Cornell University
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Training Systems for New York Vineyards

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Revised by Justine Vanden Heuvel, 2011

Introduction

The goal of this article is to discuss factors you should consider when choosing a training system and briefly discuss them in relation to varieties and growing conditions found in New York. But first we need to make clear the distinction between pruning and training.

Dormant pruning has the following basic objectives:

1. The determination of the number of buds which should be retained on the vine.
2. Removal of all buds in excess of that number.
3. Selection of canes for retention which represent the highest quality available. This last item will maximize the likelihood of winter survival and of adequate bud fruitfulness.

Training involves the placement of the retained canes and growing shoots so as to shape the vine. The vine shape in turn will influence the extent to which:

1. The fruit will be positioned to allow ease of harvest, good spray coverage and exposure to sunlight.
2. Leaves will be exposed and the leaf area to fruit ratio will be optimized.
3. There will be a continuous canopy of foliage.
4. Bud break will be uniform and high.
5. High quality canes will be produced in the renewal zone.

Training Systems

Although, by tradition, we in New York refer to training systems by name, they can also be more logically classified into four major groups.

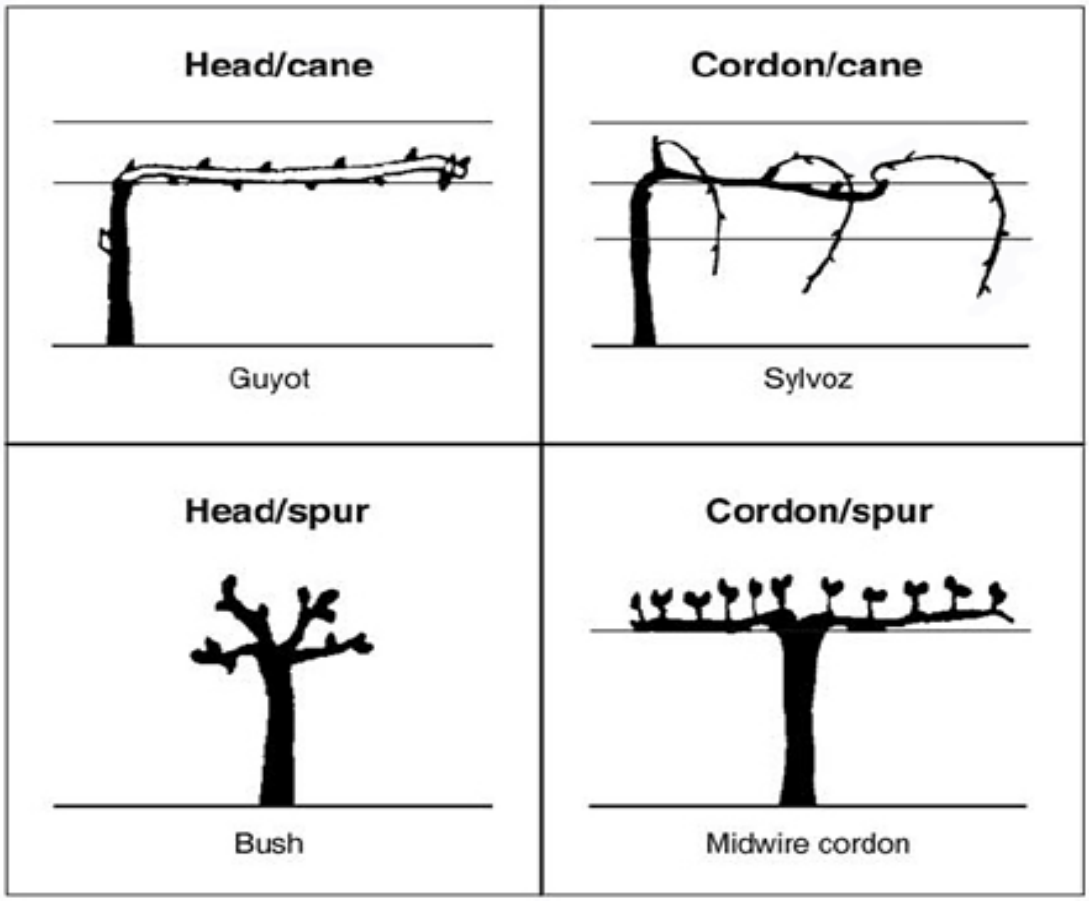

Figure 1. Common training systems can be classified as head/cane, cordon/cane, head/spur, and cordon/spur (adapted from Reynolds and Vanden Heuvel, 2009). Examples are provided for each type of training system, but remember there are many training systems in each category.

