ESTABLISHING A CIDER APPLE ORCHARD FOR MECHANIZED MANAGEMENT

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Establishing a Cider Apple Orchard for Mechanized Management

By,

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Preface

The goal of this manual is to provide commercial cider apple growers with orchard management options that will reduce the need for orchard labor. Specific objectives are to provide guidance to growers in:

1. Establishing a fruiting wall that will allow for mechanized management.
2. Mechanically managing a fruiting wall to optimize fruit yield and quality.

Equipment to be used depends on the scale of the orchard and available financial resources (Figure 1). Note that for small-scale growers, who may find mechanical harvest equipment unaffordable, mechanized thinning and pruning followed by hand harvest could still significantly reduce labor needs.

Introduction

Washington State has been dealing with labor shortages across the agricultural sector for many years (Thilmany 2001). Short-term strategies for managing labor shortages have included adjusting growing practices, increasing off-season activities, and increasing wages. Long-term strategies have included shifting to less labor-intensive crops and increasing investment in mechanization.

For cider apple production, mechanization of pruning, thinning, and harvest requires an orchard training system that is suitable for medium-to-high-density plantings that are characterized by a **planar** canopy that is about two feet in width and includes long continuous rows that all allow for safe and cost-effective use of equipment. A major obstacle to mechanization has been the high upfront capital required for establishing a compatible orchard infrastructure including the purchase or leasing of equipment.

Researchers at Washington State University Northwestern Washington Research and Extension Center (WSU NWREC) in Mount Vernon have been assessing the impact of mechanization on cider orchard profitability since 2011, evaluating fruit and cider quality as well as yield (Alexander et al. 2016; Miles and King 2014), and developing enterprise budgets (Galinato et al. 2014; Galinato et al. 2016; Galinato and Miles 2016). From 2014 to 2016, WSU NWREC researchers established a replicated research orchard of 65 cider apple cultivars on G935

Figure 1. Hand-held pruner (top left), lopper (bottom left), and tractor-mounted hedger (right). (Images by T.R. Alexander, WSU; Dan LaGasse, LaGasse Works.)

rootstock (Figure 2) to allow for the testing of mechanized hedgers, thinners, and harvesters (Figure 3), ultimately, to provide growers with this orchard management guide.

This manual outlines a specific management plan for a cider apple orchard that is designed for mechanized pruning, thinning, and harvesting. This manual also provides a first-hand account of WSU NWREC researchers implementing this management plan through the establishment of a cider apple orchard under maritime climate conditions. The experiences at WSU NWREC may be especially applicable for small-scale growers, as a lower-cost, hand-held hedger was used for mechanical pruning rather than a tractor-mounted hedger.

Apple Cultivar Habit

Apples can be classified into four cropping types based on branch development and fruiting habit (Figure 4) (Lespinasse 1977; Lespinasse 1980). The areas where flowers and fruit are borne on a tree depends on the type of bearing wood present, and this knowledge is used to guide the pruning and training of a tree (Musacchi and Green 2017; Sansavini and Corelli 1990).

Type I (e.g., 'Gravenstein')

Strong tendency to branch toward the base of the trunk (**basitonic**). The **central leader** is relatively weak. The majority of fruit spurs are located on wood that is two years and older. Since the fruit remains close to the main branches, the fruit zone follows the tree's main axis.

Type II (e.g., 'Reinette Russet')

Moderately basitonic, especially on vigorous rootstocks. The central leader is relatively dominant. The majority of fruit spurs are located on wood that is two years and older.

Type III (e.g., 'Cox's Orange Pippin')

Branches are at wide angles (60° to 90°) to the trunk. The central leader is relatively dominant. Fruiting spurs are principally situated on wood of one to three years of age. There are numerous coronate twigs (short shoots). The fruit zone is away from the center of the tree.

Type IV (e.g., 'Golden Russet')

Strong tendency to branch away from the trunk (**acrotonic**). Main branches elongate through successive arching. The majority of fruit spurs are located on wood that is one or two years of age. The fruiting zone moves towards the outside of the tree, especially in 'Granny Smith'.

Figure 2. WSU NWREC's replicated cider apple research orchard at fourth leaf (Summer 2017). (Photo by T.R. Alexander, WSU.)

Figure 3. Mechanized thinning (top left) and pruning (bottom left) of apples, and mechanized harvesting of tart cherries (right). (Photos by R.J. Anderson, Cornell Cooperative Extension; Christina Herrick, Western Fruit Grower; Dan Setniker, Littau Harvester.)

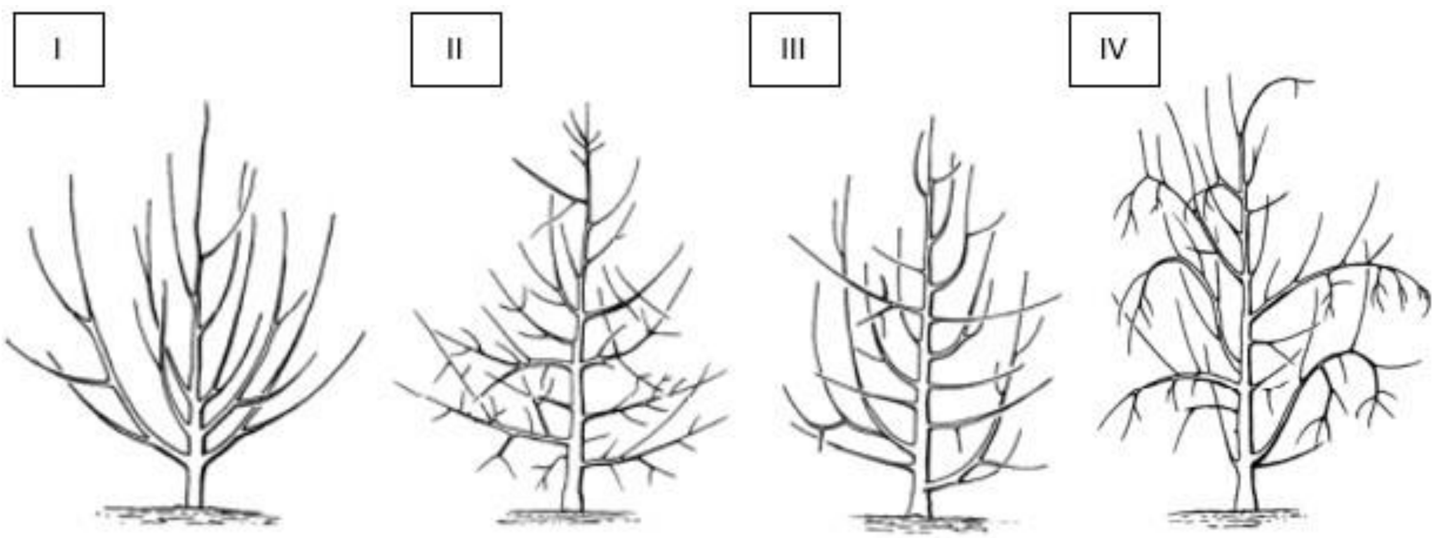


Figure 4. The four cropping types (I to IV; left to right) established by Lespinasse (1977 and 1980). (Image modified by T.R. Alexander, WSU.)

