ECONOMICS OF VINEYARD DESIGN:

Vine and row spacing, trellising

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Figure 1 — Trellis systems by canopy and foliage-support type.

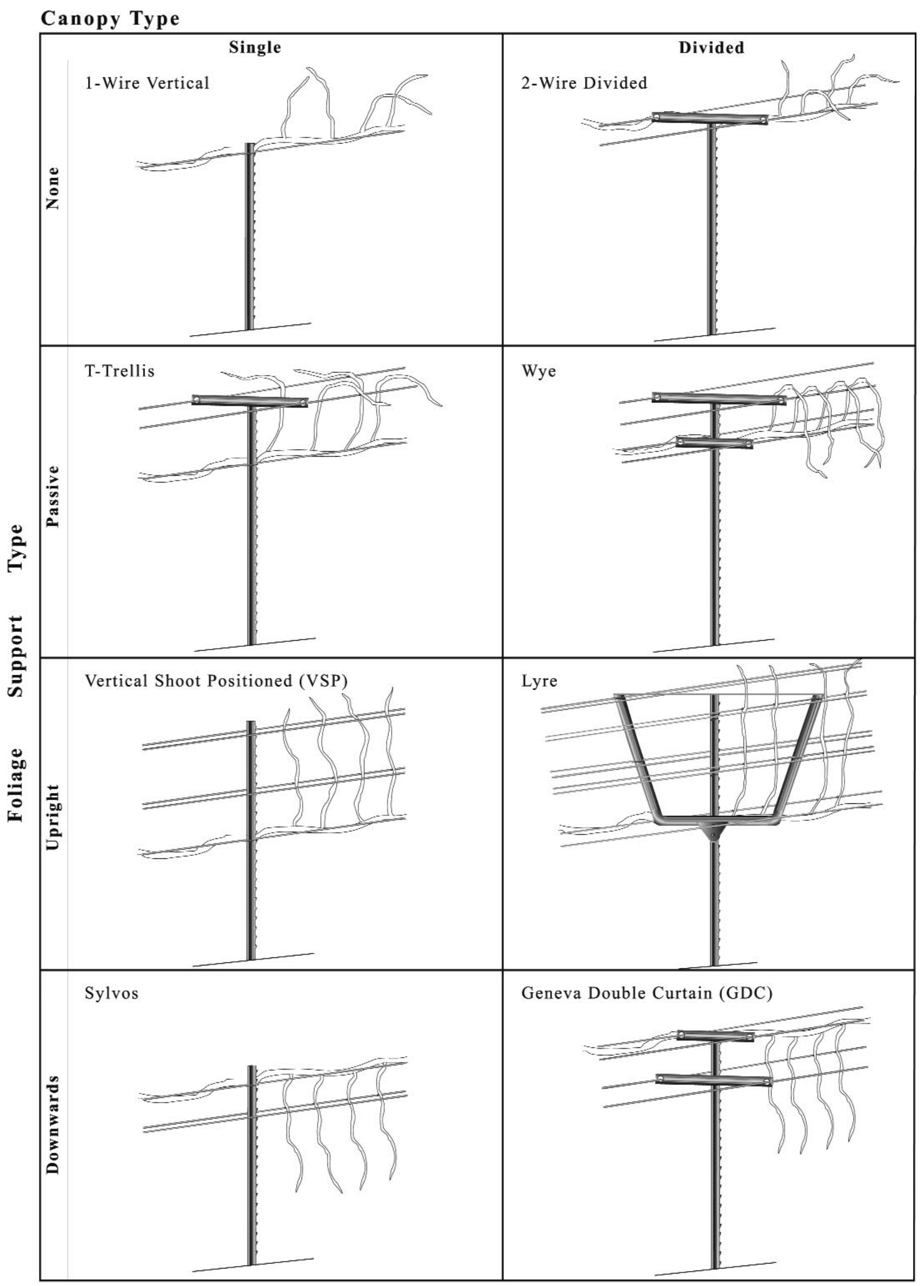


Figure 1. Trellis systems by canopy and foilage support type.

These are dynamic times in the winegrape industry. As demand for high-quality grapes rapidly increases, many wineries and growers are looking to expand production. Vineyard development is expensive, and available land for production of high-quality grapes is limited. Successful expansion under these circumstances requires careful planning and cost assessment.

In addition to soil preparation, scion variety, and rootstock, vineyard design considerations are among the most important decisions growers must make when optimizing current sites or developing new vineyard sites.

