Cornell University
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Vine Size Management in Eastern Vineyards

Revised by Timothy Martinson and Terry Bates, 2011

Rootstocks, Vine Vigor and its Management in Vinifera Vineyards

The decision as to whether you will need a special rootstock (rather than own roots) in your vineyard, and which of the resistant rootstocks should be utilized can be very complex. Because it can only be made once in the lifetime of the vineyard, the decision should be carefully and deliberately made. However, even though the decision appears complex, the practical choices for New York growers are few. This is an area of active research, so we hope you will have more and better choices in the future.

Why Consider a Resistant Rootstock?

The term resistant is important. Rootstock varieties have been bred or selected to provide resistance and/or tolerance to an insect, a soil condition, a disease or an environmental problem. If these conditions are not present, or if the roots of the scion variety itself have sufficient tolerance to the problem, then using grafted stocks will only increase expense and complicate subsequent vine management. On the other hand, using the wrong stock can be a disaster, as the growers in the Napa valley have found when they selected a rootstock with inadequate resistance to phylloxera, A x R #1 (Ganzin 1).

In New York we can expect rootstocks to do one of the following:

1. Provide increased resistance to soil borne pests such as phylloxera or nematodes.
2. Combat replant effects (primarily high initial phylloxera population, but perhaps also impact of nematodes and crown gall bacteria).
3. Provide increased lime (calcium) tolerance.
4. Provide a larger root system to improve vine drought tolerance.
5. Provide cold tolerant roots and trunk.
6. Reduce chance of virus transmission by nematodes.

In other grape production regions additional benefits, such as salt tolerance, may be expected. We are still attempting to locate a source of tolerance to low soil pH for New York grape growers. However, in New York as well as in most of the viticultural world, the overwhelming need is for tolerance of the root aphid, phylloxera. With Native American and French-American hybrid varieties the desired rootstock response in New York is always increased vigor (vine size). Although vinifera varieties have no inherent tolerance of phylloxera feeding, the goal is not always maximum vine size. Active research is underway to investigate the possibility that rootstocks can increase cold tolerance, can resist infection by crown gall bacteria or can control vegetative growth and so improve canopy density and increase cold hardiness. However, these are still theoretical, rather than actually proven, benefits of rootstocks.

Lime Tolerance (High Soil pH)

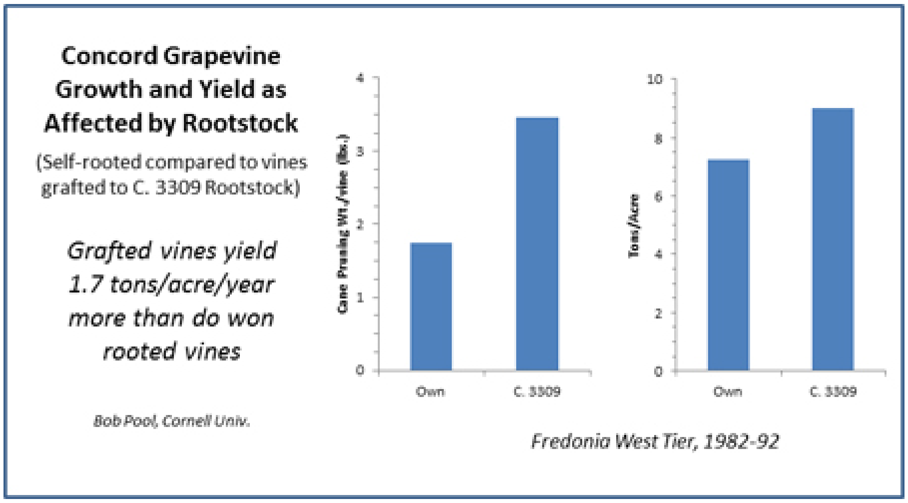
In some places in the world, especially in parts of Europe, the soil is almost pure chalk (calcium carbonate) and grapevine roots cannot absorb sufficient iron to provide the vine's needs. Because iron is a key component of chlorophyll, such vines are very yellow (chlorotic). The ability to obtain sufficient iron atoms in the presence of a high concentration of calcium (limestone) is called lime tolerance. As a class, American grape species do not tolerate lime well, but vinifera roots are among the most lime tolerant grape species. Thus the need for lime tolerance was not recognized until after the introduction of phylloxera in Europe when lime intolerant American species replaced the lime tolerant vinifera rootstocks.

Native American (*Vitis labruscana*) varieties, as a class, are very lime intolerant. For this reason grape production in New York was traditionally restricted to low limestone soils. This means that people wanting to grow Native American (and a few hybrid) varieties on higher pH soils, may need to use a lime tolerant rootstock. Although most rootstocks used in New York are only considered moderately lime tolerant by the French, their tolerance is sufficient for the more modest limestone content of our New York soils. Of the widely available rootstocks, both 5BB and 5C are noted for good lime tolerance. Both trace their tolerance to *V. berlandieri* genes. In nature that grape species grows in Texas soils which have very high lime concentrations.

The need for lime tolerance and for other desirable horticultural characteristics such as ease of propagation has repeatedly caused problems for grape growers. *V. vinifera* has been crossed with phylloxera resistant species with the aim of combining lime and phylloxera tolerance. Such progeny have found favor in several production areas of the world, but unfortunately, the phylloxera resistance has proven to be too narrow. Vineyard districts which have relied on vinifera hybrid stocks have experience the emergence of resistant phylloxera populations. The last well known example is northern, coastal California where thousands of acres of vines planted to AXR #1 (Ganzin 1) had to be replaced after phylloxera which thrived on AXR #1 roots became established. In Europe rootstocks resulting from crossing with *V. vinifera* are not allowed, except in a very few regions of almost pure chalk soil, such as Champagne. There vinifera hybrids such as 41B are commonly used.