MANAGEMENT PLAN

Year of Planting

Site Preparation: Pre-plant soil applications provide the best opportunity to amend the entire soil profile and may be the only time to significantly alter the subsoil (Moulton 1995). The following are general guidelines for fertilization; see the Resource Information section for collecting soil samples and more in-depth guides on fertility management. Collect soil samples at the topsoil (1 to 8 inches) and subsoil (8 to 16 inches) depths. A complete soil analysis should provide information on soil organic matter and pH, cation exchange capacity (CEC), major and micro nutrients, and percent of CEC made up by Calcium (Ca), magnesium (Mg), and potassium (K). A sandy soil will generally have a lower CEC and heavy soils a higher CEC. Organic matter (e.g., manure) will raise the CEC.

Apply fertilizers pre-plant and in subsequent seasons, in response to soil test analysis. Broadcast fertilizer into the tree row, and lightly incorporate using a disc or harrow. Apply fertilizer within 60 days or less of planting. Alternatively, you may apply part of the fertilizer pre-plant and the remainder after the trees have been planted using fractionated application through the irrigation system (fertigation). Table 1 provides typical tree nutrient uptake rates from the soil and loss rates from the harvesting of fruit, assuming a moderate to high yield for the apple cultivar.

Tree Selection: There are two components of a cider apple tree that need to be considered when deciding what material to plant. One component is the **scion**, the top of the tree that will produce the fruit, and the second component is the rootstock, the bottom of the tree that will take up water and exchange nutrients. The scion should be chosen for desired fruit production characteristics (e.g., size, color, and taste). Fruit characteristics have been found to vary with growing region and, therefore, growers should reference cultivar performance data originating from production areas most similar to their own.

The rootstock should be chosen in response to multiple factors, including desired whole tree size (Appendix 1, Figure 16), time from planting to fruiting, and resistances to environmental forces and diseases. As there does not exist a perfect rootstock, growers should select for the factors that are most relevant for them. A grower in western Washington need not select a rootstock for resistance to fire blight (*Erwinia amylovora*) as this disease is not prevalent west of the Cascades.

There are five major series of rootstocks currently utilized in the United States: Budagovsky (Bud; from Russia), East Malling-Long Ashton (EMLA; from England), Geneva (G; from New York), Malling and Malling-Merton (M, MM; from England), and Michigan Apple Rootstock Clones (MARK; from Michigan). It is important to note that the Malling rootstocks were not assigned Roman numerals in order of tree size; for example, 'Malling-9' produces a smaller tree than 'Malling-2'. The Malling-Merton rootstocks were developed in an effort to achieve woolly apple aphid (*Eriosoma lanigerum*) resistance. The East Malling Long Ashton rootstocks were developed in an effort to remove viruses and scion-rootstock incompatibilities.

The Geneva rootstocks were developed in an effort to provide US growers with rootstocks that are resistant to fire blight, crown and root rot (*Phytophthora* spp.), apple replant disorder, woolly apple aphid, and can also exhibit cold hardiness—all across a spectrum of whole tree size. Rootstock

Table 1. Typical nutrient uptake and removal rates in apple production, assuming a moderate to high yield for the apple cultivar (Spectrum Analytic Inc. 2017).

Nutrient Sink	**Lb/Acre**					
	N	**P_2O_5**	**K_2O**	**Ca**	**Mg**	**S**
Tree Nutrient Uptake[1]	90–120	45–80	150–240	50–80	20–32	20–32
Fruit Nutrient Removal[2]	30–50	30–60	75–120	8–13	5–8	10–16

[1] Rate at which the average mature apple tree takes up a particular nutrient from the soil. The rate will differ with soil type, soil moisture, and temperature.

[2] Rate at which nutrients are lost from the average mature apple tree due to the harvest of fruit. The rate will differ with cultivar and yield.

The WSU Cider Research program has information regarding the performance of 50+ specialty cider apple cultivars in a maritime climate; see, http://cider.wsu.edu/varietal-evaluations/.

The WSU Tree Fruit Research program has information regarding the performance of various Malling and Geneva rootstocks in a semi-arid climate; see, http://treefruit.wsu.edu/varieties-breeding/rootstocks/.

attributes have also been found to vary with growing region, and, therefore, growers should reference performance data originating from production areas most similar to their own.

Tree Establishment: Plant trees as soon as possible upon receipt. If immediate planting is not possible, prevent drying of the root system by storing the trees in a cold room with high humidity and no trace of ethylene (i.e., fruit) or by placing them in a trench backfilled with moist sawdust or wood chips, a process termed "**heeling**". If using a trellis structure, it is better to install the trellis before planting, to take advantage of the support system. See the Resource Information section for guides on establishing an orchard trellising system, and the Lessons Learned section for a description of the trellis system installed at WSU NWREC.

If you plan to use an over-the-row tree fruit harvester, posts should be 10-feet high; the length of post needed and the depth it should be set in ground will vary, depending on factors of soil composition, slope, and drainage conditions. There exist multiple pieces of harvesting equipment that could be suitable for the various scales of cider apple production, and the following are important considerations for every grower: dwarfing rootstocks such as 'Malling 9' and 'Geneva 65' are susceptible to root and trunk damage if directly shaken; the use of ground-harvested apples to produce alcoholic cider requires orchard management and food processing strategies to be covered under the Food Safety Modernization Act Produce Safety Rule (Ewing and Rasco 2018); and yield efficiency is heavily influenced by bearing habit (where and how fruit are born).

Plant trees using a relatively narrow spacing in the row (no more than 4–6 feet) so that mature trees form a fruiting wall and trees are sturdy enough to withstand mechanical harvest. Spacing between rows must be adequate for mechanical harvesters: 15 feet is adequate for most equipment, but spacing should be adjusted based on vigor of the trees and width of the specific equipment that will be used in the orchard. This tree spacing results in an orchard density of 484–726 trees per acre, which is not considered a high-density orchard. However, the in-row spacing and the fruiting wall training system are high-density orchard methods.

Plant the trees such that the **graft union** is at least three inches above ground level to avoid scion rooting or rotting (Figure 5). Planting can be done with a mechanical tree planter, in holes dug by hand, or with a tractor-driven auger, generally 1 1/2-feet wide by 2-feet deep. Alternatively, open furrows with a plow before planting (Figure 6). Start training the trees by immediately tying the trunk to the stake and clipping branches to the wires.