Additional, informal classifications for training systems include the nature of the renewal zone (that area where the buds which will produce next year's crop are formed), the extent of permanent wood (trunks and cordons), the type of bearing unit, the height, and the extent of canopy division.

The *renewal zone* may be diffuse (6-Arm Kniffen) or discrete (Mid-wire cordon). It may be at the top of the canopy (High Wire Cordon), or at the bottom (Pendlebogen).The location of the renewal zone in a given training system affects the extent to which shading influences development of retained buds. Buds that develop in shaded renewal zones are reduced in fruitfulness, and because fruit is usually located at the same place, fruit is also often shaded as well.

The *amount and nature of the permanent wood* (trunks and cordons) affects both cost and fruiting potential. Cordons are horizontal trunks (High Wire Cordon). They cost more to establish, but are more permanent (except with cold tender varieties), and can make the job of pruning more simple to visualize. They also offer more space to distribute bearing units, and so can reduce canopy crowding. With cordons, the vine canopy in the row

becomes continuous, helping to reduce canopy gaps and increase light interception. When cordons are not used, the bearing units arise from one or more discrete heads (Umbrella Kniffin, 6-Arm Kniffin, Guyot). Usually head training requires very close vine spacing or the use of long canes to ensure reasonable canopy leaf fill.

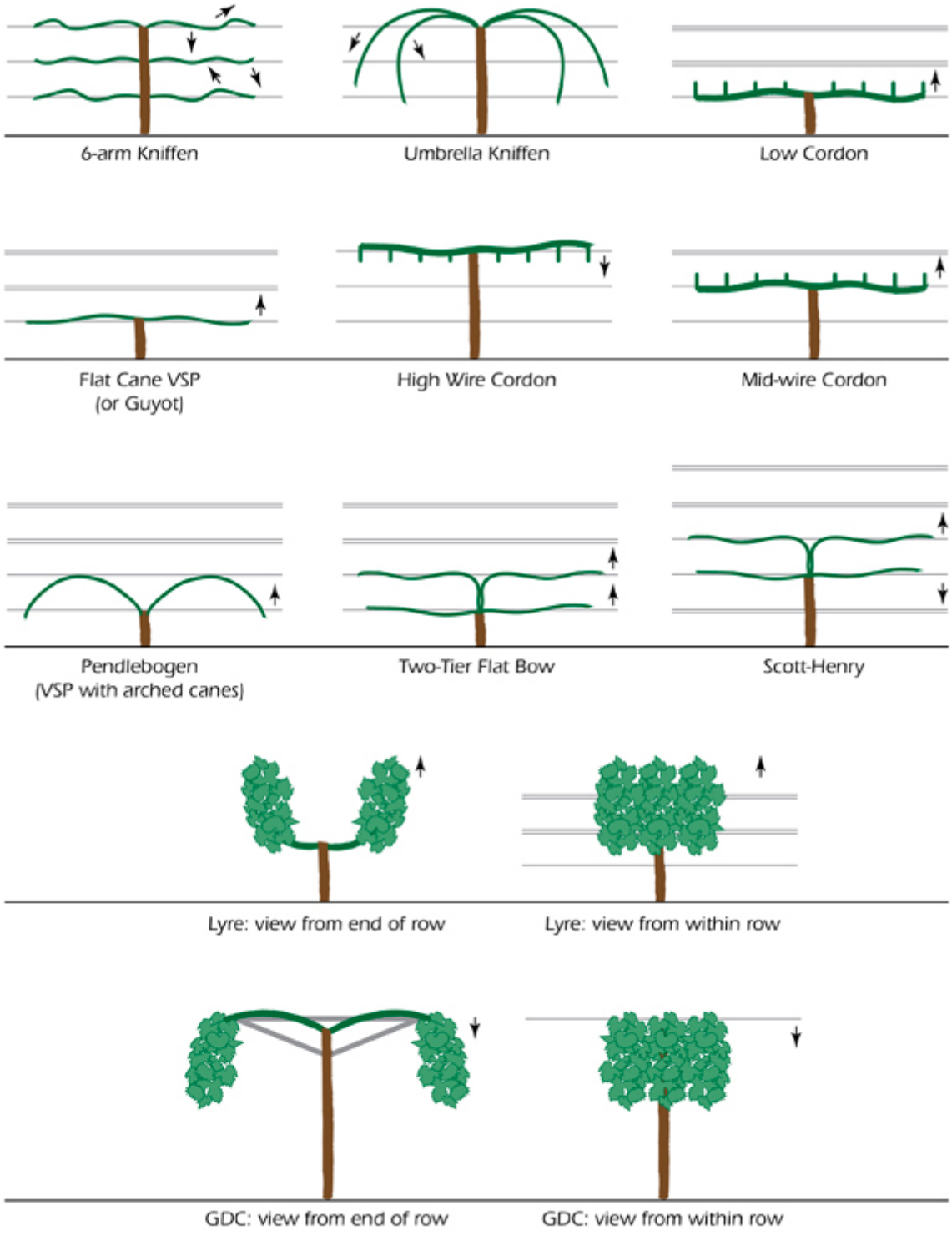

Figure 2. Training systems used in New York State. Arrows denote direction of shoot growth.

The *bearing units* are either spurs or canes. A spur is a short (less than 4 node) cane. Canes (>4 nodes) and head training are often used in cooler climates, because they allow the space between vines to be filled with shoots. With most training systems cane pruning is more expensive, because the canes must be tied into