Trellising and spacing between vines and vine-rows influence fruit quality and marketability. In addition, they determine vineyard development and operational costs, the promptness of return on investment, and the average rate of return during the vineyard's lifetime.

Using production data from viticultural literature and a fictitious model vineyard, we can evaluate expected rate of return relative to initial vineyard development costs. Use the model vineyard — which has a traditional California winegrape-growing design — as a baseline for comparing other possible vineyard designs to determine which one will work best at your site.[25]

Vineyard model

The model vineyard occupies 20 square acres (933.4 ft. per side) and is

Table I — Components of grapevine trellises included in a vineyard development economic analysis																
													Number of wires per row		
			Percent of stakes[a]				Percent of crossarms					Fruit / cordon	Stationary foilage	Moveable foilage
Trellis	Canopy type	Shoot positioning	5ft	6ft	7ft	8ft	18in	24in	36in	42in	Lyre[b]	12 gauge[c]	14 gauge[d]	14 gauge[e]
1-wire vertical	Single	None	0	0	100	0	0	0	0	0	0	1	0	0
T-trellis	Single	Crossarm	0	50	50	0	50	0	0	0	0	1	2	0
VSP	Single	Upward	50	0	0	50	0	0	0	0	0	1	0	4
Sylvos	Single	Downward	0	0	50	50	0	0	0	0	0	1	0	2
2-wire divided	Divided	None	0	0	100	0	0	0	100	0	0	2	0	0
Wye	Divided	Crossarm	0	50	50	0	0	100	0	50	0	2	2	0
Lyre	Divided	Upward	50	0	50	0	0	0	0	0	50	2	0	8
GDC	Divided	Downward	0	0	100	0	0	100	0	0	0	2	0	2

a Five ft. and 6 ft. stakes are 95 weight rail steel. Seven ft. and eight ft. are 125 weight rail steel and have spades.
b Lyre crossarm formed from 125 T-stake material.
c Wire clips required to attach wire to stake for single canopy trellises.
d All trellis systems have one stationary wire clipped about 18 in. above the soil for attaching the drip hose.
e Requires JR clips for shoot positioning wires on VSP and Lyre trellises.

planted with bench grafts in a vine and row spacing of 8-feet by 12-feet. Initial cost per acre for developing this model vineyard is likely to be somewhat higher than the cost for developing larger vineyards and somewhat lower than for smaller vineyards due to variations in the ratio of number of rows to row length and number of end posts per acre.

Vines are bilateral cordon-trained on a T-trellis composed of 7-foot stakes with 18-inch crossarms attached at the top alternating with 5-foot stakes without crossarms. All stakes are T-stakes made of 125- or 95-weight rail steel for 7-foot and 5-foot lengths, respectively. Crossarms are 14-gauge steel. End posts are 9-foot, recycled well stems with a spade. Cordons are attached to a single 12-gauge wire, and a 14-gauge wire on each end of the crossarm supports the foliage. All wires are high-tensile, galvanized steel.

The model vineyard is drip irrigated. The drip hose includes in-line, pressure-compensated, 0.5-GPH emitters three feet apart. It is attached to a 14-gauge wire by "pigtail"-type clips at three-foot intervals between the emitters. In this model, vineyard development costs other than trellis, irrigation system, vines, and planting are considered constant.

Vineyard development costs used in this economic analysis are those Duarte Nursery incurred in 1997 and 1998 while developing its vineyards in the Linden Hills area of San Joaquin County. The material costs (grapevines, trellis, and drip irrigation) are representative of most of California. Labor costs used in the study are representative of the interior valleys and are lower than in many coastal areas.

Trellising

In the recent past, only a few trellis types have been used to support winegrape vines in California. Among the simplest of these is the one-wire vertical trellis (Figure I). It consists of a single wire fastened to the top of a stake onto which cordons or canes are trained and attached.

A T-trellis is more elaborate, and it is the trellis of our model vineyard. Normally the T-trellis consists of some alternating pattern of short and tall stakes (*e.g.* one short, one tall) with a cordon or cane wire fastened to the tops of the short stakes and to the sides of the tall stakes (Figure I). At the top of the tall stakes a crossarm is attached, and wires are fastened to the ends of the crossarms to provide passive shoot positioning and foliage support.

While traditional trellis designs are often still appropriate for many vineyard applications, experimentation and experience have shown that, under some conditions, other types of trellising can improve fruit yield and quality.