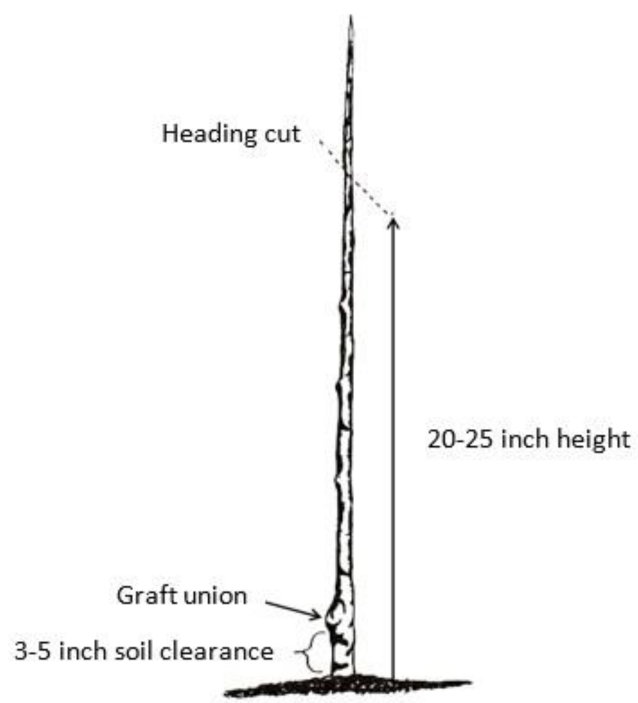


Figure 5. Properly planted and headed whip. (Image by T.R. Alexander, WSU.)

Before **budbreak**, head trees that have few, or no, branches (trees commonly termed whips) to a bud at the lowest wire, optimally 20–25 inches from the ground (Figure 6). If trees are well **feathered**, there is no need to head the main stem but shorten the **lateral** shoots by one third. Remove all the branches in the lower position (below 20 inches). Immediately treat cut wood if disease is common in the area (e.g., use a copper paste or paint to prevent anthracnose canker in maritime climate) (Crump 2009). Coat trees with an elastic paint mix from the soil line to the lowest wire, with an emphasis on areas of external physical contact (e.g., where wood may rub against wire). Diluted elastic paint has been found to provide some protection against bark splitting, sunburn, and herbivore damage (Sigler 2012).

Manage pests the first year and thereafter in accordance with local pest management guides; see the Resource Information section for more information. Table 2 provides an example of the pest management schedule that was followed at WSU NWREC in 2017.

Table 2. Pest management schedule at WSU NWREC in 2017.

Date	**Target**	**Pesticide**[1]
February	Annual and perennial weeds	Herbicide: Glyphosate
March to July	Leaf spot, powdery mildew, scab, brown rot	Fungicide: Ziram, Topsin M, Rally 40 WSP, and Manzate Prostick in combo and rotation
April	Tent caterpillars	Insecticide: Dipel DF
June to July	Codling moth	Insecticide: Assail w/ R-11 surfactant
July	Annual and perennial weeds	Herbicide: Gramoxone and Prowl H_2O

[1] Pesticides are provided only as an example and are not meant to endorse products listed nor detract from any products not listed. Check pesticide labels prior to application to confirm their registration and for specific instructions regarding timing and rate.

Figure 6. Furrows opened to facilitate planting (Ferrara, Italy). (Photos by S. Musacchi, WSU.)

Growing Season: After 3 to 4 inches of new growth, head or thin lateral shoots that are competing with the leader (Figure 7). Heading cuts result in a strong vegetative response with one shoot that becomes dominant over the others. The shoots produced by heading the tree will have a narrow **crotch angle**. In contrast, thinning cuts involve the complete removal of a branch, and energy will be diverted more evenly into new branches (Figure 8).

Spread emerging lateral branches outward to achieve strong crotch angles (45–60°)—that will reduce vulnerability to wind and ice damage and will support a heavy fruit load (Figure 9). Training trees in their first and second years so that branches are bent between 45° and 60° will also help to develop buds closer to the trunk. Tools that are effective for spreading small, young branches include clothespins, concrete weights, rubber bands, and string (Figure 10). Longer spreaders of plastic or wood can be used on larger branches.

Spreading of lateral branches has the effect of reducing vigor, so excessively wide crotch angles (greater than 90°) should be avoided when first establishing trees. Physical implements utilized to bend limbs should be left in place until such time that the limb has stiffened and can maintain the targeted branching angle without external support, generally one season being sufficient. Implements should not be left in place longer than is necessary as they can cause wounds on branches that become potential infection sites.

Remove all blooms within 30 days of petal fall so that there is no fruit production the first two years that trees are in the orchard. The goal in the first two years is to channel all energy into vegetative production so the tree can support maximum long term yield. Also, keep in mind that fruit will put excessive weight on young branches, causing them to break.

There are three physical methods of removing blooms: plucking them by hand, removing them with a battery-powered hand-held string thinner, or removing them with a tractor-mounted motorized string thinner. The first method is labor intensive, the second method’s efficiency is dependent on the capacity of the operator, and the third method requires a relatively large up-front capital investment ($10,000 or more). Growers can also chemically remove blooms with the application of plant growth

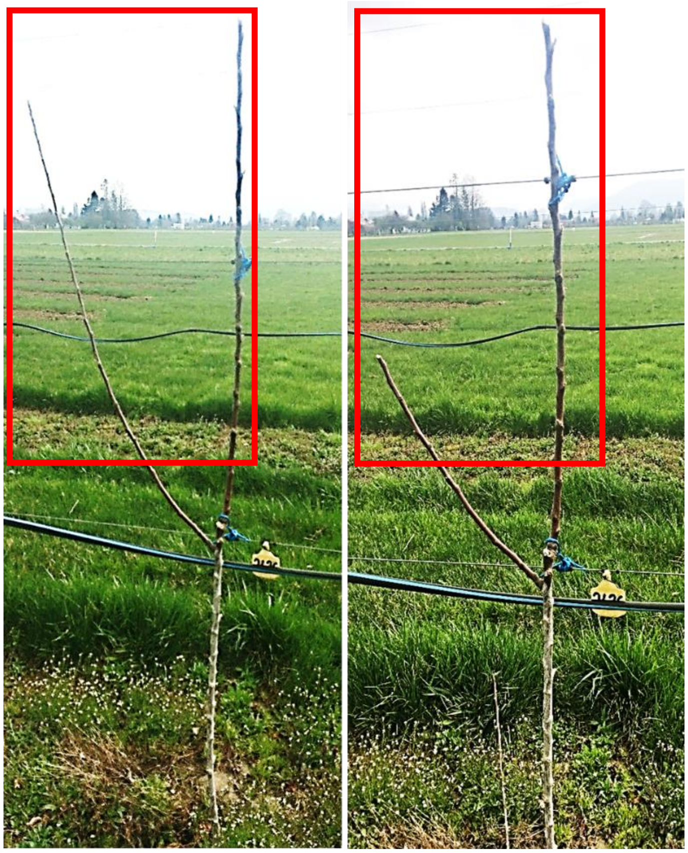


Figure 7. Lateral shoots will compete with the leader, as demonstrated in the box on the left (left photo) and should be trimmed back (box on right; right photo) or physically manipulated (e.g., clipped to horizontal wire), so as to maintain the apical dominance of the leader. (Photos by T.R. Alexander, WSU.)

regulators (e.g., MaxCel). The action of chemical thinners is not immediate, and efficacy is influenced by multiple factors including light, temperature, and moisture.

