# Recent Advances of Mechanization for the Tall Spindle Orchard System in New York State – Part 1

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Over the last 5 years we have witnessed the rapid adoption of motorized platforms in many Tall Spindle apple orchards in NY State to reduce production costs. Cornell mechanization research and extension efforts have increased the awareness of the economic benefits of orchard mechanization. The simple, narrow, and very adaptable canopy of the Tall Spindle system has facilitated the use of motorized platforms for partial mechanization of several orchard tasks. During the last three years we have introduced several platforms to growers (self-propelled or pulled by a tractor and single row or 2-row types) at each of the pruning demos conducted in Western NY and in the Champlain and Hudson Valley fruit production regions. NY growers and employees are using platforms for pruning (with loppers, pneumatic pruners, or a chainsaw on a pole), hand thinning, tree training and trellis construction and repair. The use of platforms has increased worker efficiency and also improved the successful adoption of the horticultural techniques of limb renewal pruning, and tree height control.

**"NY apple growers are rapidly adopting the Tall Spindle planting systems which has higher yields than traditional systems and is allowing them to adopt motorized labor positioning platforms to reduce pruning, hand thinning and summer pruning costs. In the future pruning costs may be reduced even further with mechanized summer side-wall shearing. To take full advantage of these advances in mechanization, new orchards should be established at a spacing of 2.5-3ft x 11-12 ft."**

Our current research and extension efforts for orchard mechanization are proceeding along three fronts: motorized platforms to position human workers for greater canopy management efficiency, mechanical pruning with hedging machines and harvest aid machines to improve the efficiency of harvest. In this article we describe the current advances and future applications of (1) new motorized platforms for dormant pruning, hand thinning, tree training and trellis construction, (2) the Cornell concept for a fruiting wall via mechanical pruning and other fruit wall experiences from around the world, and (3) the potential benefits and future challenges of robotic pruning. A future article will cover the current advances for mechanized apple harvest in NY and the US.

## Labor-Positioning Motorized Platforms

The use of motorized platforms for pruning was popularized by northern Italian growers in the South Tyrol region more than 20 years ago. However due to few tall, high-density orchards in the US and our system of contract pruning there were few platforms put into use here. With the rapid adoption of Tall Spindle orchards over the last 10 years, the use of motorized platforms has increased rapidly in New York State with approximately 50 platforms being used in NY Tall Spindle apple orchards. The platforms range from simple tractor pulled wagons built by growers to self-propelled single row or 2-row machines built in factories.

The simple wagon type of platforms built by growers have low cost (often built from scrap materials already on the farm) but have few adjustable features, require a tractor driver and often do not have adequate safety features. In contrast factory built machines have the proper safety features and adjustable features but are more expensive. There are currently 2 dealers of Italian factory-made platforms in North America (McQueen's, of Wolcott, NY who sells the N-Blosi platforms and Bartlett's of Beamsvillle, Ontario, Canada who sell the Orsi platform). There are also 3 platform manufacturers in the US (Lagasse Works, Lyons, NY, Phil Brown Welding, Conklin, Michigan and BlueLine Manufacturing, Yakima, WA). Each of the US manufactures has a self-propelled version, which are more expensive and a tractor pulled version, which are less expensive. With many of the tractor drawn platforms innovative tractor controls have been mounted on the platform, to eliminate the need for a dedicated tractor driver.

The widespread interest in platforms has resulted in 2 new platform prototypes for NY growers in 2012 (Figures 1 and 2). Both platforms were designed and built (from the ideas of Scott VanDeWalle of Alton, NY) by LaGasse Works, of Lyons, NY, USA. Both are mounted on four-wheel drive tractors with the addition of a creeper gear in the transmission. Both have a 7 ft. x 9 ft. platforms mounted over the hood of the tractor from which two workers can prune adjacent trellis walls. The larger of the two has two additional 4 ft. x 5 ft. outboard platforms suspended from booms, which can be swung out, over the adjacent rows. Each of the outrigger platforms carries a single worker. Thus, with four workers, two rows of trees can be trimmed at once while the tractor creeps along. Steering, forward motion engagement, and emergency stop features are accomplished remotely from the platform. The two new platforms were first used during the 2012 dormant pruning season with good results and pruning efficiencies averaged between 25-30%. LaGasse Orchards is cur-

rently building three more of the single row platforms for three more Western New York fruit growers. The cost of the single row trimming platform is approx. $12,000. Market price for the over-the-row trimming platform is not determined yet.