place. However, with varieties with a procumbent (drooping) growth habit and a high renewal zone, hanging canes that do not require tying can be used. With large vines, it is often difficult for light to penetrate to the basal nodes of the shoots that will be used for canes or spurs the next year. In many cases this results in wood which is not suitable for spur pruning. However, because the nodes farther out on the same shoots get more light, they will form productive canes. Thus cane pruning has been used as a way to combat shade effects.

Renewal zone and *trellis height* are both important (Figure 3). Wide row spacing requires tall canopies to ensure reasonable light interception. Practical considerations restrict canopies to about 6-7 feet high. Trellis height cannot be any greater than row width, or shading of the canopy occurs. Row width can be greater than trellis height, however in that case light interception is not optimized. The minimum row width needs to be based on equipment size. When vine growth is very vigorous, or when rows are widely spaced, canopy shading can be a problem. One way to reduce canopy density and to increase light interception is to use a *divided* canopy (GDC, Lyre, Scott Henry). Horizontally-divided canopies (GDC, Lyre) mimic the canopy distribution obtained with narrow rows, but allow machine access provided by wide trunk spacing. It is generally difficult to convert a vineyard from a single canopy system to a hortizontally-divided system (GDC, Lyre) due to the resulting reduced row width that interferes with equipment. In that case, a vertically-divided system (Scott Henry) can be used. Divided canopies are more expensive to install, but the increased yield or fruit quality (from improved light interception by buds and clusters) can compensate for the increased cost. Divided canopies require vigorous vines to fill the trellis, but they also provide a solution when standard training results in excessive vigor and canopy density.

