Quote: The open vase with Nemaguard rootstock, planted at 16 x 18 foot spacing and pruned using the minimally pruned method, is currently a very economically efficient training system for fresh-shipping stone fruits in most areas of California.

ORCHARD SYSTEMS FOR NECTARINES, PEACHES AND PLUMS: TREE TRAINING, DENSITY, AND ROOTSTOCKS

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INTRODUCTION

Choosing an orchard training system (including rootstock) is one of the most important decisions a grower is called upon to make. While poor varieties can be changed over through grafting, the original training system is difficult to change, and the rootstock impossible. For this reason, growers should carefully consider their choices prior to planting.

Probably the biggest mistake made in developing a training system is not having a clear picture of how the orchard should look when mature. Additionally, one must have a clear plan as to how to get the orchard to that point. If a grower does not know what he wants or how to get there, it is impossible to give proper directions to workers.

It is therefore very important for growers to have a plan for developing the orchard system prior to planting. When evaluating an existing orchard system, some important questions to consider are:

1. What steps were taken, and when, to get the orchard to look like it does? Consider type, timing, and severity of both dormant and summer pruning.
2. What were the major factors considered in developing that system? Consider fruit production, fruit quality, labor savings, wind protection, etc.
3. Where was the system developed? Possible differences in climate, soil, sunlight, length of growing season which may substantially alter tree growth pattern and vigor must be considered.
4. Is there a dwarfing rootstock involved? If so, is this rootstock adaptable to your situation? If not, can the system work without that rootstock?

A carefully planned and designed system, appropriate for your situation, cannot be implemented until these types of questions are asked and understood.

EVOLUTION OF CALIFORNIA SYSTEMS

The Open Vase

For more than 150 years, the open vase system has dominated California orchards as the preferred system for growing fresh-shipping stone fruits. The system was originally planted on wide spacings, 20 to 25 feet apart in both directions, to allow easy cultivation and cross cultivation with mules, horses, and later the more primitive mechanized equipment. In the 1950s and ’60s chemical herbicides were introduced and the need for cross cultivation was reduced or eliminated. Consequently, tree spacings could be slightly reduced. Today, popular spacings are 18 to 20 feet between rows and 16 to 20 feet between trees down row.

Trees are trained to 3 or 4 primary scaffolds arising from a short central trunk. These scaffolds then are each allowed to branch into 6 to 8 secondary scaffolds. These in turn may branch so that at the top of the tree there are often as many as 10 to 14 tertiary growing points. Fruitwood is developed off the primary, secondary, and tertiary scaffolds.

The open vase system is simple and easy to develop. Planting costs are low because of the low tree densities involved. Light is easily managed due to the open center nature of the tree that allows excellent light penetration when managed properly. As grown, the system has two drawbacks: 1) it is slow to come into production even under vigorous growing conditions, and 2) labor costs can be expensive because trees are generally allowed to grow to 12 to 14 feet in height, requiring considerable ladder work.

Hedgerow Systems

In the 1960s and 1970s, hedgerow systems were introduced to California from Europe. There was much discussion about how labor costs would be reduced since trees could be harvested, pruned, or thinned either mechanically or with mechanical assistance. University of California trials on these systems were initiated in 1972 (Gerdts et al., 1979).

The most popular of these systems was eventually termed the “Parallel V” or “California V” and was similar to the palmette system. Trees were planted on much narrower between-row spacings of 12 to 16 feet. Trees within the row were 8 to 12 feet apart. Two primary scaffolds oriented parallel with the row were allowed to develop. Fruitwood then was developed from these primary scaffolds. In the best orchards, secondary branching of the primary scaffolds was not allowed. This was to help prevent the tree being dominated by structure rather than fruitwood.

Another system, based on the central leader used in apples, was also planted in California. In this system, trees were also planted in close hedgerows 12 to 16 feet apart, but the trees were even closer down the row—usually 5 to 8 feet apart.

Both of these systems were very productive in the early years after planting—especially the central leader with its very high tree densities (Table 1). However, these systems became very difficult to manage after the trees reached their full size with shading and loss of fruitwood becoming large problems. Often growers did not understand or have a clear and well-thought-out plan for managing the vigor of these orchards. Most responded by making heading cuts to limit tree height and size. These cuts stimulated vigorous regrowth that usually just made the problem worse. Growers also had a difficult time determining when and how to summer prune the trees. Additionally, mechanical or mechanically aided devices for saving labor did not work out.