The same concept of using a platform mounted over the top of a four-wheel drive tractor was also recently developed by Burrows Tractor, Wenatchee, WA. Their self-propelled platform has a remote steering unit and can also be removed from the tractor, which allows the grower to use tractor for other orchard tasks the rest of the year. This "Burrows platform + tractor package" of a mounted platform on a 35hp New Holland tractor is offered at approximately $19,400 dollars.


**Figure 1. A 7 ft. x 9 ft. platform mounted over the hood of a tractor from which two workers can prune adjacent trellis walls. Notice the self-steering mechanism incorporated with the platform.**

**Figure 2. A 7 ft. x 9 ft. platform mounted over the hood of a tractor from which two workers can prune adjacent trellis walls. It has two additional 4 ft. x 5 ft. outboard platforms suspended from booms, which can be swung out, over the adjacent rows. Each of the over-the-row platforms carries a single worker.**

The main advantage of worker positioning platforms is the time and labor savings of not carrying ladders through the orchard, and climbing up and down to perform various jobs. In addition, there are two other potential advantages to using an orchard platform: (1) encouraging the same work speed of an entire work crew, with the intention of increasing productivity and preventing over/under pruning or hand thinning of trees that can happen when the rate of speed down the row is NOT controlled (as with ladders), and (2) human physical effort is reduced (if managed well), allowing a wider labor pool, people who could not climb up and down a ladder repeatedly during the day may now be able to perform this work. By using platforms, dormant pruning work is definitely less physically demanding for workers when they no longer have to climb ladders while carrying pruning tools.

There may also be disadvantages to a motorized platform. If the person managing the platform crew and setting the work speed is not experienced the work speed may be too slow resulting in idle workers or may be too fast resulting in excessive stress on the workers. If jobs are not rotated throughout the day and care is not taken to prevent repetitive motion injury there may be more injuries from work on a platform. If there are no provisions for worker comfort or there are conflicts within the crew that are not addressed in a timely, effective manner worker satisfaction may be poor. Using an experienced team manager on the platform is critical to successful platform productivity and worker satisfaction.

There are many jobs in addition to dormant pruning that can be completed using a platform: stringing and fastening multiple trellis wires; installing wire tighteners and vertical support wires; fastening trees to the wires, installing mating disruption dispensers, summer pruning, hand thinning, and harvest. U-Pick operations can harvest the tree tops while allowing the bottoms to be harvested by the U-pick customers. This will help avoid customers falling off ladders or ruining fruit and trees while trying to reach fruit in the upper portion of the tree.

Miranda Sazo *et al.,* (2010) studied labor efficiency with a platform and showed that dormant pruning time was reduced from 1.26 minutes/tree to 0.92 minutes/tree when the same workers utilized a platform and pruned mature Gala and McIntosh's Tall Spindle trees on a dwarfing rootstock in Wolcott, NY. The prun-

**Figure 3. Very little regrowth occurred after mechanical summer pruning and a new shoot was developed with a terminal floral bud. Shoot responses to mechanized summer pruning can vary according to cultivar, tree vigor, and time of cut during the summer.**

**Figure 4. With a Super Spindle tree and 10-11 ft. row spacing the hedging is done one ft. from the trunk (the fruit wall is very narrow).**

ing platforms reduced labor costs by about 27-30 percent. There was little difference in labor efficiency between the three types of platforms used. An economic analysis of investment in a platform, showed that the use of a motorized platform could save $102/acre, $104/acre, and $45/acre for dormant pruning, hand thinning and trellis installation respectively. A 2012 study (Miranda Sazo and Robinson, unpublished) compared the efficiency of hand thinning of four workers with a platform pulled by a tractor (self-steered) and measured a saving of $150/acre when the same workers hand thinned Gala trees with ladders.

## Mechanization of Summer Pruning by Hedging

When managed correctly, the Tall Spindle apple system at maturity gives a narrow, tall fruiting wall with good fruit quality due to good light exposure in the narrow canopy. After year 5, partial mechanization of dormant pruning by using labor positioning platforms has increased dormant pruning labor efficiency by 25-40%. Further mechanization of pruning by using side wall shearing of the tree canopy in the summer with a cutter bar may offer further reductions in annual pruning costs of the tall spindle. Although mechanical pruning that was conducted in the 1960's and 70's it was generally unsuccessful because it resulted in excessive regrowth and poor fruit quality due to vigorous rootstocks and the cutting of large limbs. However, current NY high-density Tall Spindle orchards are now more suitable to mechanized pruning due to the use of dwarfing rootstocks, a better managed and calm tree, and the presence of more small pendant fruiting branches (15-18 branches) at year 5 or 6.