In cooler winegrape growing areas, the vertical shoot-positioned (VSP) trellis is used to invigorate shoots and assure buds and fruit are adequately exposed to sunlight. This trellis consists of very short stakes and very tall stakes arranged in some alternating pattern with cordon or cane wires attached to the tops of the short stakes and to the sides of the tall stakes as with the T-trellis (Figure I). Wire clips (usually two J-R type) or very short crossarms are fastened to the tall stakes at intervals above the cordon wire, and pairs of wires are attached at each end of the clips or crossarms during the growing season to position shoots into a vertical plane in line with the stakes.

Where sunlight is not too intense during the growing season but shoots grow vigorously, vines are sometimes devigorated by downward shoot positioning. The Sylvoz or Hudson River Umbrella (HRU) trellis was designed for this purpose. It is very similar to the one-wire vertical trellis with only a few minor differences (Figure I).

First, the stakes are taller, so cordons or canes are higher above the ground. This allows vertical space for the shoots below the cordon. Also every second or third stake is taller still, so a pair of wires may be temporarily attached near its top and above the cordon during the early part of the growing season. After the shoots are long enough, these wires are brought down on either side of the trellis, and the weight of the wires is used to hold the shoots downward. Sometimes the wires are attached to a short crossarm.

Cordons or canes are the bearing surface of vineyards. That is, they are the location for both the apparatus for capturing sunlight and converting it into chemical energy (*i.e.* the leaves) and for the products of the vines work (*i.e.* the fruit). The trellises described above all have cordons in a single line within the vine row with the foliage forming a single canopy.

Many vineyard sites have the potential to grow more leaves and produce more fruit than a single line of cordons will allow. This potential can be realized by dividing or splitting the canopy to form two parallel bearing surfaces within the vine row. This is most easily accomplished by use of a crossarm with wires on each end to support cordons. Either two or four cordons are trained and attached on the wires. Typically, the vines within the rows of vineyards with divided canopies are planted more closely together than vines within the rows of vineyards with single canopies to avoid overcropping of individual vines.

As with single canopies, the foliage of divided canopies may have no support or may be positioned passively, vertically, or downward. The corresponding trellises for these types of foliage support or positioning are the two-wire divided, Wye, Lyre, and Geneva Double Curtain (GDC), respectively (Figure I).

Table II — Grapevine trellis costs/acre. Trellis costs relative to T trellis costs, and relative trellis materials and labor costs.

Trellis	Cost/ acre $	Percent T-trellis Total	Materials	Labor	Percent of total cost Materials	Labor
1-wire vertical	2,084.	99	106	88	64	36
T-trellis	2,113.	100	100	100	59	41
VSP	2,268.	107	110	103	61	39
Sylvos	2,352.	111	122	96	65	35
2-wire divided	4,528.	214	276	125	76	24
Wye	4,353.	206	250	141	72	28
Lyre	7,603.	360	500	155	82	18
GDC	4,808.	228	287	141	75	25

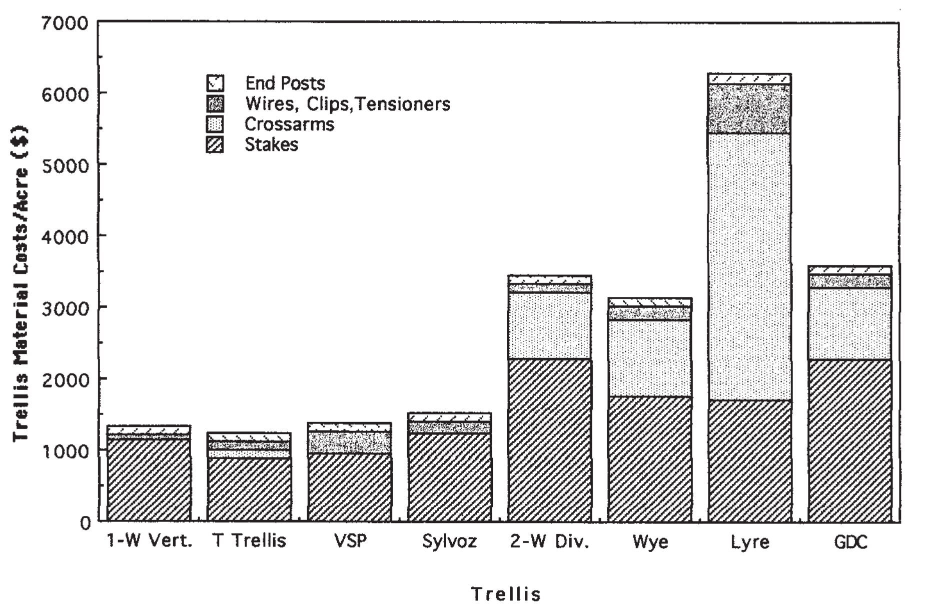
Trellis costs

Particular requirements of the site, grape variety, mechanization, budget, winery and grower perceptions, and other factors affect trellis materials, design, and construction. However, in the following economic analysis, the trellises are designed to have as many features in common as possible, fully realizing that, for a few trellises, other designs may be more common and less expensive. As each is discussed, we will also examine some alternate design features that can reduce the cost of more elaborate trellises.