Irrigation scheduling the first year and thereafter can be conducted with the assistance of mobile applications, such as WSU AgWeatherNet Irrigation Scheduler or Purdue University's Irris Scheduler (WSU 2017; Purdue University Agronomy 2017). These programs generally use the inputs of soil type, temperature, and rainfall to estimate water use and should be used in conjunction with onsite measurements to create a more precise schedule that fits your orchard. See the Resource Information section for links to the online programs.

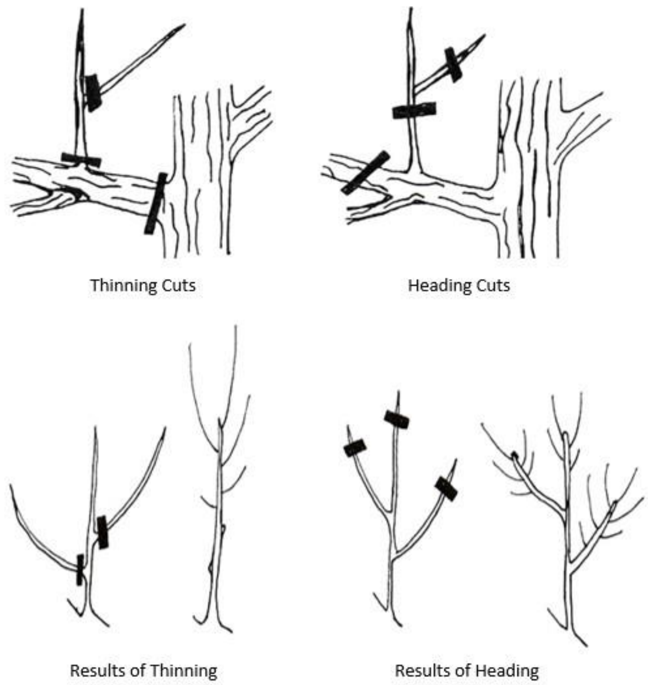


Figure 8. Two types of pruning cuts, thinning and heading, and their impact on vegetative growth. (Image by T.R. Alexander, WSU.)

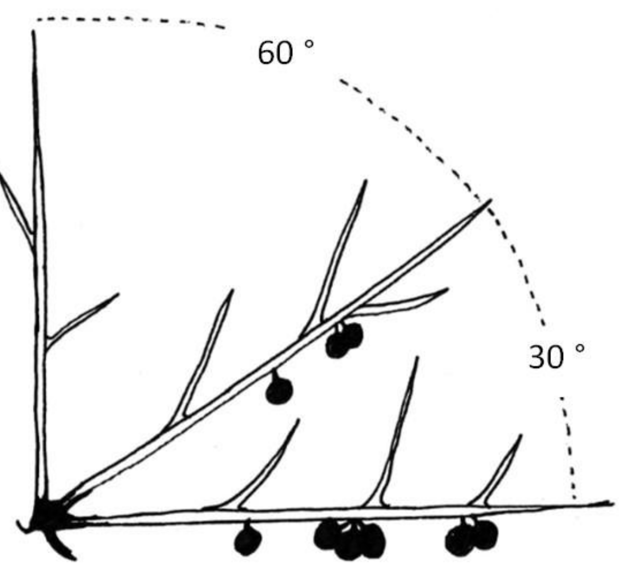


Figure 9. To achieve a balance between vegetative growth and fruit production, a branch should be trained 30° above horizontal, a 60° crotch angle. (Image by T.R. Alexander, WSU.)

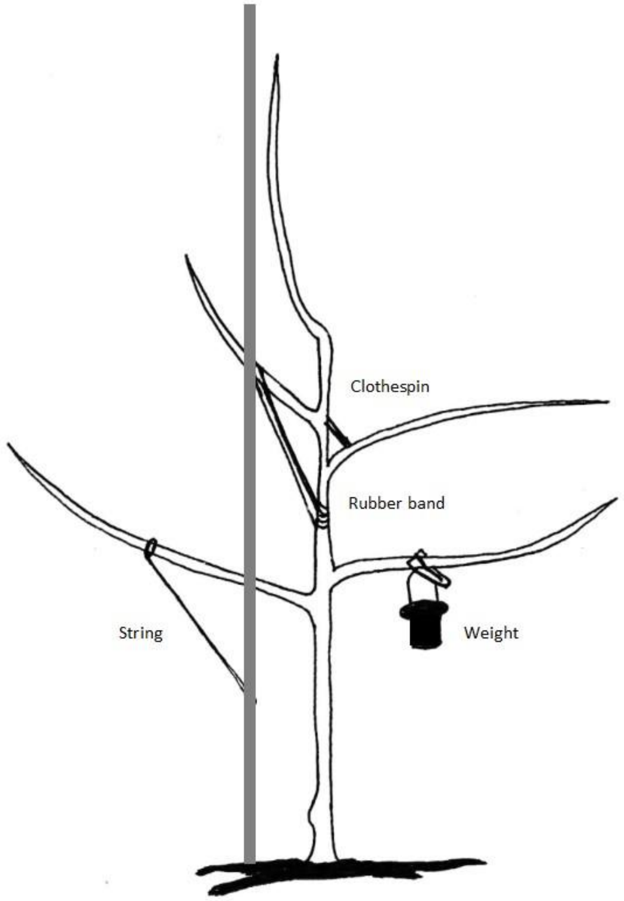


Figure 10. Various methods of physically manipulating crotch angle. (Image by T.R. Alexander, WSU.)

Overall, it is critical that young trees are provided with sufficient water, that competition from weeds is minimized, and that pests are monitored regularly and actively controlled. It is very hard for trees to recover from deficiencies that occur in the first year.

2nd Leaf

Dormancy Period: Re-assess the leader, ensuring that it is tied to the wire and that all the upright competing shoots are removed or trimmed back. To minimize hand pruning over the long run, it is crucial that hand pruning be employed with accuracy. See the click pruning method in the Resource Information section (Musacchi 2017). Prune back branches with narrow crotch angles (less than 45°, which bending cannot correct) to two buds (leave a stub) to allow for redirection in the following season.

Pruning on tip bearing cultivars (Type IV; e.g., 'Golden Russet' and 'Harrison') should be done with relative caution to avoid significant elimination of fruiting buds, as trees with this fruit bearing habit will naturally bear fruit at their tips. Appendix 1, Table 8 provides the bearing habit for cider apple cultivars included in the orchard at WSU NWREC. Also, Type IV cultivars tend to produce blind wood in the **basal** part of the branches, so leave a two-inch stub when removing a branch to improve the possibility of obtaining a new shoot.

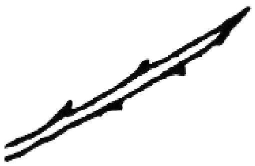
Ken Muir LTD (2017) provides a simplified step-by-step plan for pruning in response to reproductive habit (Table 3). If there is a large amount of blind wood on the main axis, it is possible to utilize girdling and scoring techniques before bud break, at the phenological stage of green tip (Figure 11), to stimulate growth in these blind regions. In the case of Type IV cultivars, it is possible to combine girdling and scoring.

