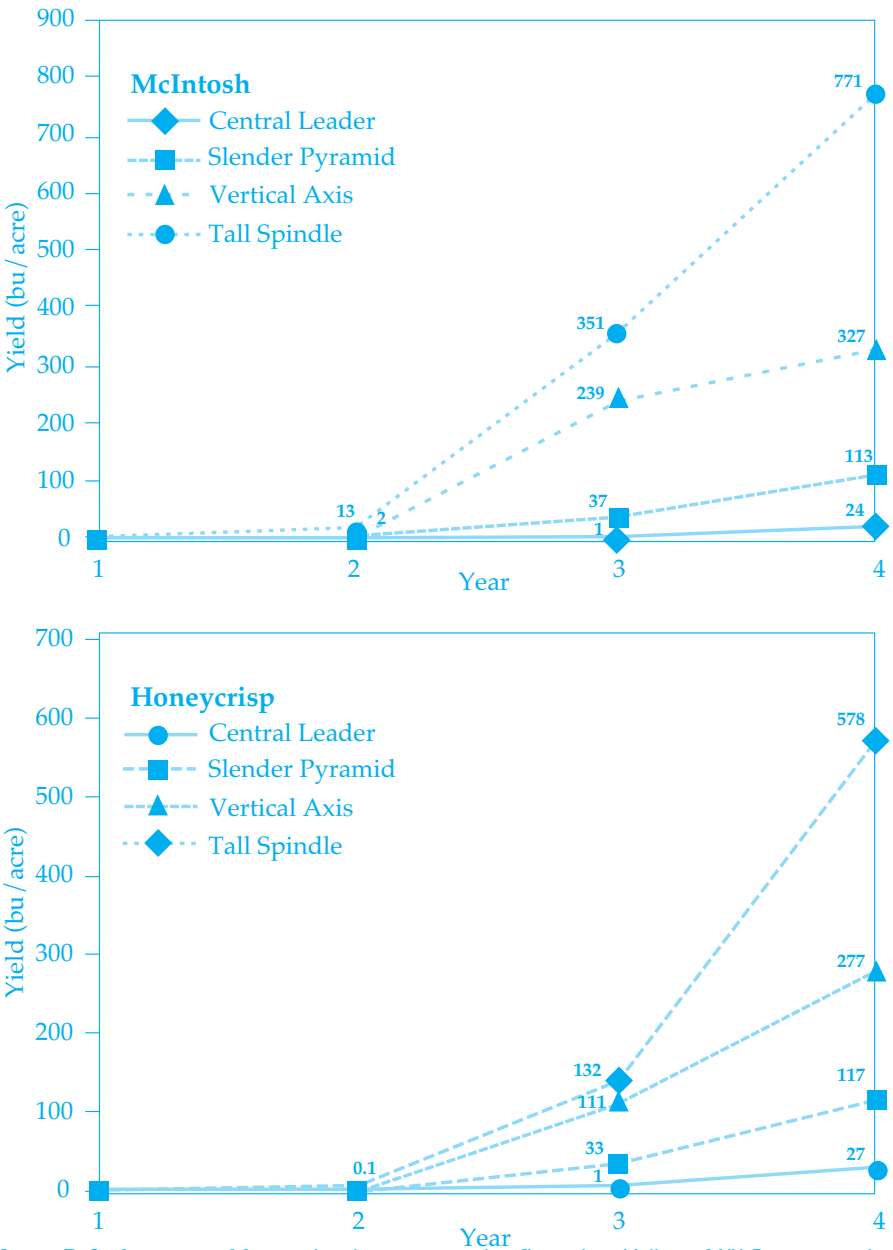

Figure 7. Performance of four orchard systems in the Champlain Valley of NY State over the first four years with McIntosh and Honeycrisp.

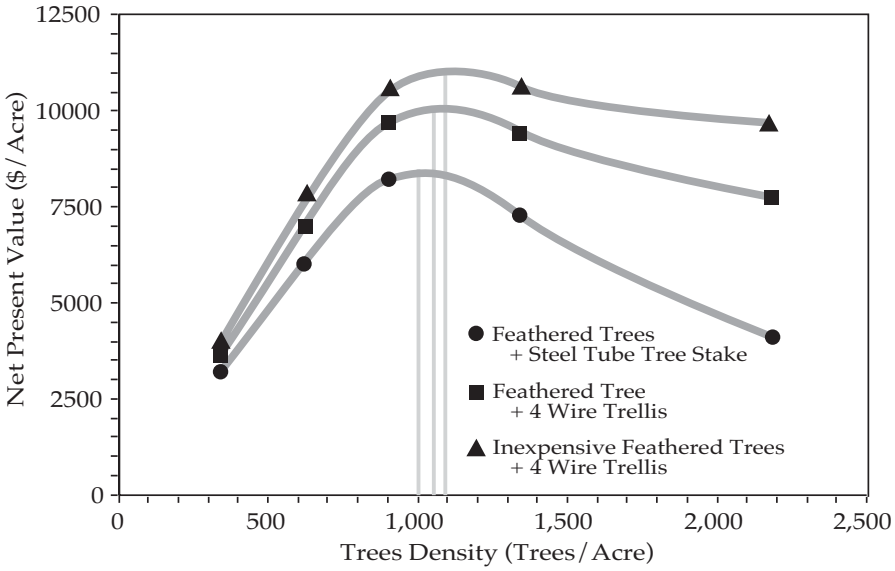

Figure 8. Effect of tree density on orchard profitability after 20 years (Net Present Value/acre).

15 feathers. Thus its performance was not up to the potential of more highly feathered trees.

In 2002 we planted a new trial in the Champlain Valley to test the Tall Spindle. In this case we obtained trees with 6-8 feathers. The results after four years have been quite impressive (Figure 7). With McIntosh and Honeycrisp the Tall Spindle system has had twice the yield of the more traditional Vertical Axis. With McIntosh the yields reached 771 bushels/acre in the fourth year while with Honeycrisp the fourth-year yield was 578 bushels/acre. It appears that the Tall Spindle will be quite manageable and very productive.

This year (2006), we recently planted two new trials of the Tall Spindle system in the Hudson Valley and Wayne County. In this case with Gala, Honeycrisp, and Fuji, we obtained trees with 8-10 feathers. We expect even greater yields from the new trials since we have better quality trees.

Conclusions

The key objectives for a new orchard are to maximize yield in the early years and still effectively produce large yields of high quality fruit after the trees are mature. The Tall Spindle system accomplishes these objectives by combining high tree planting densities, highly feathered trees that have many small branches instead of a few large branches, minimal pruning at planting or during the first three years, branch angle management by tying down all of the larger feathers at planting to induce cropping and prevent the development of strong scaffold branches that cause difficulty in tree management in later years, and branch caliper management by the systematic removal of large branches to keep the tree manageable. Since large branches contribute to the development of large trees, the Tall Spindle trees that have no large scaffold branches

remain small. Our most recent economic analysis shows the optimum economic density for NY is the 1,000-1,100 trees / acre of the Tall Spindle system (Figure 8). It appears to be an excellent system for NY apple growers.

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