The T-trellis described in this model vineyard is the base reference, and all other trellises in this economic model have been designed to be as similar to it as possible (Table I). Like the model T-trellis, all these trellises with foliage support (VSP, Wye, Lyre) have a foliage support apparatus on every other stake. Metal T-stakes, which cost about 9% more than wood (95 rail steel compared to 2 in. x 2 in. pressure-treated Douglas fir), are used for all trellises. All cordon wires are 12-gauge steel, and all foliage-support wires are 14-gauge. J-R clips are used to hold foliage wires of the two trellises with vertical foliage support (VSP and Lyre).

Eliminating the foliage support of the T-trellis to make a one-wire vertical trellis reduces initial cost negligibly (Table II). Cost of the VSP and Sylvoz are only about 10% more than the cost of the T-trellis. The slightly higher costs of these trellises are due to additional wires, clips, and tensioners and their installation and to more expensive stakes. Since costs are similar for all of the single-canopy trellises, other factors, such as extent of fruit exposure and adaptability to mechanization, are

Figure 2 — Relative costs of grapevine trellis materials.



more important and should determine which single-canopy trellis you choose.

Cost for the two-wire divided, Wye, and GDC trellising are 206% to 228% more than for the T-trellis (Table II). Typically, the Wye system has foliage support on every third stake, which will reduce its cost relative to the T-trellis by an additional 10%.

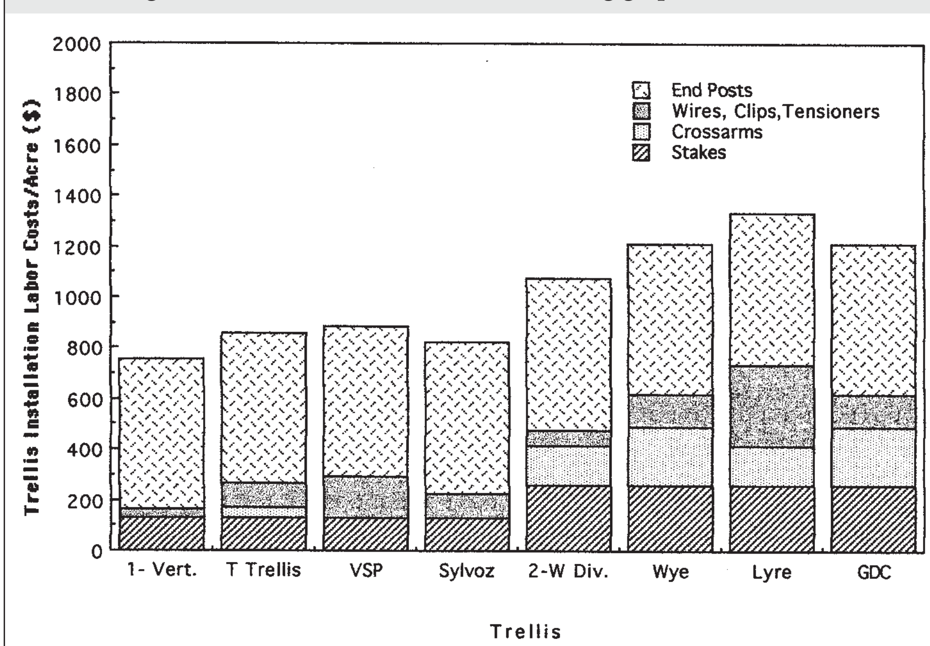
Cost of the Lyre trellis in this analysis is 360% greater than the cost of the T-trellis, principally because of the high cost of the Lyre crossarms. In practice, the Lyre trellis is usually constructed less expensively. Often crossarms are spaced further apart in the row, for example, at every third or fourth vine. These arrangements reduce Lyre trellis cost by 18% or 28%, respectively. The increased distance results in less fruit-wire support within the vine row and greater tension on the end posts. More elaborate end-post assemblies are usually required to accommodate the added wire tension, which consumes about 2% or 3% of the savings from further crossarm spacing.