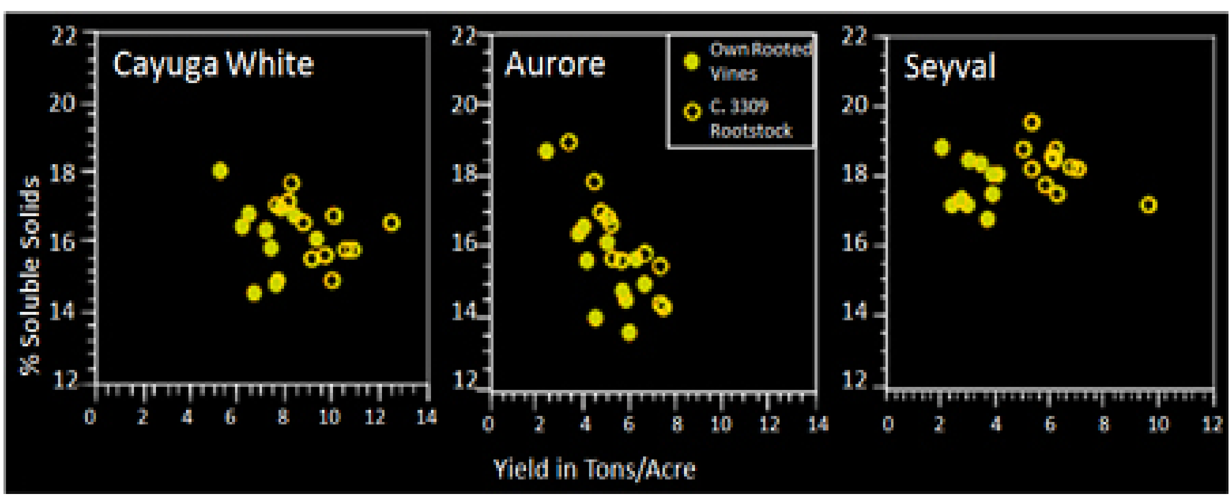
Resistant Stocks for Native American and French American Hybrid Varieties

The phylloxera resistance of these native and hybrid varieties is variable, but rarely high. Most have sufficient resistance to grow and maintain adequate vine size when the initial phylloxera pressure is not great. However, there is an interaction between vine vigor and pruning or crop level. In New York, the yield potential of most of these varieties will be increased when a more phylloxera resistant rootstock is used.



The figure above illustrates the effect of phylloxera resistance on vine size and productivity of non-divided Concord grapevines growing at the Vineyard Laboratory in Fredonia, NY. The long term effect of using C.3309 rootstock was an increase in cane pruning weight by about 1 lb. per 8 foot spaced vine, and yield only increased about 1.5 ton/acre/year. In years of abundant rainfall there has been little yield response to grafting, but in years when vines experience drought stress the response is marked.

The response of French-American hybrid varieties to a phylloxera resistant rootstock is illustrated below. These data are for vines which had been machine hedge pruned and machine (or hand) thinned for several years. Open symbols are vines grafted to C. 3309 and closed are own rooted vines. The points represent different thinning levels. The figure illustrates several important points. First grafting increases vine crop capacity (by increasing vegetative growth). Secondly, response to grafting is more important as crop stress is increased (brought about in this case by reduced thinning level), and thirdly, the benefit may be expressed as larger crop size or as enhanced fruit maturity. Because of competition from other grape producing regions, economic reality requires New York growers of all but the most premium varieties to maximize yield of mature fruit. Thus in the future, the yield payoff for grafting hybrid and American varieties to resistant rootstocks will probably become more important.



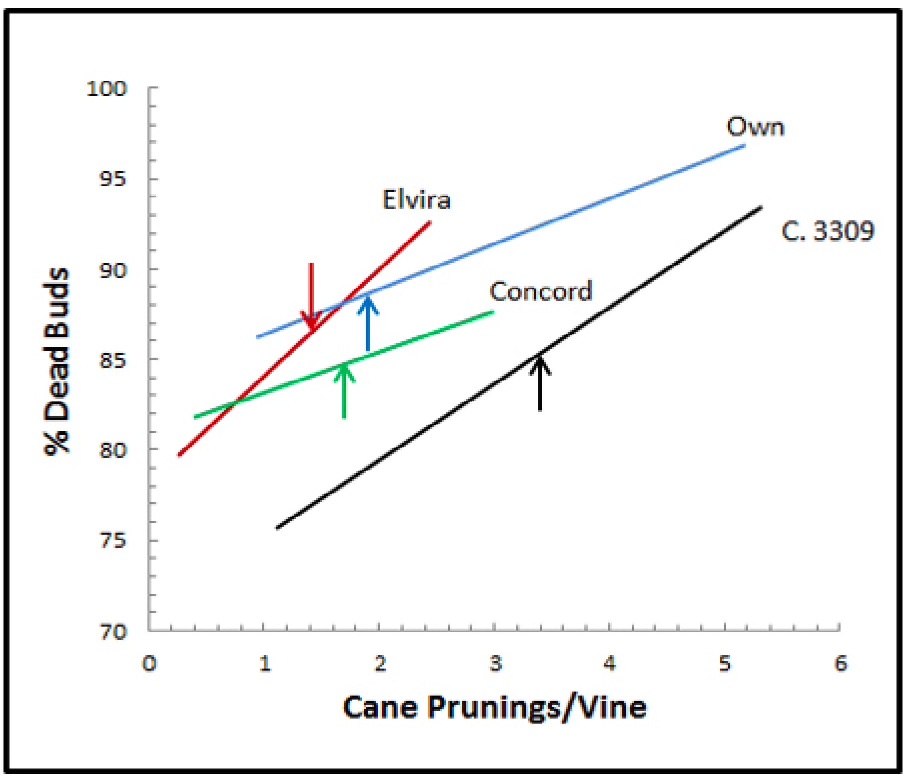
Hybrid Varieties and Soil Born Virus

Another way rootstocks can protect grapevines is to reduce the chance of infection of soil born virus. Most soil born viruses are transmitted by nematodes and are called nepovirus. The most important grapevine nepovirus is grapevine fanleaf (GVF). This virus is transmitted by the nematode, Xiphenema index. Special rootstocks which resist both the nematode and the virus have been produced at the University of California, Davis, California. In France genetic engineers have modified standard rootstocks to resist GVF infection, but these are not yet available for commercial use. Fortunately, the nematode vector for GVF is not present in New York, and the disease has not been a problem to our growers. However, two other related viruses – Tomato Ringspot and Tobacco Ringspot – are endemic in many New York soils. These two viruses are present in many of our native and weedy plant species, and can be vectored by the nematode, Xiphenema americanum which is also widely distributed in New York. Work by Dr. Dennis Gonsalves at Cornell's Geneva Plant Pathology department indicates that most commonly used New York phylloxera resistant rootstocks are almost immune from infection by the ringspot virus complex.