If disease pressure is observed or known to be significant, these wounding techniques should be avoided and chemical treatment with plant growth regulators (e.g., Promalin) utilized instead to encourage budbreak and lateral development in blind wood. See product labels for more details and instructions on application of these chemicals.

Girdling and Scoring

Girdling is the incision of the whole circumference of the trunk, while scoring is a less severe and more targeted cut that can be done just above a dormant bud, located in a position where a new branch is needed. In both cases, make a narrow cut of the cambium and phloem. These techniques are applied before bud break, at the green tip phenological stage, and will temporarily subdue apical dominance of the leader, thereby promoting bud swelling. An inexpensive and effective tool for this scoring cut is an old hacksaw blade with one end taped for a handle, it is just wide enough yet will not create a big wound; make one pass to cut the bark about ½ inch or so above the bud that you want to stimulate.

Table 3. Pruning strategy in response to reproductive bearing habit. (Images by T.R. Alexander, WSU.)

Habit	Pruning Strategy
Spur Bearing 	1st winter: cut back laterals to four buds
	2nd winter: cut back laterals underneath 1st or 2nd flower bud
	3rd winter onward: remove dead, diseased, and crowded wood
Tip Bearing 	1st winter: select strong, well-placed laterals
	2nd winter: prune back laterals to the old wood
	3rd winter: prune back the fruited laterals to one- to two-inch stubs
	3rd summer: select newly established laterals to repeat cycle
	4th winter onward: remove dead, diseased, and crowded wood

Growing Season: It is important to understand that pruning at different times of year has different consequences. Pruning performed during the dormant period tends to result in invigorated growth in the coming growing season (due to the reduction of growing points that would compete for resources), whereas pruning performed during the growing season generally results in a growth reduction.

Use summer pruning to control growth of young trees, improve light penetration in fruiting zones, and to remove water sprouts. Remove all vigorous, vertical growth from branches (commonly termed water sprouts) and the trunk and roots (commonly termed suckers). Remove wood in the upper zone of the tree if its diameter is 30% of that of the main trunk, and remove wood in the lower zone of the tree if its diameter is 40% of that of the main trunk. Prune branches that have grown beyond their desired length to a secondary lateral branch of similar diameter.

Do not practice this type of pruning during the dormant period, as it would create an undesired flush of new growth at the site of pruning. Generally, all pruning should be avoided in the weeks following budbreak (spring) and just before the onset of dormancy (fall) as trees are highly vulnerable to environmental pressures such as late frost. Remove all blooms within 30 days of petal fall.

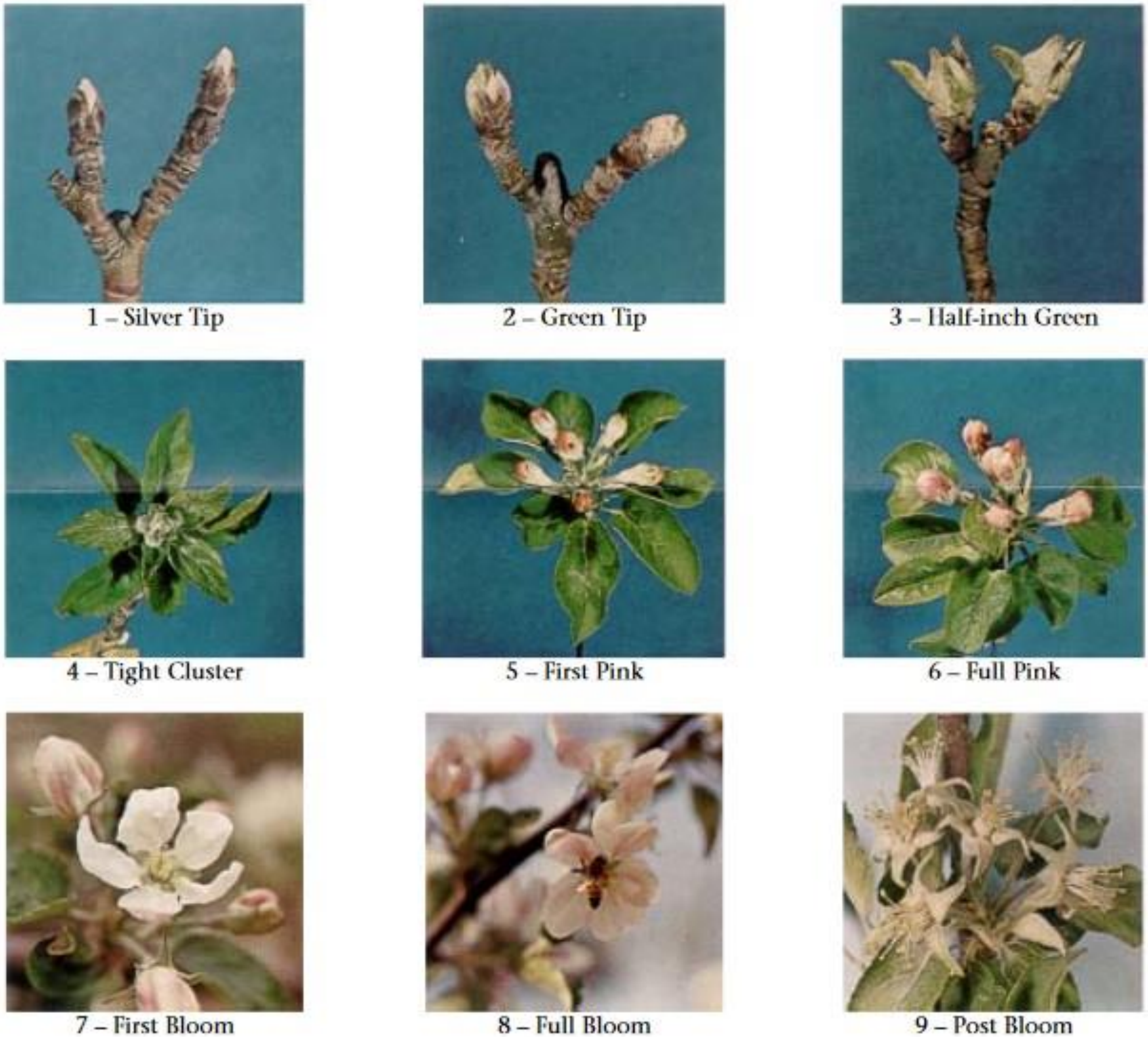


Figure 11. Bud stage chart for apples, from silver tip to post bloom (DuPont 2017).

3rd Leaf

Dormancy Period: Mechanical pruning can start in the third year during the dormant season, if the trees have filled the space and if the tree vigor is well-balanced. Mechanical pruning is performed on a cutting plane (horizontal, vertical, and oblique) and is done with a sickle-bar or saw-bar. Other equipment can open windows (slot pruning) of different depths in the canopy.