Another cost-saving measure for the Lyre trellis is the substitution of rebar (⅜-inch diameter) or some other metal rod, wooden stick, or twine and anchor combination for the stakes that do not have crossarms. The rebar substitution further reduces the trellis cost by 23%. These substitutions, which are also sometimes used with the VSP trellis, decrease development costs substantially, but Lyre trellis costs still remain 30% to 70% more than Wye or GDC trellis costs. Such modification also limits mechanical harvest methods to bow-rod harvesting, because the trellis will not be sufficiently rigid for trunk-shaker harvesting.

While crossarms are the largest material cost for the Lyre trellis, stakes are the largest material cost for other trellises (Figure II). Excluding the Lyre trellis, stake costs range between 57% and 86% of the total trellis material costs. Crossarms, however, generally comprise a large portion of the material costs of divided canopy trellises (60% for the Lyre and about 30% for the others). End posts, wire, clips, and tensioners form a small portion of single-canopy trellis material costs and an even smaller portion of divided-canopy trellis material costs.

End-post installation is the most expensive labor cost, accounting for 45% to 78% of the total labor cost (Figure 3). The relative labor cost to install stakes is similar for all the trellises, but it is slightly more for divided-canopy compared to single-canopy trellises (about 15% and 21%, respectively).

Figure 3 — Relative labor costs for installing grapevine trellises



Crossarm installation accounts for 12% to 19% of the cost of divided-canopy trellis installation, but it is only a small part of T-trellis installation (about 5%). The cost to install wires, clips, and tensioners varies proportionately with their number and is least for trellises with no foliage support (*i.e.* one-wire vertical and two-wire divided) and most for trellises with upward shoot positioning (such as VSP and Lyre).

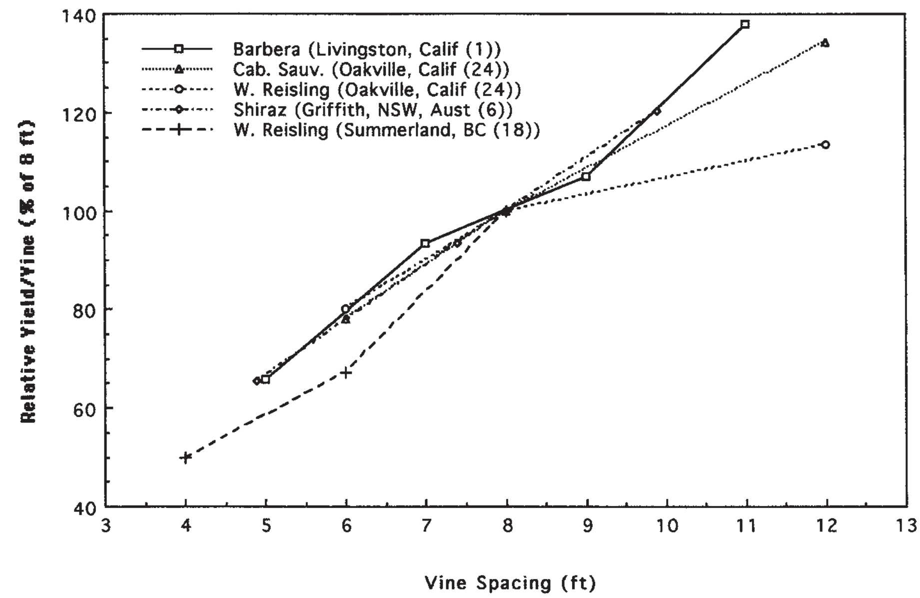
Returns on trellis investment

Although type of foliage support has been shown to affect fruit yield,[5] it is considered mainly a fruit quality factor, and therefore, assigning a monetary value to it is difficult. Selection of foliage-support type usually depends on regional climate, perceived fruit-quality benefits, or grower or winery preference rather than production economics.

Fruit perceived to be, or demonstrated to be, of superior quality due to foliage support is most easily marketed to wineries and, consequently, has a definite economic advantage for the grower.

A final economic consideration regarding foliage-support type involves operational costs. Some elaborate trellising may limit mechanization of some vineyard operations. For example mechanical prepruning, which may reduce pruning costs by 35% to 80%,[4, 7, 14, 21] is currently not possible with most Lyre trellises because of horizontal supports across the top of the crossarm.

Figure 4 — Effect of vine spacing on relative grape yield per vine.