Table 1. Summary of the initial high density peach planting trials at the Kearney Agricultural Center; trees planted in 1972, cumulative yield from 1974 through 1978 (after Gerdts et al., 1979).

Variety	Spacing (feet)	Trees per acre	System	Cumulative yield (t/acre)
Springcrest	8x15	363	Central leader	42.6
Springcrest	10x15	290	Parallel V	44.1
Springcrest	22x19	104	Open vase	23.7
June Lady	8x15	363	Central leader	54.6
June Lady	10x15	290	Parallel V	46.4
June Lady	22x19	104	Open vase	28.0
Fantasia	8x15	363	Central leader	76.3
Fantasia	10x15	290	Parallel V	58.8
Fantasia	22x19	104	Open vase	42.0
O'Henry	8x15	363	Central leader	72.3
O'Henry	10x15	290	Parallel V	65.5
O'Henry	22x19	104	Open vase	38.3

Successful growers managed these orchards by controlling excessive vigor through proper fertilization and pruning. Excessive amounts of nitrogen were avoided; most orchards received no more than 50 to 125 pounds of nitrogen per acre annually. Also, and most importantly, pruning tactics centered on the use of thinning cuts rather than heading cuts. These growers found that four or five light, frequent summer prunings were more beneficial than one or two severe prunings. The use of mechanical topping and side-hedging was eliminated. These tactics made the orchards much more manageable. Most growers, however, lost patience with these systems and replaced them when the orchards got old or production dropped off due to shading or other problems.

Today there are only a few hedgerow-trained orchards in the fresh-shipping region of central California. Most of these are managed by one large firm that has taken the time to understand these systems. The system they have settled on is the parallel V at a spacing of 8 x 12 feet. All hand labor is performed using ladders.

Trellis Systems

Trellis-based systems have not worked out in California. Many have been tried, mostly vertical hedgerow systems, but also some Tatura type "V" plantings. Under our climate, these systems have not been necessary to prevent wind damage. Growers made similar mistakes to those encountered with the other hedgerow systems, and vigor became difficult to control in these orchards. A complicating factor with trellis systems is that the California fruit industry replaces varieties about every 8 to 12 years. At costs of $3000 to $5000 per acre for the support system alone, the trellis systems were viewed as too expensive to remove with the trees. Often the trellis was left in place, but this made replanting difficult since ground modification such as deep

ripping, fumigating, and leveling became nearly impossible. The cost and difficulties involved were viewed as too great and trellis systems have been virtually abandoned within the stone fruit industry.

Open Center High Density Systems

Kearney Perpendicular V

In 1982, University of California pomologists planted the first orchard of what would later become known as the "Kearney Perpendicular V" system (DeJong et al., 1994). The system was essentially a Tatura "V" without the trellis. Also, the spacing was not as close, the trees were planted 6.5 x 18 feet. This planting compared the Kearney "V" with the open vase, parallel "V" and central leader systems (Table 2). The system proved to have merit, and many orchards were planted. Since then, many different spacings were tried, but the best seems to be about 6 feet apart within the row and 16 feet apart between the row.

Table 2. Cumulative fruit yields in tons per acre for four peach, nectarine and plum training systems for the first 10 years after planting (after DeJong et al., 1991a).

System	Flavorcrest Peach	Royal Giant Nectarine	Simka Plum
Central Leader 6.5'x18' 372 trees per acre	88.4	145.9	90.5
Kearney V 6.5'x18' 372 trees per acre	110.1	186.4	88.3
Parallel V 10'x18' 242 trees per acre	96.1	148.9	80.3
Open Vase 20'x18' 121 trees per acre	107.4	169.5	82.4

Quad V

In the late 1980s growers became concerned with the high initial planting costs of the Kearney V System. In an effort to reduce tree costs, but at the same time increase early production, several growers in the Dinuba/Traver area of Tulare County began experimenting with very close open vase orchards in which trees were planted 10 to 12 feet apart down the row. These had very high yields during the first 4 or 5 years of orchard life but, as the trees matured and grew together, they began to have shade problems, causing yields to drop. Several of these orchards were eventually modified by sawing out scaffolds oriented parallel with the row and leaving scaffolds protruding into the alleyways. The rows had a rough "V" shape with an open center.