The recent efforts to mechanize pruning were begun by Alain Masseron and Laurent Roche of CTIFL (Center for Techniques of Production and Distribution for Fruit and Vegetables in France) about a decade ago. They began mechanically shearing Tall Spindle trees in the early summer to develop a narrow fruiting wall they named "Le Mur Frutier" (The Fruiting Wall). The trees were sheared in early June (when shoots had about 8-10 leaves) about 15 inches from the trunk. The tops of the trees were also cut mechanically at 10-11 feet height. This left a tall rectangular tree which was confined to a space 32 inches wide by 10 feet tall. Little shoot regrowth occurred at this timing and especially when the trees were carrying a full crop which utilized much of the carbohydrates the tree produces for fruit growth. Some commercial fruit growers who have adopted this system prune only mechanically each year in June with no additional hand pruning. Other commercial fruit growers who have adopted this system implement a follow up dormant hand pruning every third year. The mature fruiting wall tree has many weak and fruitful side branches within the rectangular space allowed by the hedging machine but no branches that extend out into the alleyway between rows.

The initial good success of mechanized summer pruning conducted by CTIFL in France was followed by research trials in Italy (Alberto Dorigoni), Spain (Ramon Monserrat), and Germany (Gerhard Baab). In 2011 and 2012 we began several hedging trials in NY State to study the benefits of mechanized summer pruning of NY Tall Spindle orchards. Our experiments involve both Tall Spindle trees and Super Spindle trees on M.9 or B.9 rootstocks.

Our main goal of mechanized summer pruning is to have a narrow fruiting wall with good light distribution but not create a vigor response in the tree and reduce pruning costs by 2/3. A second important research objective is to study the shoot response of several important apple cultivars in NY State to mechanized summer pruning timings and severities. The ideal response to the mechanical summer cut is to generate a short shoot regrowth (3-8 inches long) with a terminal floral bud (Figure 3) instead of a vegetative bud. The correct timing of mechanical summer pruning is critical for maximum floral bud initiation during the early part of the summer so a very a productive and efficient fruiting wall can be started.

## Materials and Methods

Initial exploratory hedging trials in 2011 led to 5 replicated trials in 2012 at the following sites: (1) VanDeWalle Orchards, Alton, NY with Tall Spindle Gala and McIntosh, (2) Lamont Fruit Farms, Albion, NY with Super Spindle Macoun, Honeycrisp, Aceymac and Gala, (3) Crist Bros Orchard, Marlboro, NY with Tall Spindle Gala and Jonagold, (4) Everett Orchards, Peru, NY with Tall Spindle McIntosh and (5) at the Agricultural Experiment Station in Geneva,

NY with Tall Spindle Gala, Jonagold, Golden Delicious and Fuji. For sites 1 and 2 the hedger cutting bar was positioned almost vertically along the hedge of the canopy (Figure 4). The VanDeWalle site had two severities of hedging at 12 and 24 inches from the trunk. The Lamont site had one severity of hedging at 18 inches from the trunk. For sites 3, 4, and 5 the hedger cutting bar was positioned at a slight angle along the edge of the canopy 24 inches from the trunk at the base of the canopy and 12 inches from the trunk at the top of the canopy (Figure 5). In each study we evaluated the effect of timing of summer sidewall shearing (first week of June, first week of July and first week of August) on Tall Spindle apple trees. At the Lamont site (using mature Super Spindle apple trees) we also evaluated an earlier timing (first week of May) and at the Everett site we only evaluated the early August timing. Tops were not mechanically pruned. For all studies we evaluated proportion of shoots on the whole tree which were cut by the machine, number of fruits cut off, shoot re-growth, light intensity in the canopy at 3 heights and fruit quality at harvest. We plan to evaluate return bloom next spring (May 2013). At each location fruit yield was recorded at harvest and a fruit sample was collected to evaluate fruit color and sugar content.


**Figure 5.** With a Tall Spindle tree and a row spacing of 12 ft. the hedging is done 2-3 feet from the trunk. A Tall Spindle canopy should be an angled wall of 4 ft. wide at the base and 2 ft. wide at the top.

**Figure 6.** A Tall Spindle tree converted to a fruiting wall at Pomanjou, Angers, France. (Photo courtesy of Michel de la Sayette).