Fruit quality can be enhanced by canopy division, particularly if it decreases shoot density and leaf layers in the fruit zone,[20] but it is considered primarily a production factor. Under conditions of sufficient sunlight atmospheric heat, soil depth, soil moisture, and soil fertility, a divided-canopy trellis may yield up to 85% more fruit than a single canopy.[5, 11, 15, 16, 17, 19] In addition, under these conditions a divided-canopy vineyard will produce larger quantities of fruit ***earlier*** in the vineyard's life than it would as a single canopy.

However, some operational costs involved with crop and foliage for divided-canopy trellises will increase substantially, perhaps nearly doubling. The most prominent examples include hand operations such as pruning, shoot thinning, and crop thinning. (Again, mechanical prepruning can help to reduce the cost of hand pruning.)

Still, in the majority of cases, the incremental returns from increased fruit production from canopy division will be much larger than the incremental cost increases in vineyard development and operations. For example, a Wye-trellis vineyard in a high-capacity

Figure 5 — Effect of vine spacing on relative grape yield per acre.

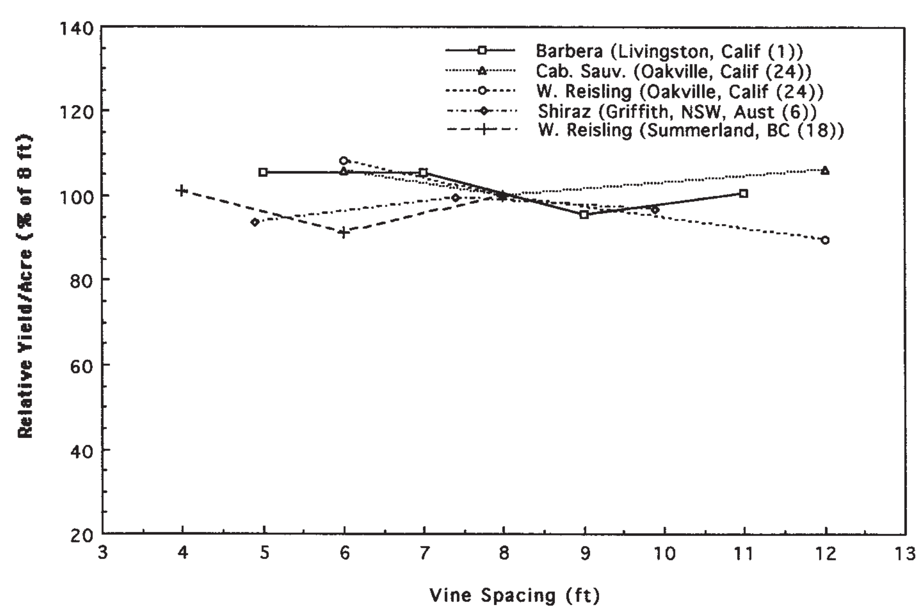
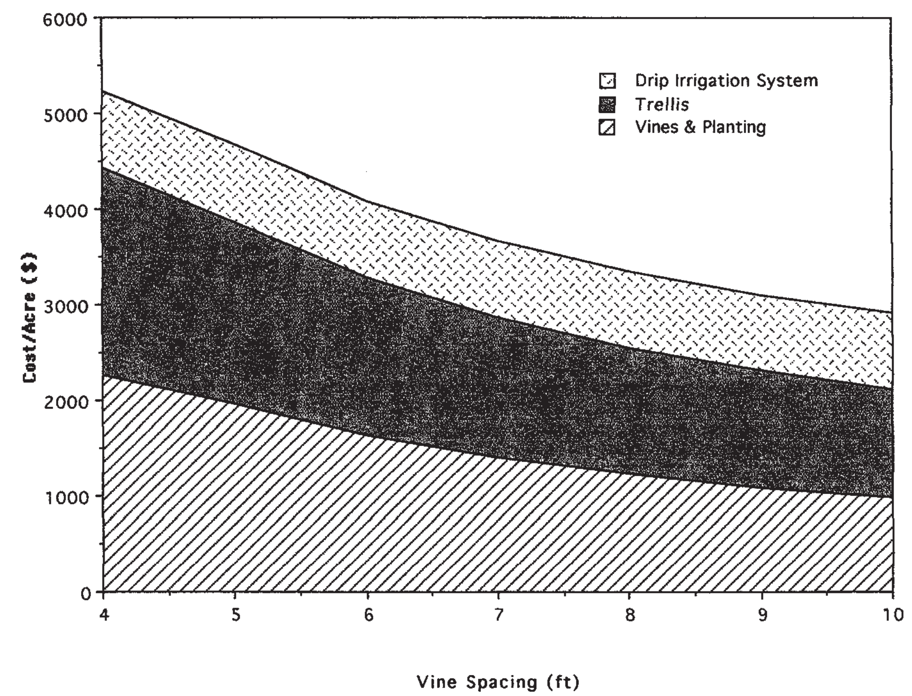


Figure 6 — Effect of vine spacing on variable vineyard development costs.



site will cost about 106% more per acre to develop (for trellis and training) and about 10% more per acre to operate (for pruning, shoot thinning, and crop thinning) compared to the same vineyard with a T-trellis, but it will generate about 85% more revenue per acre.