Resistant rootstocks have a hypersensitive reaction to the virus. When a nematode injects the virus into root tissue, the affected cells usually die preventing infection. Apparently most *Vitis vinifera* varieties have a similar reaction. The worst possible case is to graft a hypersensitive scion to a susceptible rootstock. When the rootstock becomes virus infected and the virus moves upward to the graft union, the hypersensitivity causes the death of reactive scion tissue. The result is graft union necrosis and vine death.

At one time is was felt that only a few of the hybrid varieties were ringspot susceptible, but experience has shown that while only a few varieties produce severe leaf symptoms, many are substantially devigorated. Because of this, many of the traditional hybrid cultivars benefit from rootstocks that directly or indirectly (by suppressing disease) increase vine size. Newer releases from Geneva (Corot noir, Noiret) and *V. riparia*-based cold-hardy cultivars such as Marquette and Frontenac tend to produce large vines in some soils – which can be exacerbated by rootstocks. Grafting hybrids may be beneficial, but growers will need to take into consideration both vine size and disease susceptibility when deciding whether or not to grow grafted hybrid vines.

There is some disagreement regarding the desirable vigor level for vinifera vines. Clearly vines which are growing actively late in the season are excessively vigorous because cold hardiness acquisition is delayed. However, vigor levels can certainly be too low, especially when small vine size is achieved by using practices which deprive the vine of factors needed for good function.



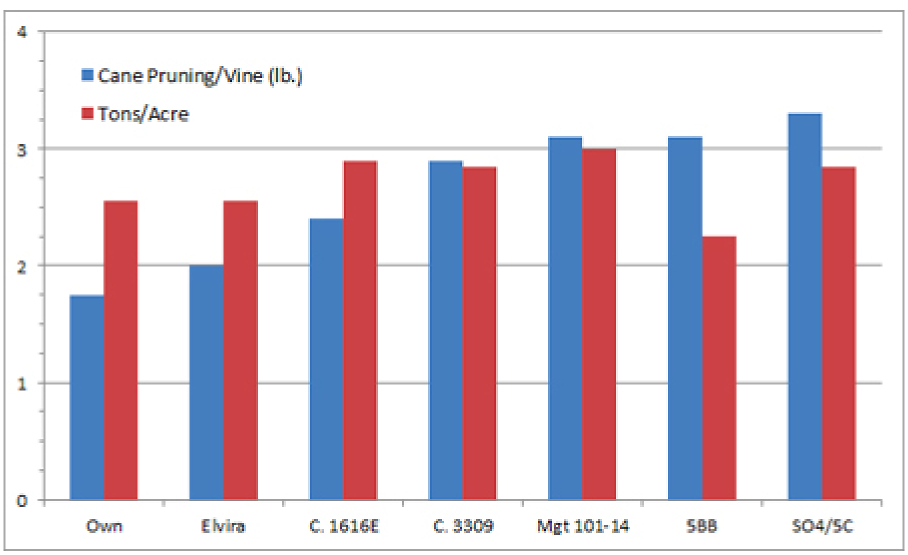
Relationship between cane pruning weight and winter survival following severe cold in December for vinifera grafted to 4 different rootstocks.ne pruning weight and winter survival

In the above figure, only one of the rootstocks, C. 3309, is a standard one for growing vinifera vines. Concord and Elvira have only partial phylloxera resistance and own rooted vinifera has none. The arrows indicate the average pruning weight, and the range of vine size is indicated by the length of the lines. Note that every stock produced a negative relationship between vine size and bud survival. Larger vines had more injury than smaller vines. However, when average vine size was reduced by phylloxera feeding or other maltreatment, the injury level at a given vine size increased. In other words, a large (3.5 lbs. cane pruning/vine) vine grafted on C. 3309 had no more injury than a smaller vine grafted to Concord or Elvira.

Vine growth, fruit yield, fruit soluble solids concentration and bud freezing temperature in January the following season for vinifera vines grafted to different rootstocks.

Rootstock	Cane Prunings/Vine (lb.)	Cane Prunings/Ft of Row	Fruit Yield (tons/acre)	Fruit Brix	Midwinter Bud Freesing Temp. (°F)
C. 3309	3.2	0.4	5.0	19.4	-12.1
Own	2.7	0.3	3.0	18.8	-10.7
Elvira	1.8	0.2	3.6	18.2	-11.5
Concord	1.8	0.2	3.7	19.4	-11.5

Even though vine health is more important than vine size, most New York growers avoid the use of high vigor rootstocks such as 5C and 5BB for vinifera in New York. Most experience has been with C. 3309 which is very commonly used. The table above records 3 year means for the same vines. Note that the small vines not only are not as cold hardy as those grafted to C. 3309, but they also have inferior yield and fruit maturity.