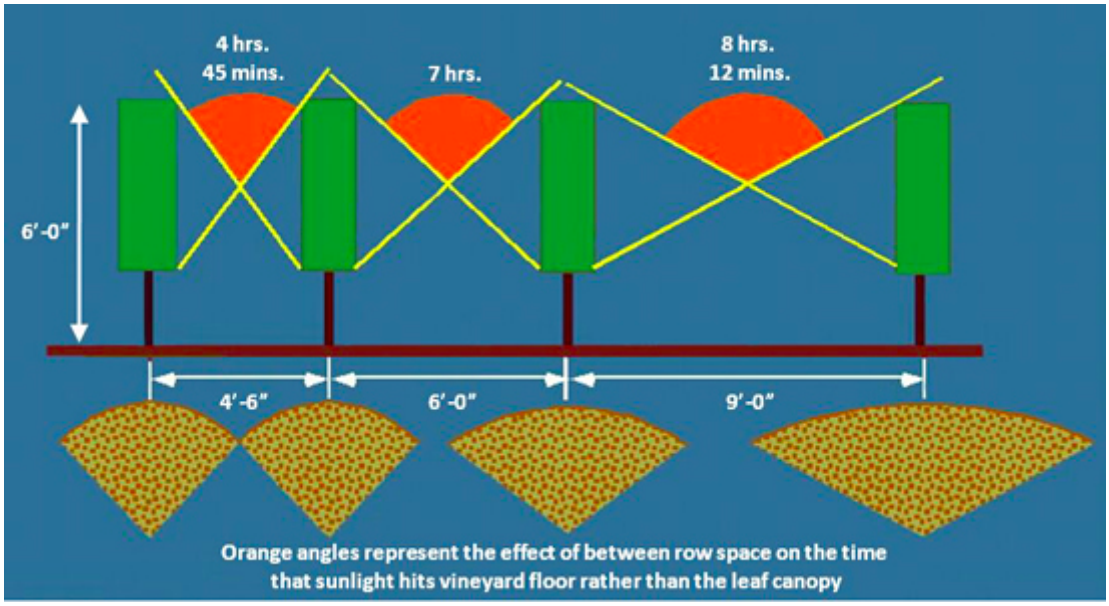

Figure 3. Effect of row spacing on hours of the day when direct sunlight is not intercepted by a leaf canopy. Note that wide rows and narrow canopies are not efficient at intercepting light during mid-day hours. Note that wide row spacing encourages vine vigor by providing a greater root volume to support vegetative growth.

Choosing a Training System

Site Considerations

Some site factors to consider when choosing a training system include soil, temperature and status of vines. Soil depth, texture and drainage will all influence vine size. The summer temperature as well as potential cold injury

in the winter also needs to be considered when selecting a training system. And finally the replant status of the vines needs to be considered. Were there vines in the proposed vineyard last year or was there a fallow period? This will also affect vine size.

Cultivar

Cultivar is the most important factor to consider when thinking about a training system. Essentially we grow three kinds of wine grapes in New York: Native American, hybrids and vinifera. Each class has very important characteristics which influence training system choice. Native American varieties have procumbent (drooping) growth habits which dictate a high renewal zone. Their bud development is very sensitive to shade, so there is a need for an extensive, diffuse canopy system such as obtained with High Wire Cordon. With conventional pruning, special treatment such as shoot positioning may be required to obtain sufficient illumination of the renewal zone.

Many hybrid cultivars have very fruitful buds and a tendency to produce fruit from base buds (which arise at the base of a cane). Their growth habit is variable, but shoot growth is usually more erect than with the Native American varieties.

Vinifera varieties tend to have upright to very erect growth habits. As a class they are winter tender which makes it difficult to produce long-lived trunks. As a result cordon training is generally not suitable except where cold injury is rare (such as Long Island).

Cultivar considerations in choosing a training system:

1. Basic growth habit – upright or procumbent (drooping). This relates to light penetration into the renewal area.
2. Leaf size. Are the leaves thick and large or small, thin and deeply lobed? These factors relate to how much light penetration into the canopy may be expected.
3. Winter hardiness. This will help determine how many trunks should be retained, and how often they will need to be renewed.
4. Fruitfulness of base buds. With fruitful base buds, cordon training will contribute to the potential of the vine to overcrop.
5. Rootstock. This relates to the expected vine size.
6. Internode length. This determines suitability for some head/cane systems such as Guyot, where node number can be limited by amount of space between vines.

Growth Habit

Varieties with erect growth habits lend themselves to systems with lower renewal zones such as mid-wire cordon or pendlebogen. Varieties with procumbent habits should have a high renewal zone to improve the light environment in the renewal and fruiting zone.

Fruiting Habit

Crop control is easier with cultivars that have fruitful base buds when there are fewer sites for base bud retention. Cordons have many sites where base buds are retained, and these greatly increase the number of clusters produced at a given pruning level. In one study, we found that 60% of the crop of DeChaunac originated from base buds. Head/cane training systems will reduce crop potential from base buds.

Another factor to consider is cluster weight. Traditional spur pruning generally retains fewer nodes per vine than cane pruning. Thus spur pruning is useful for varieties with high crop weight production per retained node, and cane pruning is used for varieties with small cluster weight.

Disease Susceptibility

Fruit and the buds in the renewal zone tend to be produced in the same place. Shaded renewal zones also affect

the microclimate of the fruit zone. Dense canopies restrict air flow, increase drying time and interfere with spray penetration. For varieties that are sensitive to bunch rot, such conditions can spell disaster. This is the reason that Riesling does well when Pendlebogen trained. When Pendlebogen-trained vines are vertically shoot positioned, their fruiting zones can become very well ventilated, substantially reducing fruit infection. Cheaper alternatives such as Umbrella Kniffin are compromises where fruit crowding is avoided by distributing the clusters widely over the trellis, and are suitable for moderately valued fruit.