Mechanical pruning only requires about 1.5 hours per acre, while follow-up hand pruning may require an additional 16 hours per acre, especially in the initial stages of orchard establishment. Follow-up hand pruning is necessary to remove vertical shoots and shoots that are growing along the row, as mechanical pruners are only effective at removing growth perpendicular to the row.

After mechanically pruning the trees, assess the leader to ensure that it is tied to the trellis, free of competing shoots, and does not exceed the height of the trellis system. If the leader is too tall, head it back to a weak side shoot with a terminal flower bud (Figure 12) to minimize vigor at the top. Areas of the

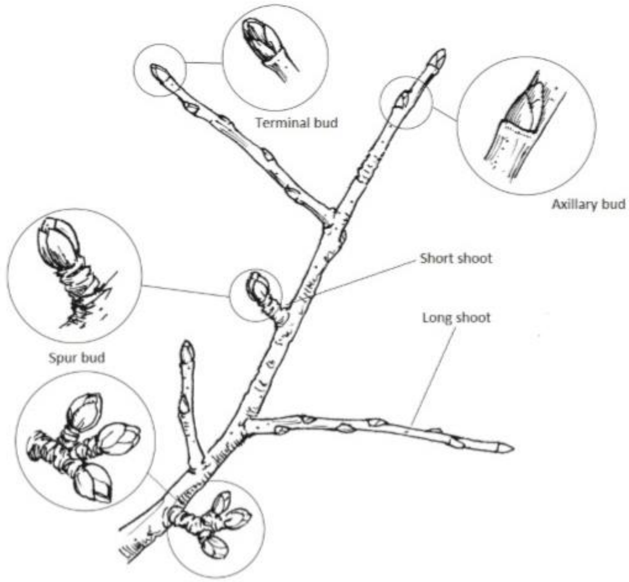


Figure 12. Schema of the different types of buds and shoots on an apple tree. (Image by Elayne Sears from Phillips 2005.)

tree with extensive blind wood (Figure 13) should be girdled, scored, or both to stimulate new growth.

Growing Season: If trees are not as vigorous as desired, remove all blooms within 30 days of petal fall. If trees are vigorous, start mechanical pruning in the summer—after fruit set—and this will remove fruit. Pruning at this time of year will have a positive effect on flower bud formation for the following year and will help to control overall tree vigor. Use follow-up pruning to remove branches that are too large, cutting back to a secondary lateral branch. Remove all water sprouts and suckers. If fruit load appears too large for small trees (for example, more than 25 fruits per inch of trunk diameter above the graft union), thin fruit within 30 days of petal fall.

Figure 13. Region of blind wood, as demonstrated in the box, stimulated by the bending of branches downward on a Type IV cultivar. (Photo by S. Musacchi, WSU).

4th Leaf to the End of Productivity

Dormancy Period: Assess the trees' response to mechanical pruning that was done in the previous year. If tree vigor is too low, mechanically prune in the dormant season so that vigor is enhanced in the summer. After mechanically pruning the trees, assess the leader to ensure that it is tied to the trellis, free of competing shoots, and does not exceed the height of the trellis system. If the leader is too tall, head it back to a weak side shoot with a terminal flower bud. Girdle and score areas of the tree with extensive blind wood to stimulate new shoot growth. Remove vertical shoots, branches that are competing with the trunk, and branches and shoots that are growing along the row. Also, remove wood that excessively shades basal branches, damaged, or dead.

Growing Season: Blossom thinning is reported to mitigate alternate bearing in apple and increase fruit size. Thinning blossoms by hand is expensive and requires a large workforce for a short time period. Efficacy and performance of chemical blossom thinning is highly dependent on weather conditions, tree status, and application methods. The fruiting wall training system is well suited for mechanical blossom thinning (Figure 3). Organic producers have few products to chemically thin blossoms, so mechanical removal may be the best option. See the Resource Information section for guides on hand, chemical, and mechanical blossom thinning.

If trees responded well to summer mechanical pruning, repeat mechanical pruning in the summer. Take into account the reduction of tree vigor and fruit size when making this decision. In follow-up pruning, remove all water sprouts and suckers (Figure 14). Focus summer pruning on maximizing light penetration and gas exchange. It is imperative that heavy fruiting wood be tied up to stakes or wires to avoid breakage of limbs and loss of yield. If fruit load appears too large for the trees, thin fruit within 30 days of pruning.

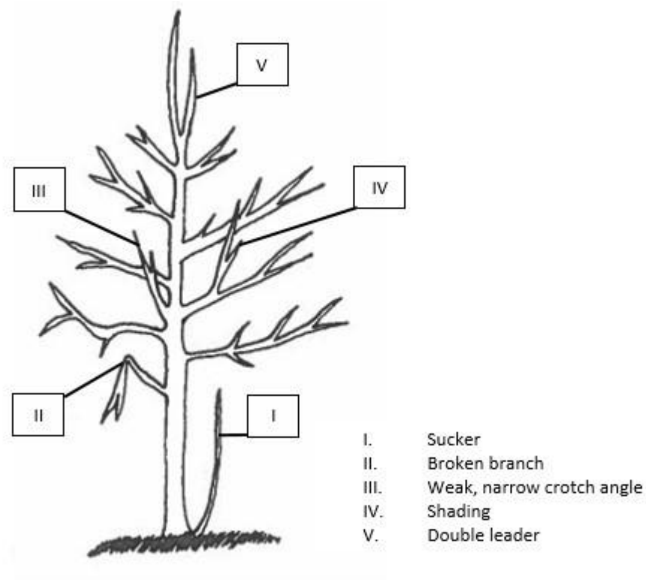


Figure 14. Non-productive wood to be removed. (Image by T.R. Alexander, WSU.)

LESSONS LEARNED at WSU NWREC RESEARCH ORCHARD

Tree Density: 473 trees planted on 0.85 acres = 556 trees per acre.

Orchard Dimensions: 258 ft (N-S) by 144 ft (E-W) = 0.85 acre; 6 ft in-row, 12 ft between rows.

Scions and Rootstock: 65 varieties (see Appendix 1, Table 4) on G935 rootstock.

Wood Source: Grafted trees provided by Biringer Nursery, Mount Vernon, WA; scionwood from WSU NWREC foundation block and rootstock from Cummins Nursery, Ithaca, NY.

Planting Dates: March 2014 and January 2016 (two planting dates due to shortage of rootstock).

Support System: 10-foot posts, spaced 36 feet apart, 8 posts per 252-foot-long row; 4-wire trellis.

Irrigation System: Drip tube (0.7 inch) on lowest wire. 24-inch emitter spacing at 0.5 GPH flow.

Soil Type: Skagit silt loam.

Climate: See Table 4.

Fertilization: The following are fertilizer recommendations for western Washington drawn from Stiles and Reid (1991) and Moulton (1995). Based on soil test results, prior to planting adjust the soil pH to 7 in the topsoil and 6.5 in the subsoil, and then determine your soil management group (Type I–V) by comparing the CEC number of your soil test result with the CEC group numbers shown in Table 5.