Consider a T-trellis vineyard that would have yielded an average of six tons per acre of $1,000 per ton grapes. Developing that vineyard with a Wye instead of our model T-trellis would result in an increase in development and operational costs during the first 15 years of about $4,390 per acre, but revenues over that period could increase by about $63,750 per acre.

Vine Spacing

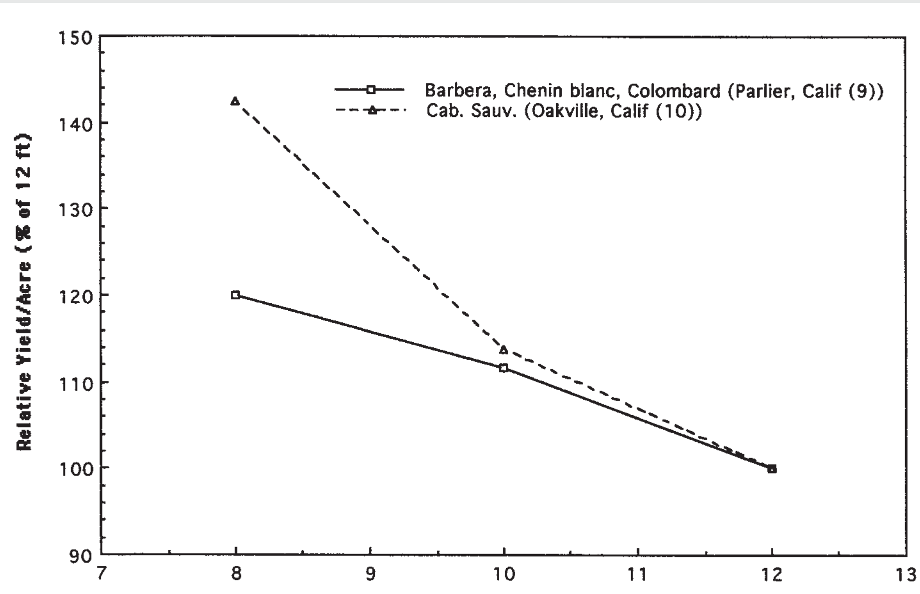
Unless in-row vine spacings are either extremely narrow or wide, they usually have a much larger effect on yield per vine than they do on yield per acre (Figures 3 and 4). Therefore, the economics of established vineyards are usually not greatly affected by in-row vine spacing.

There are, however, two exceptions. The contribution of each vine to the overall vineyard yield increases with more space between vines. As a result, missing vines have a greater impact on yield per acre and vineyard revenues in vineyards with wider spacings than with narrower spacings. Missing vines are of minor consequence for the vast majority of vineyards. Wider-spaced vineyards have an additional disadvantage, however. They normally come into production more slowly than narrower-spaced vineyards and, therefore, have a later return on investment[22].

There are viticultural considerations regarding vine spacing beyond yield and rate of return. First, for any given variety, site, and set of management practices, excessive foliage and canopy density are problems when the vine spacing is too narrow, and insufficient foliage and overcropping are problems when the vine spacing is too wide.

Both of these extreme conditions are detrimental to fruit yield and quality and usually produce other undesirable side effects. They also result in increased operational costs for extra canopy management (*e.g.* hedging and leaf removal) or extra water, fertilizer, and crop management (*e.g.* cluster thinning) for excessively narrow and wide

Figure 7— Effect of row spacing on relative grape yield.