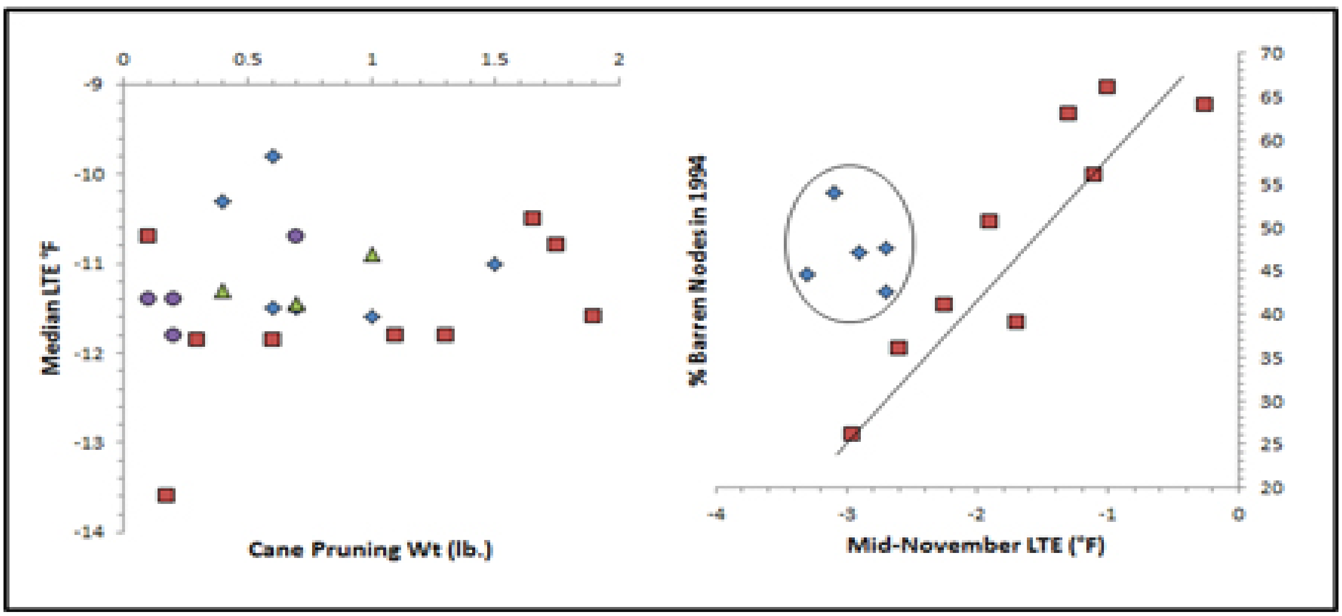
Effect of rootstock on three year average vine vigor and yield of White Riesling vines growing at Geneva, New York

The data above shows the other side of the coin. Grafting to 5BB or 5C resulted in bigger vines, more bunch rot, less mature wood, more winter cold damage and lower average yield.

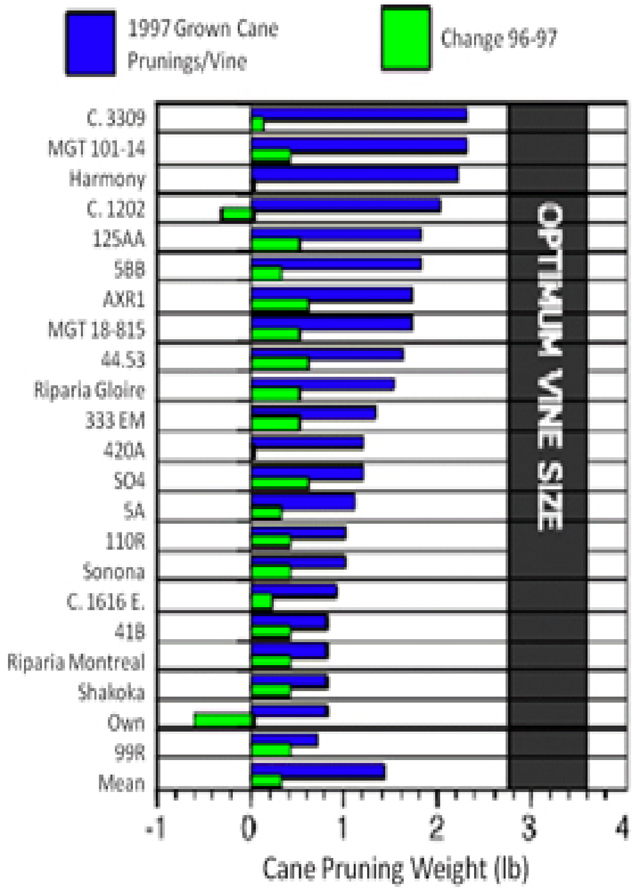
Rootstocks and Early Wood Maturation

Although these data suggest that intermediate vine size is best, there are many reports in the literature that some low vigor rootstocks induce earlier wood maturity which not only aids cold hardiness, but prevents shoot growth from competing with fruit maturation in late summer. What has been missing is data. We have been investigating the relationship between vine vigor, winter hardiness and yield for several years.

Beginning in 1992 we planted Chardonnay vines grafted to 23 different rootstocks. To date the results have been mixed. The data below on the left is typical. Each point represents the mean for Chardonnay grafted to a different rootstock. Note that there are large differences in vine size, but January bud freezing temperature appears to have little relationship with vine size.



However, the effect of rootstock on early wood maturation may be more important. The data on the right illustrates the mid-November, 1993, bud freezing temperature for Chardonnay grafted to 14 rootstocks against the bud survival following January, 1994 temperatures of -16°F. Note that there are two types of response to rootstock. For most stocks there was an association with early wood maturation and increased winter survival. However, another group of rootstocks (the circled ones) had substantial injury in spite of obtaining early bud hardiness, and none of the late hardening stocks had less than 60% bud death.



This work will require time, not only to wait for further damaging winters, but to achieve true vine size response. The 1996 growing season was generally satisfactory, but it was the third year of above average crop size. Note there are substantial differences in Chardonnay vine size among these rootstocks, but also substantial differences in how the vine size is changing. C.1202 and own rooted vines suffered drastic loss in vine size in a year when most vines grew larger. This probably reflects the cumulative impact of phylloxera on these more susceptible varieties.

For the time being, our best advice is still to use the intermediate vigor stocks like C. 3309 or MGT 101-14, and for most situations, avoid the high vigor stocks like 5C, SO4 and 5BB. On the other hand these stocks may offer desirable stimulation to Native American and French-American hybrid varieties.

Rootstock recommendations published by INRA, the French equivalent to our USDA, are given in the table below. INRA conducts the national agricultural research programs for France and has an experiment station at Pont-de-la-Maye in Bordeaux. This station was responsible for this research and the authors of this work are - R. Pouget and J. Delas.