Calculate the amount of each nutrient that needs to be adjusted in your topsoil and subsoil, respectively, by taking the difference of your current estimated content and the recommended amount. Recommended amounts of macro and micronutrients are provided in Table 5 and Table 6; however, not all nutrients are included. See Table 7 for some examples of how to convert between the units commonly reported in soil test results (e.g., parts per million) and the unit (pounds per acre) that is provided for the recommendations in Table 5 and Table 6.

Table 4. WSU Mount Vernon NWREC during the apple growing season (Mar.–Sept.) and dormant season (Oct.–Feb.);15-year average (Washington State University 2017).

Climate Parameter	Growing Season	Dormant Season
Average Air Temperature (°F)	57.9	50.1
Total Precipitation (inches)	13.9	18.4
Average Relative Humidity (%)	77	86

Table 5. Calcium, magnesium, and potassium recommendations for pre-plant (PP) and established (EST) orchards for different soil management groups in pounds of nutrient per acre at 8-inch depth for topsoil and 8- to 16-inch depth for subsoil (Stiles and Reid 1991).

			Calcium		**Magnesium**		**Potassium**
Soil Mgmt. Group		**CEC**	**PP**	**EST**	**PP**	**EST**	**PP & EST**
I	topsoil	25	8,900	7,800	1,100	950	520
	subsoil	17	5,900	4,600	700	550	300
II	topsoil	20	7,100	6,200	850	750	450
	subsoil	13	4,700	3,700	600	450	260
III	topsoil	18	6,400	5,600	780	700	430
	subsoil	12	4,300	3,300	500	400	250
IV	topsoil	16	5,700	5,000	700	600	400
	subsoil	11	3,800	2,900	450	350	240
V	topsoil	12	4,300	3,700	500	450	330
	subsoil	8	2,800	2,200	350	350	200

Table 6. Boron, zinc, copper, and manganese recommendations (Stiles and Reid 1991).

Nutrient	**Recommendations**
Boron	Soil readings > 1 ppm: require no adjustment
	Soil readings 0.5 to 1 ppm: apply 2 lb B/acre
	Soil readings < 0.5 ppm: apply 4 lb B/acre
Zinc	Soil readings > 2 ppm: require no adjustment
	Soil readings < 2 ppm: apply 120 lb Zn/acre
Copper	Soil readings > 2 ppm: require no adjustment
	Soil readings < 2 ppm: 90–120 lb Cu/acre
Manganese	Soil readings > 5 ppm: require no adjustment
	Soil readings 3 to 5 ppm: apply 30 lb Mn/acre
	Soil readings < 0.5 ppm: 50 lb Mn/acre

Stiles and Reid (1991) recommend utilizing the following formulas for calculating the amounts of phosphorus oxide (P_2O_5) to add to your soil, negative numbers are treated as zero:

Pre-plant: [(9 lb - current content lb/acre) × 10] + 40 lb = lb P_2O_5 per acre.

Established orchard: [(9 lb - current content lb/acre) × 5] + 20 lb = lb P_2O_5 per acre.

Table 7. Nutrient unit conversion table.

Nutrient	Conversion
Ca	Multiply meq[1] per 100 g soil by 532
	1 meq Ca / 100 g soil = 532 lb Ca/acre
Mg	Multiple meq per 100 g soil by 323
	1 meq Mg / 100 g soil = 323 lb Mg/acre
K	Multiply ppm[1] by 2.66
	1 ppm K = 2.66 lb K/acre
P	Multiply ppm by 2.66[2] by 2.66
	1 ppm P = 2.66 lb P/acre

[1] meq = milliequivalents; ppm = parts per million.

[2] Test result value is dependent on the analysis method; refer to the test report for low, normal, and high ranges of the specific test.

Foliar application is the best method to supply micronutrients; research at Cornell has demonstrated poor micronutrient uptake and unjustified expense with pre-plant soil amendment of micronutrients (Stiles 2004). The threshold between deficiency and toxicity for trace elements, in general, is very small, so caution should be taken with application.

1st Leaf

Dormancy Period: To bring all trees in the orchard to the same relative growth stage, for ease of management, trees were pruned uniformly in February 2017 with a battery-powered hedger (20 V MAX Lithium-Ion Hedge Trimmer from DeWalt, Baltimore, MD). Since WSU NWREC did not own a tractor-mounted mechanical hedger, a hand-held hedger was used for mechanical pruning. Limbs extending beyond the two-foot profile were cut back with the hedger (Figure 15).

It took about two hours to hedge the entire 0.85-acre orchard; however, the orchard was not at capacity, and not all trees were sufficiently large to warrant hedging. A hand-held hedger may be a more economically feasible pruning tool for smaller-scale orchards that cannot afford to purchase or lease large-scale equipment, especially in the first few years of orchard establishment when costs are relatively high and there is no income from the orchard.

Following hedging, the orchard was hand pruned with a primary focus on removing wood below the first wire to allow for easier management of weeds and soil (1), removing wood that had blind areas (regions of wood with no apparent shoot or spur growth) (2), and removing wood that was outcompeting the selected leader (3).

It is crucial that wood is removed correctly, specifically, cut wood back to a bud of optimal angle. In addition, it is recommended that supplementary strings and ties be avoided once a wall is established as they increase human labor input. To withstand (and not counteract) the powerful shaking force of a mechanical harvester, the trees need to be as strong and independent as possible.

Figure 15. Using a battery-powered hedger to maintain the tree profile such that branches do not extend into the alley. (Photo by E. Scheenstra, WSU.)

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Appendix 1

Table 8. Tree growth habit and tree characteristics of cider apple varieties observed at the WSU Mount Vernon NWREC (2000–2009) (Moulton et al. 2010).

GROWTH HABIT AND CHARACTERISTICS					
Cultivar	**Spur**[1]	**Mixed**[2]	**Tip**[3]	**Blind Wood**[4]	**Irregular Bearing**[5]
Amere de Berthcourt		X		1.5	Y
American Forestier		X		1	-
Blanc Mollet		X		1.5	-
Bouteville		X		1.5	-
Bramley's Seedling		X		2.5	Semi
Breakwell Seedling		X		1	N
Brown's Apple		X		2	Y
Brown Snout	X			1	N
Brown Thorn		X		2	-
Bulmer's Norman		X		1	Y
Campfield		X		2	-
Cap O' Liberty	X			1	Y
Cimetiere		X		1	Y
Coat Jersey		X		2.5	Y
Court Pendu Plat		X		1.5	-
Court Pendu Rose		X		1.5	-
Crow Egg		X		2	Y
Dabinett		X		1.5	N

GROWTH HABIT AND CHARACTERISTICS					
Cultivar	**Spur**[1]	**Mixed**[2]	**Tip**[3]	**Blind Wood**[4]	**Irregular Bearing**[5]
Finkenwerder Herbstprinz			X	2.5	N
Frequin Audievre		X		1	-
Frequin Rouge		X	X	1.5	semi
Frequin Tardif		X		1	-
Golden Russet			X	2.5	Semi
Granniwinkle				2	-
Grindstone			X	4	-
Harrison			X	2	N
Harry Masters' Jersey		X		1	Y
Jouveaux		X		1.5	N
Kermerrien		X		1	Y
Kingston Black		X		2	Semi
Lambrooke Pippin		X		3.5	-
Major		X		1.5	Y
Medaille D'Or		X		1	-
Metais		X		2.5	-
Michelin		X		2	Y
Muscadet de Dieppe			X	2.5	Y
Muscat de Bernay		X		2	-
Peau de Vache		X		1	N