Shortly thereafter in 1990, an orchard was planted at the Kearney Agricultural Center comparing the Kearney V and a variation of these modified close-spaced open vase orchards (Table 3). From these orchards came what is now known as the “Double V” or “Quad V” system. Typical tree spacings in these orchards are 9 to 10 feet between trees in a row, with row widths of 16 to 20 feet. Trees are pruned so that there are four leaders growing out into the alleyways. These leaders support only fruiting wood and are not allowed to branch. Trees are essentially structured and treated like a double Kearney V. Yields have proven comparable to the Kearney V, but at a reduced establishment cost.

Table 3. Systems yield summary of the Kearney V and Quad V trial at the Kearney Agricultural Center; yields in tons per acre (after Day et al., 1993).

Variety/system[z]	1991	1992	1993	Total
Mayglo				
Kearney V	1.06	5.36	7.25	13.67
Mayglo				
Quad V	0.37	5.65	7.53	13.55
Sparkling May				
Kearney V	0.72	5.76	8.87	15.35
Sparkling May				
Quad V	0.37	6.78	10.22	17.38

[z]Kearney V planted at 6’x18' for a density of 403 trees per acre; Quad V planted at 9’x18' for a density of 269 trees per acre.

Other Considerations for High Density Systems

Both the Kearney V and Quad V systems combine advantages of the open center system with those of other high-density systems. Because the center of the tree is kept open, light can penetrate through the canopy during peak sunlight hours. An area is kept open between trees to allow lateral sunlight penetration as well. Because of increased tree densities, full yield is reached more quickly than with standard density systems.

Another quality of both the Kearney V and the Quad V is that every tree is nearly identical in shape. Such uniformity makes it easier to prune and thin the trees. For example, if 300 fruit are normally desired at harvest on a Kearney V, and if 3 fruit are normally left per fruiting shoot, then the tree should be pruned so that 100 shoots are left—50 on each side. Double-checking can be performed at pruning by counting the number of shoots and at thinning by the number of fruit on each shoot. In this way, worker performance can be evaluated very quickly.

Despite the performance of the Kearney V and Quad V, many Californians have been reluctant to embrace high density systems. This is primarily due to the expense related to planting. Current tree prices are about $5 per tree with breeder royalty payments of $2 to $3 per tree as well. At $8

per tree, a high density planting could cost as much as $3500 for trees alone. The more popular open vase system would cost about $1200. With California's long growing season and excessive vigor, the yield advantages of high density systems last only 1 to 3 years. Depending on the other economics involved, this may not be enough to justify such an additional planting cost. Consequently, few Kearney V systems are currently being planted in California. Because of tree cost, most growers favoring high-density systems have switched over to the Quad V.

Minimal Pruning of Open Vase Trees

In 1989, Day and Johnson (1997) began studying the effect of pruning severity on peaches and nectarines. The experiment was expanded in 1992 to a newly planted block of Fairtime peaches planted at an 18 x 18 foot spacing. The experiment (Table 4) had the following treatments:

1. HH—trees pruned heavily at the end of the first and second growing seasons (normal for the industry).
2. HM—trees pruned heavily at the end of the first season and moderately at the end of the second.
3. LM—trees pruned very lightly at the end of the first season and moderately at the end of the second
4. LL—trees pruned very lightly at the end of the first and second growing seasons.

By the end of the third growing season, all trees had reached full height and were pruned the same way thereafter.

Table 4. Summary of Fairtime minimal pruning trial; trees planted in 1992 and trees first cropped in 1994 (after Day and Johnson, 1997).

Treatment[z]	Total yield 1992 to 1997 (kg/tree)	Average fruit size, 1992 to 1997 (g/fruit)	Trunk cross-sectional area 1997	Scaffold cross-sectional area 1997
HH	435a[y]	253a	256a	27a
HM	604b	237b	254a	30a
LM	619bc	253a	270a	27a
LL	687c	226b	303b	30a

[z]See numbers 1 to 4 above.
[y]Within columns, values followed by the same letter are not significantly different.

The minimal pruning vastly outperformed the other systems and reached full production in the third growing season (Table 4). There were no negative effects from the minimal pruning system. Since this trial, numerous growers throughout the state have adopted this system.

Minimal Pruning and Branch Bending of Plums

Minimal pruning studies were also performed on plums beginning in the late 1980s. From these studies, a system has been developed which uses metal clips driven into the ground as anchors so that limbs can be tied into the exact orientation desired. This pruning system has allowed plum trees planted on an 18 x 18 foot spacing to reach full production in the fourth growing season. It is important not to bend the branches below 50 degrees above horizontal so that the dominance of the terminal growing point is maintained.