Vine and Row Spacing

Vine and row spacing will affect vine size and thus affect training system choice. Closer row spacing can decrease individual vine size by reducing root volume per vine. Vine canopy density tends to be decreased as in-row vine spacing increases. However, very wide in-row spacing will dictate a cordon training system in order to ensure the space between canopies is filled with leaves.

Economics

Economic considerations with respect to labor inputs are important when choosing a training system. Divided canopies generally require more hardware than non-divided canopies and therefore increase the cost of installation at planting. Additionally, labor costs associated with training choice need to be considered. While some low-vigor hybrids may do well on a VSP system, labor costs for shoot positioning and leaf removal may not be feasible due to the lower value per ton of hybrid fruit.

Management

The value of the crop will dictate how many inputs the grower can afford to put into their vineyard. Economic pressures are leading more and more people to adopt machine pruning. Machine pruning systems are best adapted to cordon training which tends to enhance canopy uniformity along the row. Mid-wire cordons work well with close hedging of fruitful varieties, and top wire cordons are more useful for Native American varieties.

Management considerations:

1. Will mechanical harvesting be used? What about mechanical pruning? These are not practical with all training systems.
2. What intensity of management is anticipated? Some growers are reluctant to invest time in shoot positioning or cluster thinning. If so, systems that require them to be successful should be avoided regardless of their ultimate yield and/or fruit quality potential.
3. What inputs will the manager put in yearly? If weed control, fertilization, or other required inputs will not be regularly applied, training systems that are designed to combat problems associated with large vine size need not be considered.

Vine Vigor

Ultimately the training system must be matched to the vine vigor. Training system will have little impact on the open canopy found with low vigor vines. However, these vines will also be low yielding. Most often the goal is intermediate vigor, but as vigor increases training system will have a greater and greater impact on canopy density, yield and quality. Very high vigor vines may require canopy division to prevent excessive canopy density.

Special Considerations for Cold Tender Cultivars

The primary strategy for growing cold tender grape cultivars in New York is the use of spare parts so that cold damage can be tolerated. Because both trunks and buds can be winter-injured, the attempt is to provide an excess of both, and adjust the final crop only after spring growth signals winter survival. Thus training systems that are costly to establish, such as high wire cordons and GDC, should be avoided for cold tender cultivars. It is easier to

distribute and rapidly adjust the crop when many short trunks are utilized and when cane pruning is done. Thus the majority of cold tender grapes are produced on a low head, cane pruned system such as Flat cane VSP (i.e., Guyot) or Pendlebogen. These systems requires intense management, and the alternative, Umbrella Kniffin is often more suitable for lower value fruit.

Table 1. Effect of training system on survival and yield of Chardonnay grapes in 1994.

Training System	Cane Pruning Wt. (lb)	Total Nodes/ Vine	Total Shoots/ Vine	Adjusted Shoots/ Vine	% Barren Nodes	Tons/ Acre	*Brix	Total Acid (g/100 mL)
Low Cordon	1.1 a	58.4 b	19.3 c	16.4 d	67.3 a	0.7 d	19.3 c	0.9 a
Flat Cane VSP	0.7 c	60.1 b	21.3 c	17.7 d	60.9 b	1.1 c	-	-
Pendlebogen	0.8 b	66.5 b	33.5 b	21.5 cd	49.4 c	1.3 c	20.5 ab	0.8 ab
Mid-Wire Cordon	1.0 ab	62.1 b	32.6 b	21.0 cd	45.1 c	1.4 c	20.6 a	0.9 a
Lyre Cordon	0.8 bc	84.5 a	36.6 ab	28.9 ab	57.2 b	1.9 b	20.6 a	0.8 ab

The winter of 1993/94 was one of the coldest on record in the Finger Lakes. Temperatures in our experimental plantings reached -16°F on more than one occasion in January, 1994. Table 1 shows winter survival of young Chardonnay vines trained to 7 different systems. Lowest bud kill was associated with highly managed systems, but maximum return yield was from Lyre training. It appears the high yield was not only due to well matured, winter hardy canes, but also to the very large number of buds available to survive the winter. The low cost Mid-wire cordon system produced quite substantial yields, but we had to replace all of the cordons over the next few growing seasons.