**Table 1.** Effect time of summer hedging on percentage of shoots cut off, number of fruits cut off and shoot regrowth at Geneva, NY 2012.

| | % of Shoots Cut Off | | | N of Fruits Cut Off | | | Shoot Regrowth (cm) | | |
|---|---|---|---|---|---|---|---|---|---|
| **Variety** | **June** | **July** | **August** | **June** | **July** | **Aug** | **June** | **July** | **Aug** |
| Fuji/M.9 | 33.2 | 36.7 | 29.5 | 8 | 2 | 6 | 24.1 | 13.6 | 0 |
| Golden/M.9 | 32.9 | 35.3 | 28.5 | 6 | 1 | 2 | 14.3 | 12.4 | 0 |
| Jonagold/M.9 | 25.7 | 24.4 | 28.2 | 7 | 7 | 5 | 28.2 | 22.6 | 0 |
| Gala/M.9 | 35.4 | 38.6 | 44.6 | 13 | 13 | 2 | 20.2 | 5.7 | 0 |
| **Average** | **31.8** | **33.8** | **32.7** | **8.5** | **5.8** | **3.8** | **21.7** | **13.6** | **0** |

## Results

Summer sidewall shearing was fast and left the trees with a "manicured" look (Figures 4 and 5). The cost and time amounted to a fraction of the time (5%) to do manual summer pruning. At each of the summer timings the shearing cut an average of 30% of the growing points on the tree (range 24-44%) (Table 1). This means that about 70% of the growing points on the trees were not touched by the machine. When the sidewall shearing was done at bloom there were some flowers cut off but the grower viewed it as a dormant pruning. However, when the sidewall shearing was done in June, July or August some fruits were cut off and the growers were more concerned. Fruit counts showed that the number of fruits cut off was about 5 fruits/tree (range 1-13%) (Table 1) and would be no more than dropped to the ground by hand thinning.

PAR (photosynthetically active radiation) measurements at each site showed that the summer sidewall shearing improved light intensity in the lower part of the canopy by about 10%. There was little improvement of light exposure in the top of the canopy. The trees we used in these studies had canopies already quite well shaped for good light distribution and the shearing removed only a small portion of the shoots and thus had a small effect on light distribution in the canopy.

The sidewall shearing treatments did not induce vigorous shoot regrowth regardless of the timing of the mechanical pruning. However, with the early timing (early June) we saw the development of short re-growths (8 inches) with a terminal bud, which likely will be flower buds next spring. With the July timing regrowth was about 5 inches and at the August timing there was no regrowth at all (Table 1).

At harvest there were no large differences in fruit color among treatments. However, the sidewall shearing treatments had slightly better fruit color than the unsheared controls.

## Discussion

Our first year results with summer shearing were positive but will require 2 more years to fully determine if this approach has long term positive results or if negative tree growth will negate the labor savings from mechanical sidewall shearing. If side-wall shearing in the summer can reduce summer pruning costs by 95% and improve fruit color without negative effects on return bloom or vigorous growth response it will also have a significant impact on orchard profitability. Results from 2012 are encouraging so far in that there was little or no regrowth from the sidewall shearing treatments with the Tall Spindle system. It appears that the early July timing was the best since it had short regrowth with terminal flower buds

A long-term strategy that a grower in France (Pomanjou) has implemented is to use annual side-wall shearing of Tall Spindle trees for 3 successive years with no other dormant pruning but

in the third year to add a dormant winter corrective pruning to remove limbs that have become large and are causing internal canopy shading and poor fruit quality (Figure 6). Such a pruning strategy could reduce total annual pruning costs in Tall Spindle orchards by about 65% and help NY apple growers remain profitable and competitive.

Bruno Billote, another French apple grower converted his orchard seven years ago to mechanical pruning. His orchard has only had a modest manual pruning input in three of the intervening years and he has been able to keep a narrow wall with mechanized pruning. He prefers the early timing (March/early April). When he tried mechanical pruning in early June, mildew and scab became a problem. He concludes there are some limitations with a fruiting wall: (1) tree height is limited, (2) production (on Gala) is limited to 70-80 ton/ha, and (3) fruit size tends to be about 5 mm smaller. He suggests Golden Delicious performs well with a wall width of 60cm, Honey Crunch with a wall width of 70-80cm, Gala requires a wall width of 80cm, while Granny Smith requires a width of 1m.

Alberto Dorigoni, an Italian scientist from the Agrarian Institute of Saint Michele suggests that different mechanical pruning timings could provide different benefits. Mechanical pruning in winter, could be used in moderate-growing orchards, with the aim of shaping trees for the following early summer shearing. Hedging at Pink bud is useful to prevent a little bit the regrowth, while early summer (8-12 leaves) to maximize flower differentiation and reduce regrowth. Mid-summer minimizes regrowth, and hedging pre-harvest increases fruit color, while hedging after harvest reduces regrowth and shape trees and the fruit wall for winter pruning. He is currently studying the use of a "Window Pruning Machine", or WMP.