Depth of Rooting	Soil Water	Soil Texture	Neutral to Acid Soils	Calcareous Soils		
				Slightly Calcareous	Calcareous	Very Calcareous
Shallow (<1.5 ft)	Droughty	Sands Gravels	3309 110R Gravesac			
		Clay/Loam		110R 1103P 140 Ru	110R 1103P 140 Ru	140Ru
	Wet in Spring	Sands Gravels	101-14 Fercal Gravesac			
		Clay/Loam		101-14 Fercal Gravesac 1103P	Fercal 1103P	Fercal
Moderate (up to 3 ft)	Droughty	Sands Gravels Schists	101-14 SO4 3309 110R Gravesac			
		Clay/Loam		101-14 RSB 3309 420 A Gravesac 41 B Fercal SO4 110R	Fercal SO4 420 A 110R RSB 140 Ru 41B	Fercal 140 Ru
	Well Drained	Sands Gravels	Riparia Gloire 420 A 101-14 Gravesac 3309			
		Clay/Loam		101-14 SO4 420 A Fercal 3309 41 B RSB 161-49 Gravesac	Fercal RSB 161-49 SO4 420 A 41 B	Fercal 41B
	Wet in Spring	Silts Sandy/Silts	101-14 Gravesac Fercal	Gravesac Fercal 1103P		
		Clay/Loam			Fercal 1103P RSB	Fercal
Deep (>3 feet)	Well Drained	Sands Gravels	Riparia Gloire 420 A 101-14 Gravesac 3309	101-14 Fercal 3309 420 A Gravesac 41 B		
		Sandy/Loam Silty/Loam Clay/Loam			Fercal 41 B 420 A	Fercal 41 B
	Wet in Spring	Silty/Clays Silty/Clay/Loam	Not Appropriate For Vines			

Vinifera Vine Vigor

Vinifera as a class are more vigorous than the other varieties we grow in New York. They are lime tolerant, but do not tolerate acid soils well. We have not identified acid tolerant rootstocks for vinifera scions, and suggest raising the pH of vinifera vineyard soils to at least pH 6.5.

Vinifera Vine Vigor in NY

Because our cool season climate sometimes can border on frigid, the primary goal for most of our growers is to ensure early maturity of both the fruit and the vine. Failure to do so will result in a loss of quality and increased winter cold damage. In addition, because New York is a region of summer rainfall, irrigation systems are rare and disease pressure is high. In our situation growers must strive to optimize all available management decisions so that the quality potential of the grapevine is expressed. Too often growers put excessive emphasis on the impact of a single practice on vine vigor. No matter how important or influential it is, no single tool can guarantee success. Success depends upon making appropriate decisions about a whole series of cultural practices which have interrelated influences on vine growth. One of these decisions is the choice of rootstock.

Vine Size Versus Vine Vigor

These two terms have had quite precise and distinct definitions which are detailed in A.J. Winkler's book, General Viticulture. In Winkler's usage, vine size refers to the weight of cane prunings produced by a vine during a growing season; it is a measure of the vine's overall growth capacity. Vine vigor refers to the rate of shoot growth. However, in recent years the distinction between the two terms has become blurred. I now tend to use both interchangeably to refer to the amount of vegetative growth a vine makes during a growing season.

Problems of the Low Vigor Vineyard

Because there are many more vinifera vineyards with excessive vigor than with inadequate vigor, low vigor is often thought of as a goal rather than a problem. However, I have seen vinifera vineyards with inadequate vigor in every viticultural area I have visited in the world. Inadequate vigor is a serious problem and the cause(s) should be identified and corrected. Except when very close row spacing is used, vineyards with vines that have less than 0.2 lbs. cane prunings/foot of canopy will produce low yields of inferior quality fruit. Their buds and trunks also have reduced cold hardiness.

Problems of the High Vigor Vineyard

The vines of an excessively vigorous vineyard have more than 0.6 lbs. of cane prunings/foot of canopy. On such vines, shoot growth is prolonged, resulting in a dense canopy of leaves and the diversion of photosynthates from the developing fruit and vine carbohydrate reserves to investment in superfluous vegetative growth. Bud and cane maturation is delayed resulting in low cold hardiness and sometimes reduced fruitfulness. The vigorous growth produces dense leaf canopies which are characterized by senescing leaves, poor spray penetration, high relative humidity and long drying times. Diseases flourish in such canopies. Fruit developing in these shaded canopies is of poor quality because of high potassium levels, must pH and malic acid concentration.

Viticultural Factors Influencing Vine Vigor

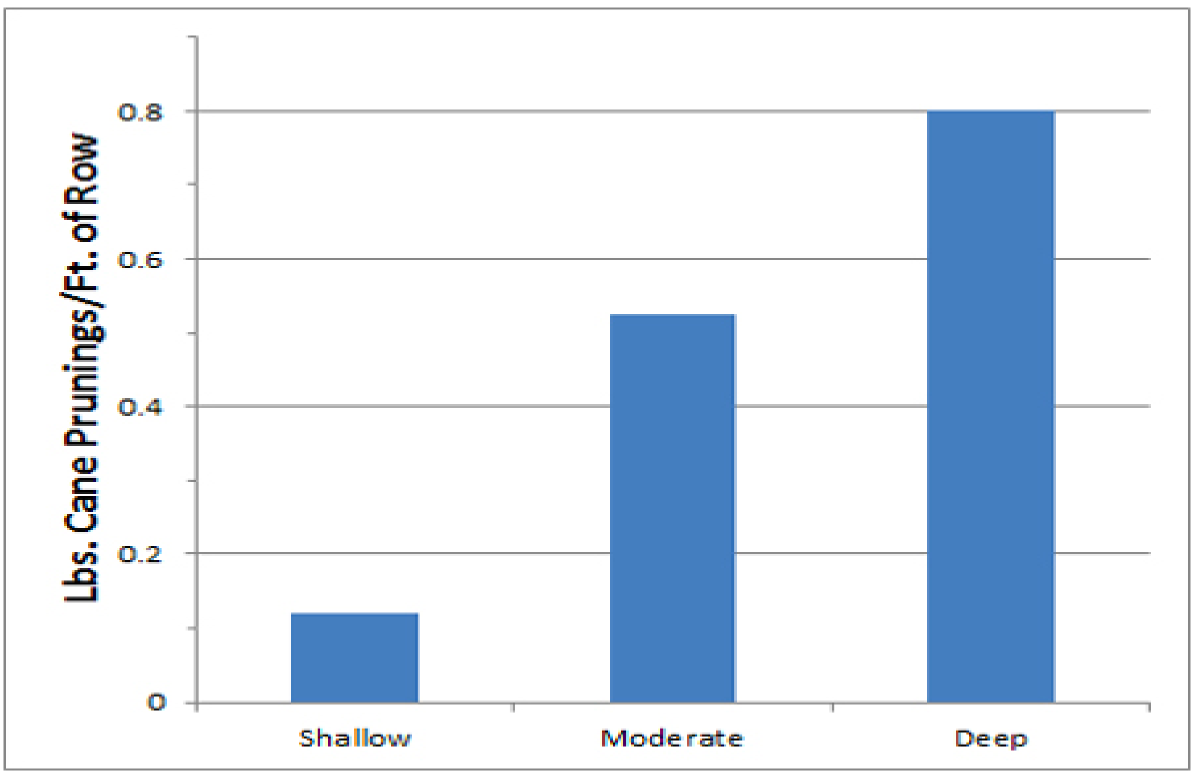
Pre-planting decisions:

The nature of the site and soil will effectively determine the vigor potential of the vineyard. Depth, texture, aeration, water holding capacity and pH of the soil will largely determine the size of the root system and, for nonirrigated vineyards, the water supply. The vineyardist should consider these site effects when making decisions about rootstock and vine spacing in an attempt to modify the potential vigor of the site in a desirable direction.

Post-planting decisions:

Once the vineyard is planted, the grower still makes many annual decisions which influence vine vigor. These include fertilization, especially nitrogen fertilization, choice of vineyard floor management program, pruning and cropping level, and training system. If all of these decisions have been made wisely, then little more will need to be done. However in the real world optimal vine growth is rare, and often corrective practices, such as summer pruning or leaf removal, will improve the vine canopy formed in response to the particular set of cultural practices used in a given vineyard.

Soil Characteristics and Vine Vigor The typical soil profile of a Long Island vineyard is 12 inches of silty/loam topsoil which has developed from the native sand. The sand comprises the subsoil. Because the topsoil is very easily eroded, soil landscape has had a profound effect on topsoil depth. The topsoil tends to wash down to lower parts of the vineyard. Thus a single vineyard row may have level sections with moderate topsoil depth and moderate water holding capacity. It may also have eroded sections where the topsoil is gone and only the sandy sub-soil is left which has very low water holding capacity. Finally there may be a low area where topsoil has collected and where the water supply is always plentiful. The result is shown below. These are actual vine growth data along two adjacent vineyards rows. There is little crop in the shallow sections and almost no crop in the deep sections. The very large and late growing vines kill to the ground almost every winter. Fortunately, most of the vineyard has moderate soil depth.



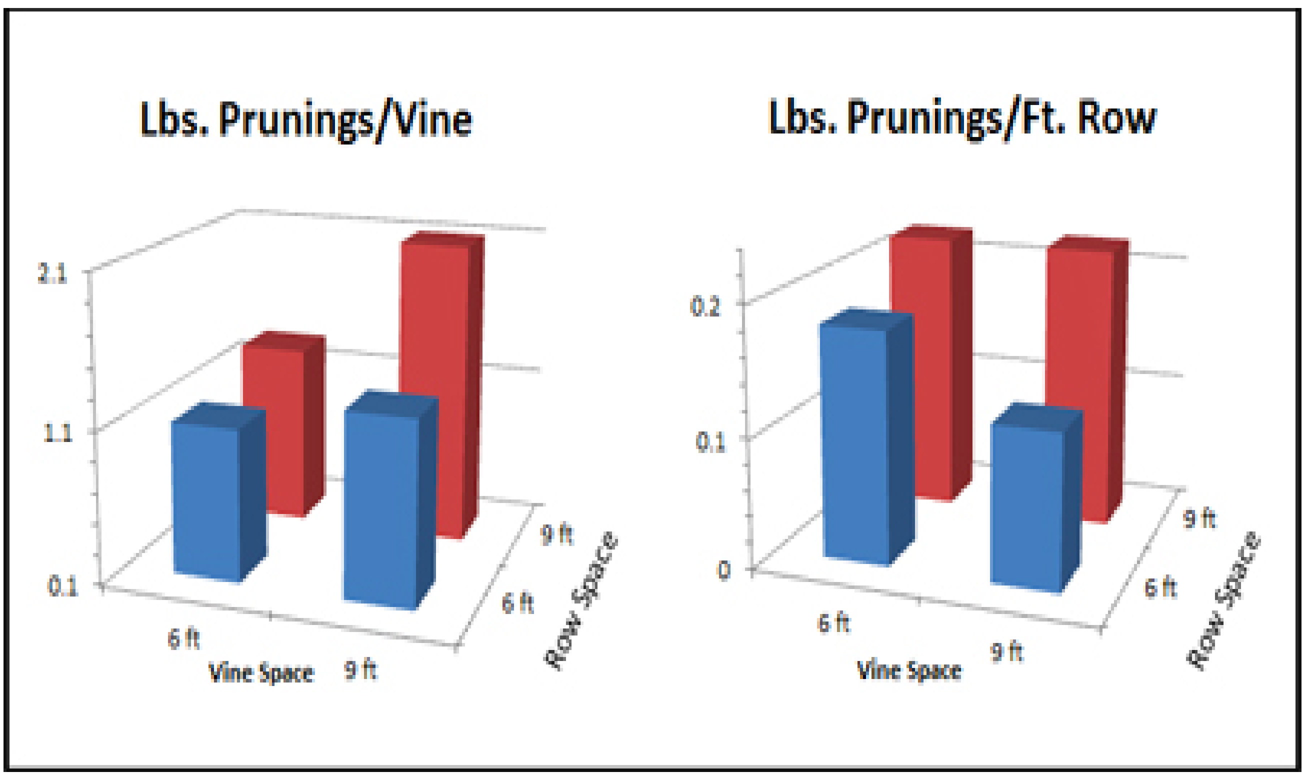
Effect of topsoil depth on vine size (vigor) of Cabernet Sauvignon grapevines in a Long Island, New York vineyard.