GROWTH HABIT AND CHARACTERISTICS					
Cultivar	**Spur[1]**	**Mixed[2]**	**Tip[3]**	**Blind Wood[4]**	**Irregular Bearing[5]**
Red Jersey		X		1.5	Y
Redstreak			X	2.5	Semi
Reine des Pommes		X		3	Y
Royal Jersey		X		1	-
Roxbury Russet			X	3.5	N
Smith's Cider		X		2	-
Sweet Alford		X		1	Semi
Sweet Coppin		X		2	-
Taylor's		X		2.5	-
Tom Putt		X		2	Semi
Track Zero Seedling		X		1	Semi
Vilberie		X		2	Y
Whidbey		X		2.5	-
Yarlington Mill		X		2	Y
Zabergau Reinette		X		2	-

[1] Spur = fruit born on two-year-old wood, and as spurs (short, branched shoots) on older wood. This habit gives a compact appearance.

[2] Mixed = Fruit observed to be born on spurs and the tips of long shoots.

[3] Tip = Fruit born on the tips of long shoots produced the previous year, very few spurs produced. The overall appearance of the tree is relatively untidy and branching sparse.

[4] Blind wood where: 1 = None to few areas (less than 4 inches); 2 = Few bare areas (most between 4 and 6 inches with no bud break); 3 = Several bare areas between 4 and 6 inches with no bud break; 4 = Several bare areas less than 1 foot but most longer than 8 inches with no bed break; and 5 = Several areas on numerous branches with 1 foot or longer having no bud break.

[5] Irregular bearing where: Y = Yield observed to fluctuate over seasons due to environmental or management stress; Semi = Yield observed to fluctuate over seasons due to severe environmental or management stress; N = Yield not observed to fluctuate over seasons even with environmental or management stress; and (-) = Insufficient data.

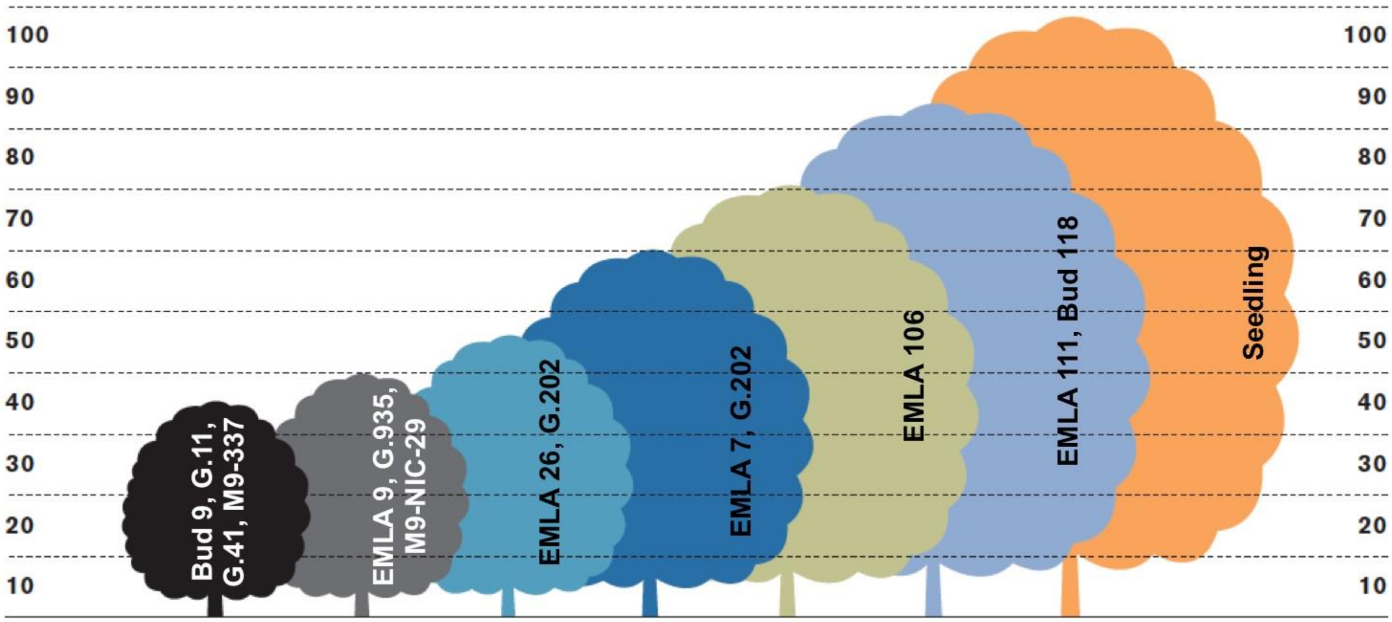

Figure 16. Tree size comparisons of different rootstocks of various series relative to a standard apple seedling (100%) (WSU Tree Fruit 2017).

Glossary

acrotonic: The prevalent development of lateral axes in the upper (distal) part of the parent growth unit or annual shoot.

basal: Lower, or below, as opposed to apical (upper or top).

basitonic: The prevalent development of lateral axes in the lower (proximal) part of the parent growth unit or annual shoot.

budbreak: Initiation of growth from a dormant bud. Buds contain embryonic shoots, leaves, or flowers.

central leader: Training system usually used with semi-dwarfing rootstocks and characterized by one main trunk, crotch angles greater than 60 degrees, and uniform and alternate spacing of branches around the leader.

crotch angle: Angle formed between the trunk and a side branch. Narrow angles can result in bark inclusions (incomplete cell unions at the joint) and, later on, the weakened branch will break away from the trunk under heavy fruit load. Wider crotch angles promote strong side branches.

feathered: Young tree with a single trunk from which short lateral branches extend.

graft union: The point at which rootstock and scion tissue are fused.

heeling: Temporary burying of wood material in soil in preparation for planting and to avoid desiccation and damage from herbivory.

lateral: Shoot that develops from axillary or side buds on the stem of current season's growth providing for filling of a tree’s profile, as opposed to the terminal shoot that develops from terminal buds at the tips of stems providing for expansion of a tree’s profile.

PGR: Plant growth regulator (PGR) functions as a chemical messenger in the growth and development of a plant.

planar: Shallow, two dimensional, in contrast to deep, three dimensional.

rootstock: The portion of the whole tree that provides for anchoring in, and biochemical interaction with, the soil. Rootstock is usually chosen for multiple factors: tree size, soil type, training system, and potential disease resistance.

scion: The portion of the whole tree that provides for leaves (energy collection and conversion units), branches (leaf and fruit platforms), and fruit (reproduction for the tree and a commodity for consumers).

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