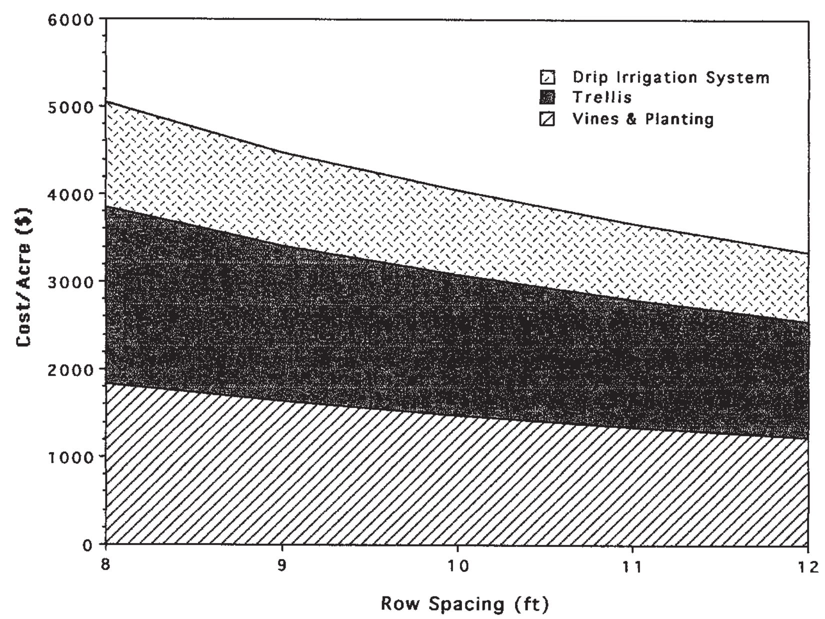
vine spacing, respectively. Therefore, they should be avoided.

In California, the most common vine spacings for single-canopy trellises range from six feet to eight feet (recall that eight feet is the vine spacing of our model vineyard), although both narrower and wider spacings can easily be found. Frequently these same common vine spacings are used in divided-canopy vineyards, but not always with satisfactory results.

Some grapegrowers with divided-canopy vineyards spaced at six feet to eight feet find that their fruit ripens later and is of lower quality than their neighbors' single-canopy vineyards with similar vine spacing. These are the results of overcropping, which can be avoided by using narrower vine spacings (four feet or five feet).

In the model vineyard, development costs per acre decrease by $2,325 (from $5,234 to $2,909) as in-row vine spacing increases from four feet to 10 feet (Figure 6). With more space between vines, the relative costs of vines, planting, and trellising decrease, while the cost for drip irrigation remains constant. The rate of return during a vineyard's early years will have to exceed the increased development cost of narrower spacing to make it the best economic alternative. This would only be possible if early yields or crop value, or both, were sufficiently high.

Figure 8 — Effect of row spacing on variable vineyard development costs.



Row Spacing

Reducing the distance between rows of vines from 12 feet to 10 feet to 8 feet increases the number of rows per square acre from 17 to 21 to 26, respectively. This relationship between rows per acre and row spacing is nearly linear with the number of rows per acre increasing by about two for every foot the space between rows decreases. How narrow the spacing between rows can be is limited only by the width of available vineyard machinery.

There is a positive relationship between the number of rows per acre and relative yield per acre (Figure 7). Thus, row spacing is an important vineyard production factor. There is no evidence that row spacing is a fruit quality factor. Given that rows per acre and vines per acre increase proportionately with narrowness of row spacing, it follows that operational costs increase proportionately with narrower spacing between rows.

Development costs for the model vineyard also increase with decreasing space between vine rows. Costs increase by $1,700 per acre (from $3,350 per acre to $5,050 per acre) when decreasing space between vine rows from 12 feet to eight feet (Figure 8). However, for all spacings between vine rows, the relative costs for vines and planting (36%), trellis (40%), and drip irrigation (24%) remained constant.

Relative yield and development costs for different spacing between vine rows are roughly proportionate. That is, for the initial expenditure in vineyard development with narrower row spacing, there is a return in gross revenues that continues over the lifetime of the vineyard and pays for itself several times.

Relating vineyard design factors

Vineyards are horticultural systems with multiple design elements that influence vine growth, fruit production, and fruit quality. These elements also influence development costs, operational costs, and rate of return. Some of them are independent and others are interrelated.

Because row spacing normally has a negligible influence on other vineyard design elements, it is an independent factor. In-row vine spacing influences the extent of fruit- and foliage-bearing area, while trellising affects the position of the fruit and foliage bearing area in space. It is the fruit- and foliage-bearing area connection that relates vine spacing and trellising.

Costs of vine spacing and trellising can be evaluated together, using the information presented here. Start by selecting a trellis. In Table II find the cost of the trellis. Calculate the trellis cost relative to the T-trellis by dividing by 2,113. Find the development cost for the vine spacing in Figure 6 and multiply it by the relative trellis cost quotient to obtain the cost estimate for vineyard development, less land preparation. ■

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