Soil pH – remember that vinifera scions do not confer an ability for roots to tolerate aluminum ions in acid soils the way that native grape varieties do. Currently no rootstocks are known to resist low soil pH, but some will help ensure a balanced supply of mineral nutrients in high pH soils.

Vine and Row Spacing

After selecting the site and preparing the soil, the most important pre-plant decision which will affect vine vigor is row and vine spacing. It is also the most misunderstood. There is a belief that increasing vine density (number of vines per acre) will cause a large reduction in vine vigor. The most common reason for this belief is the comparatively high vine densities common to European viticulture. Unfortunately, this is a half-truth.

Helen Fisher is viticulturist for the Province of Ontario, Canada (and faculty member of Geulph University). The figure below presents grapevine growth data that was part of her Cornell PhD thesis which investigated the question of vine spacing and vigor. She confirmed that increasing vine density decreases vine vigor in the sense that cane pruning weight per vine was reduced. However, when vine vigor is expressed as weight of cane prunings per foot of canopy, a reduction was only obtained by decreasing between row spacing. With wide rows, increasing vine spacing had no impact on vigor, and with narrow rows, increasing vine density actually increased vine vigor.



Effect of in- row and between-row vine space on vine vigor expressed as lbs. cane prunings vine or per foot of row.

Vine Cane Pruning Weights for Chardonnay Vines Growing at Geneva, NY Vines were planted in rows 9 feet apart and at various in-row distances			
	Cane Prunings lbs. per		
In-row planting distance (ft.)	Vine	Foot of Row	Acre
4	1.7	0.43	2,075
6	2.0	0.33	1,614
8	2.4	0.29	1,423
Significance Linear Quadratic	0.0001 0.0001	0.0001 0.05	0.0001 0.01

The table at left shows the effect of in-row vine spacing on Chardonnay vigor. It demonstrates that, as within-the-row spacing decreases, pruning weight per vine decreases, but does not decrease as fast as vine density increases. Hence, close in-the-row spacing tends to increase effective vine vigor (prunings/foot of row or per acre). These data suggest that we should examine the potential for decreased between row spacing and increased, not decreased, within-the-row spacing if our goal is to reduce vine canopy density and effective vine vigor.

Nutrition and Vine Vigor

Frequently growers withhold fertilizer in an attempt to reduce vine vigor. However, any practice which reduces the fundamental health of a vineyard will result in increased winter injury. This includes unbalanced nutritional status. The low pH soil disorder of vinifera cited above is especially associated with poor winter survival.

Commonly growers are afraid to supply vinifera vines with sufficient nitrogen in the belief that any stimulation will result in poor wood maturity and increased winter injury. Dr. Tony Wolf, the viticulturist for Virginia State University, studied the interaction between rootstock, nitrogen fertilization and Chardonnay performance in the Finger Lakes region of New York during his doctoral research. He showed that, when Chardonnay was grafted to a phyloxera and lime resistant rootstock (C. 3309) applying up to 75 lbs. of N annually did no measurable harm to vine productivity or winter cold tolerance. With a non- lime resistant rootstock, Elvira, failure to add supplemental nitrogen reduced yield and quality. Reducing nitrogen additions did more harm than good.

Floor Management and Vine Vigor

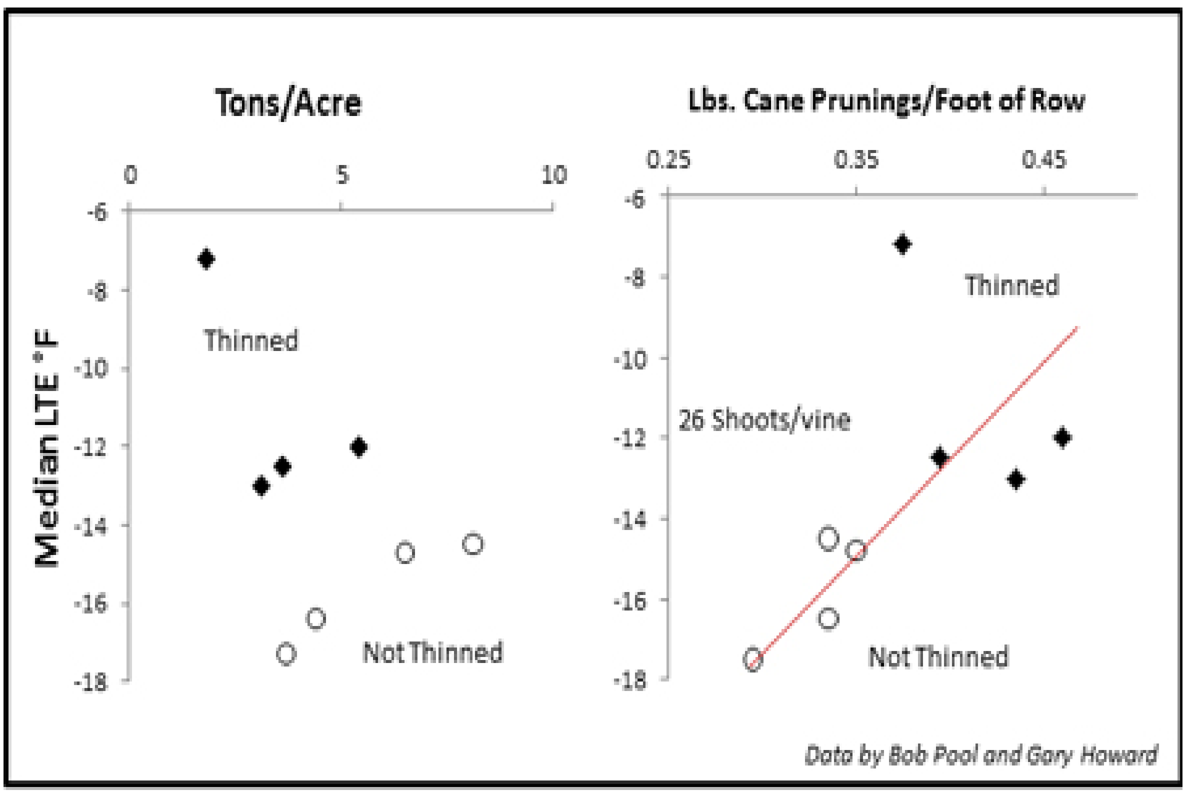
Because New York vinifera vineyards should have a slope sufficient to ensure good air and surface water drainage, they are susceptible to soil erosion. As a result many are sown to permanent between-the-row sod. This is a desirable practice so long as soil depth and water holding capacity are sufficient to supply the needs of both the vine and the cover crop. However when vine size is inadequate, an alternative practice should be used.