Table 2. Advantages and disadvantages of various training systems

Training System (Classification)	Advantages	Disadvantages	Recommended for...
Appropriate for downward-growing cultivars			
4 (or 6) Arm Kniffen (Head/Cane or Cordon/Spur)	Inexpensive to maintain due to lack of shoot positioning, and lack of tying (if spur pruned)	Poorly adapted to mechanical harvest Lower canopies can be shaded by upper canopy, resulting in reduced node fruitfulness and fruit quality	Not recommended
Umbrella Kniffen (Head/Cane)	All canes originate from upper arms, thereby reducing shading Apical dominance minimized as a result of cane bending Adaptable to mechanical harvest	Tying of canes required. No mechanized pruning currently envisioned	Hybrid and native cultivars susceptible to cold damage, or white vinifera intended for bulk production
High Wire Cordon (a.k.a. Top Wire Cordon, Hudson River Umbrella) (Cordon/Spur or Cordon/Cane (if pruned to longer spurs))	Large trunk and cordon provide reservoir for carbohydrate storage Tying is minimized Renewal area not shaded Allows for mechanical pruning	Large trunk and cordon more difficult to replace when winter injury occurs Large trunk and cordon results in many sites for emergence of non-count shoots	Hybrid or native cultivars where a low cost of production is desired
Geneva Double Curtain (Cordon/Spur)	Discrete curtains further reduce shade Increases yield per acre thereby reducing production cost per ton Can be mechanically pruned and harvested	More expensive to establish and maintain than high wire cordon Requires wider row spacing	Highly vigorous hybrid or native cultivars

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Table 2. Advantages and disadvantages of various training systems (Cont.)

Training System (Classification)	Advantages	Disadvantages	Recommended for...
Appropriate for upright cultivars			
Flat cane VSP (a.k.a. Guyot) (Head/Cane)	Minimal vine structure makes for easier replacement after winter injury Use of canes results in more fruitful nodes than spur pruning Cannot be mechanically pruned	Apical dominance at cane tip can result in uneven shoot growth along cane Fruiting zone can be compressed compared to Pendlebogen	Lower vigor vinifera where fewer nodes are required
Pendlebogen (a.k.a. Arched cane) (Head/Cane)	Minimization of apical dominance allows for more consistent shoot growth along cane Use of canes results in more fruitful nodes than spur pruning Can fit more nodes than Flat cane VSP on same vine spacing	Requires more tying than Flat Cane VSP Cannot be mechanically pruned	Higher vigor vinifera where more nodes are required, or when shoot growth is inconsistent along the cane
Low Cordon (Cordon/Spur)	Spurs allow for mechanical pruning or reduced manual labor when pruning No cane tying required	Cordon allows for emergence of non-count shoots in fruiting zone	Vinifera with fruitful basal buds
Midwire Cordon Cordon/Spur)	Spurs allow for mechanical pruning or reduced manual labor when pruning Fruit zone intensely shaded on large vines No cane tying required	Longer trunk and cordon allows for emergence of non-count shoots in fruiting zone	Higher vigor vinifera with fruitful basal buds

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Table 2. Advantages and disadvantages of various training systems (Cont.)

Training System (Classification)	Advantages	Disadvantages	Recommended for...
Appropriate for upright cultivars			
Two tier flatbow (a.k.a. Double Guyot) (Head/Cane)	Allows for more nodes than Flat cane VSP on the same vine spacing Use of canes results in more fruitful nodes than spur pruning Easy to convert to Scott Henry if needed	Fruiting zone of upper tier is shaded by shoots from lower tier Cannot be mechanically pruned	Vigorous vinifera where more nodes are required
Scott Henry (Head/Cane or Cordon/Spur)	Divided canopy improves light penetration and air flow through vine Vine de-vigored due to more nodes and downward shoot positioning of lower tier Fruit quality and yield generally improved	Expensive to install Timing of downward shoot positioning critical for canopy maintenance Lower shoots can interfere with weed control	Vigorous vinifera where more nodes are required
Lyre (Cordon/Spur)	Divided canopy improves light penetration and air flow through vine Fruit shading reduced in vigorous canopies	Expensive to establish Requires wider row spacing	Highly vigorous vinifera

Conclusion

There are a wide variety of training systems appropriate for the myriad of cultivars, sites, and production goals that exist within the NYS grape industry. Repeatedly, research has demonstrated that the appropriate choice in training system can result in high yields with good fruit quality, however this can only be achieved when all vine conditions and management goals are factored into the choice of training system.

Literature Cited

Reynolds, A.G. and J.E. Vanden Heuvel. 2009. Influence of grapevine training systems on vine growth and fruit composition: A review. Amer. J. Enol. Vitic. 60(3): 251-268.