## Robotic Pruning

In the USA there are several efforts to utilize robotic technology in orchard tasks to reduce hand labor. In our opinion the current efforts to develop robotic harvesters will require many more years of research and development due to the extreme complexity of identifying the fruit location, detaching the fruit without bruising, and transporting the fruit to the bin without bruising and may not be practical. However we believe that robotic pruning has a greater potential for success in future Tall Spindle orchards for the following reasons: (1) leaves will not interfere since dormant pruning is done in the winter, allowing the tree structure to be highly visible, (2) the sparse nature of newer tree architectures such as the Tall Spindle allows branches to be visible and reachable by a robot, and (3) when branches are cut, they do not have to be handled with care, unlike fruit.

The robotic pruning process will include sensing the tree with digital cameras, constructing a virtual three dimensional model of the tree, making pruning decisions based on branch lengths, diameters, and density and finally, directing a robotic arm with cutter blades to cut at the branch locations determined from the previous step.

To facilitate such robotic pruning, we believe that future orchards for robotic pruners will basically need simple trees with no permanent branches such as the Tall Spindle or the Super Spindle, and one or two simple pruning rules. The Tall Spindle could be adapted to such robotic system since pruning could be simplified to the single rule of removing any branch that is larger than 2 cm in diameter.

**Figure 7. A fruiting wall of Pink Lady done by Ramon Monserrat at IRTA research station in Lleida, Spain.**

**Figure 8. A fruit wall of Pink Lady with tri-axis trees at Trento, Italy. (Photo courtesy of Alberto Dorigoni).**

Such robotic pruning technology is possible and would be a valuable tool in orchard management. However, its value to apple growers must be evaluated in economic terms. If the technology is costly with only a small gain in efficiency it will not be of any significant value. If the mechanized shearing in the summer results in reduced costs with good fruit quality it will be much cheaper than a robotic pruner machine. The more costly, complicated and risky the technology, the more thorough the evaluation needs to be (O'Rourke, 2013).

## Summary

NY apple growers are rapidly adopting the Tall Spindle planting systems. This is allowing them to adopt motorized labor positioning platforms to reduce pruning, hand thinning and summer pruning costs. There are several new and innovative "design concept" for a motorized mounted platform mounted over a tractor initially developed in NY State, and more recently also available in Washington State. This type of equipment promises versatility, easy maneuvering in snow, higher efficiency, and a much lower investment. The cheapest mounted platform option with self-steering mechanism without considering tractor cost starts at approx. $12,000 dollars ($12, 300 dollars for a model with a self-leveling feature) with potential use for medium as well as high-density orchards.

In the future pruning costs may be reduced even further with mechanized summer side-wall shearing. This technology works best with proper trellis design and with tree planting with GPS guided tractors for straight rows. A long-term mechanization strategy that we envision is to use annual side-wall shearing of Tall Spindle trees for 3 successive years with no other dormant pruning but in the third year to add a dormant winter corrective pruning with a motorized platform to remove limbs that have become large and are causing internal canopy shading and poor fruit quality. Such a pruning strategy with the use of a motorized platform in the winter and a hedger in the summer could reduce total annual pruning costs in Tall Spindle orchards by about 65% (averaged over 3 years) and result in a narrow, tall fruiting wall (Figure 7).

The modification or adaptation of a Tall Spindle orchard system to a fruit wall concept could be well suited to the majority of NY apple cultivars. With some cultivars the system may involve a 2 stem tree (bi-axis) or a 3-stem tree (tri-axis) to manage vigor (Figure 8). It could also allow for cheaper production of a similar quantity and quality of fruit (size, color, and eating quality) as from current mature Tall spindle apple orchards. Potentially, the size and color of the fruits could be more uniform as a result of better light penetration and distribution. The water volume needed for good spray coverage for pest control could also be reduced. The uniformity of chemical thinning could also be improved and the fruit wall could be thinned mechanically with the Darwin machine as long as we reduce the potential spreading of fire blight in the orchard during blossom. The fruit wall concept using Tall Spindle trees will increase even more the performance of motorized platforms, future harvest equipment, and worker efficiency. To take full advantage of these advances in mechanization, new orchards should be established at a spacing of 2.5-3ft x 11-12 ft. Trellises should use 12 ft. posts, a correct post spacing of not more than 30 ft., and a minimum of four or five wires.

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