No weeds should be allowed to develop under the vines. Because of the practice of hilling earth over the graft union as a means of winter protection, in-the-row weed control for most NY vinifera vineyards is by mechanical or a combination of mechanical and chemical methods. Some growers hill-up on a semi-annual basis, and use only chemical weed control in the alternate years. Hills must be removed at least semi-annually or scion roots will develop which greatly de-vigorate the vine.

Pruning and Cropping

Again, the there is a widespread fear that vinifera vines are so fragile that they must be pampered in order to survive in a region with cold winters, has dominated the way the vines are pruned and cropped. In terms of disease control it is probably true that more is better, but with fertilization or cropping levels, excessive concern can cause the very problem the grower is trying to avoid. Severe pruning or thinning to reduce crop below its vine capacity will increase vigor and the likelihood of winter injury.

The following data are from a pruning/thinning experiment on Chardonnay vines growing at Geneva. Actual pruning levels used in the experiment were 26, 52 or 78 shoots/vine at an eight foot in-the-row planting space or balance pruning using a formula of 20 shoots per pound of cane prunings. Half of the vines were thinned to one flower cluster per vine or not thinned at all. Note that, within a thinning category, smaller crops result in increased bud cold hardiness (lower median low temperature exotherm (LTE) temperature), but also that increased vine vigor (cane pruning/foot of row) is associated with less, not more cold hardiness, and the higher crop levels in the unthinned vines produced buds with lower freezing points. In each plot the thinned, 26 shoots/vine treatment does not match up well with other treatments. That is because the severe pruning induces very vigorous shoot growth, but 26 shoots do not produce enough growth to make comparable cane pruning weight data.



Effect of pruning level and flower cluster thinning on freezing temperature (LTE) of Chardonnay winter buds.

In most years there has been not difference in fruit maturity between the different treatments. Taste panels rated wines made from the low crop vines to be inferior to those from high crops vines.

Training Systems

In regards vigor control, we have seen little difference between non-divided training systems. However, canopy division as with lyre or Geneva Double Curtain training can be a very useful technique to better display the foliage and reduce effective vigor (wt. of cane pruning per foot of canopy, rather than row).

Effect of training system on vigor, yield and maturity of White Riesling grapes

Training System	Cane Prunings/Vine (lb.)	Cane Prunings/Ft. of Canopy (lb.)	Tons/Acre	Brix
Pendlebogen*	3.4 b	0.4 a	5.2 b	18.8 ab
Umbrella	3.6 b	0.5 a	5.4 b	18.8 ab
Fan	3.6 b	0.5 a	5.8 ab	17.9 b
Low Cordon*	4.3 ab	0.5 a	6.9 a	19.1 a
Lyre*	5.1 a	0.3 b	6.9 a	19.1 a

* These are forms of vertical shoot positioned (VSP) training systems. The others have high or diffuse heads.

The data in the table above exemplify the benefits of canopy division for large vines. Note that in terms of vine vigor, there is little difference between the non-divided training systems, but that vine size (cane prunings/vine) is greatest with the divided canopy Lyre training. However if vine vigor is expressed on a foot of canopy basis, the divided canopy has a lower and more desirable value. Fruit from Lyre trained vines also had highest maturity and lowest rate of botrytis bunch rot.

Divided Canopy Training Systems

The first and still most popular divided training system was Geneva Double Curtain (GDC) which is an aerial simulation of close row spacing in rows (vine trunks) which are widely spaced to accommodate standard US vineyard equipment. The high cordons allow tractors to pass under the vines. It was developed for Native American varieties which have a procumbent (trailing) growth habit. GDC is not suitable for cold tender varieties in New York because of the vulnerability of the extensive cordon system to winter injury.

Lyre training is an adaptation of GDC which uses low cordons (or less commonly canes) to produce two angled VSP canopies which accommodate tractors. The drawbacks of Lyre training are expensive trellis, difficult floor management, greater labor requirement and unsuitability for machine harvest. However, when preplant decisions have resulted in excessive vine vigor, yield and especially wine quality have greatly benefited from conversion.

Vertically divided training systems have been developed as an intermediate step between simple VSP and GDC or Lyre to reduce canopy density. The fundamental concept is that two thin canopies are produced on each vine. The canopies are stacked rather than separated horizontally. Cordon and cane systems have been developed. Currently the most popular versions are Scott Henry – which uses cane training. Half of the canopy is vertically shoot positioned up, and half is vertically shoot positioned down. Another version uses single or double cordons and is called Smart-Dyson. Growth from the upper cordon is positioned upward and growth from the lower cordon downward. A modification of both systems is done by eliminating the extensive and rigorous downward shoot positioning. This approach is termed ballerina. Positioning shoots in a downward direction reduces their vigor (rate and extent of shoot growth), and positioning shoots upward does the reverse. In New York we have had difficulty maintaining sufficient vigor in the downward pointing canopy to mature the fruit and wood. The lower canopy tends to die out. It remains to be seen if the use of the ballerina approach or careful cane selection can allow the system to be utilized for cold tender varieties in New York.

Shoot Positioning, Shoot Thinning, Summer Pruning and Leaf Removal

The cultural practices discussed above indirectly affect canopy density by influencing growth potential (vine vigor). Shoot positioning, summer pruning, shoot thinning and leaf removal directly affect the canopy. With some training systems shoot positioning or summer pruning may almost be mandatory, but in general, these are corrective actions that must be taken when the other viticultural decisions have not lead to an optimum vine size and hence canopy structure. As corrective actions they can lead to dramatic improvements in disease and fruit quality. However, they are expensive and will only partially compensate for unbalanced vine vigor. Every grower who has to depend upon these practices in order to obtain satisfactory canopy structures should review all the viticultural management options used to see if changing other practices might alter vine growth so that the canopy does not require so much direct manipulation.