ROOTSTOCK SELECTION

As mentioned at the opening of this paper, rootstock selection is the single factor in the orchard that is virtually impossible to change without total removal of the trees. Therefore rootstocks should be selected carefully, wisely, and conservatively. There is no need to be the first grower to find out that a rootstock does not work in your area—leave that to someone else.

Standard Rootstocks

In California only three rootstocks are used for peaches and nectarines, Nemaguard, Nemared and Lovell peach. Nemaguard and Nemared are preferred because of their resistance to rootknot nematode. However, they are not as tolerant of wet soil conditions as Lovell. Therefore in heavy soils, and where rootknot nematode is not a problem, Lovell is preferred. Lovell is also slightly more resistant to bacterial canker than Nemaguard, but neither is immune, and other options must be considered in areas where bacterial canker occurs.

Plums (*Prunus salicia*) can be grown on Nemaguard, Nemared or Lovell. They can also be grown on plum rootstocks such as Marianna 2624 and Myrobalan 29C. As for peaches and nectarines, Nemaguard is the preferred rootstock when it can be grown. In heavy, wet soils the plum rootstocks Marianna 2624 and Myrobalan 29C provide much better tolerance of wet conditions than any of the peach rootstocks. Marianna 2624 has been the preferred choice over Myrobalan 29C for many years. This is somewhat surprising since Marianna 2624 has a profusion of rootstock suckers that are nearly impossible to control. Myrobalan 29C has very few if any suckers but gives a more vigorous tree than Marianna or the peach rootstocks. Growers also feel that plum fruit size is reduced on peach rootstock, but yields are heavier and maturity is advanced. The advanced maturity is probably a function of crop load.

Dwarfing Rootstocks

Growers would very much like to have a dwarfing rootstock option for orchard system design. Such an option would allow for smaller, more compact trees and reduced labor costs. Current feelings are that a semi-dwarfing rootstock would be of more value than a true dwarfing rootstock because very high summer temperatures in California would otherwise burn fruit if they were not sufficiently protected.

In 1982 UC pomologists began evaluating Citation, then a new semi-dwarfing rootstock from Zaiger Genetics. Peaches, nectarines, and plums growing on Citation were compared against standard rootstocks. Nearly all of the peaches and nectarines developed some incompatibility symptoms after a few years and had to be removed. Similar experiences were observed in grower plots. However, all of the plums grew well, and Citation appeared to reduce tree growth by 10 to 25% and also advanced fruit maturity.

Based on this trial, another block was planted on Citation and Nemaguard in 1986 that compared four plum varieties with a wide range of growth habits (Table 5). The results were the same as the first trial. Citation reduced tree growth by about 15 to 20%, advanced fruit maturity 3 to 5 days, and increased fruit size when cropped to the same level as the trees on Nemaguard (DeJong et al., 1991b). Only the Queen Ann/Citation combination performed poorly. Queen Ann is a very weak growing tree, and its fruit are prone to sunburn when exposed to excessive sunlight. The degree of dwarfism produced by Citation yielded a tree that was too weak for California conditions.

Table 5. Yields for plum cultivars growing on Citation or Nemaguard rootstock at the Kearney Agricultural Center; trees planted in 1986 at a 6 x 12 foot spacing (605 trees per acre) (after DeJong et al., 1991b).

Variety/ Rootstock	Yield (pounds/tree) 1988	1989	1990	1991	Total
Red Beaut/ Citation	9.5	37.7	55.6	14.2	117.0
Red Beaut/ Nemaguard	3.3	33.4	30.7	7.9	75.3
Santa Rosa/ Citation	28.1	39.3	12.2	68.7	148.9
Santa Rosa/ Nemaguard	16.9	37.2	11.8	62.5	128.4
Queen Ann/ Citation	8.3	24.1	31.2	16.5	80.1
Queen Ann/ Nemaguard	5.9	26.3	41.8	18.0	92.0
Royal Diamond/ Citation	24.8	44.5	39.1	33.6	142.0
Royal Diamond/ Nemaguard	9.9	41.7	32.4	25.8	109.8

Since this study, many plum blocks have been planted on Citation in California. It has performed very well in virtually every instance. Trees are smaller, harvest is earlier, and fruit size is improved. The trees appear to be adapted to a wide range of soil types. They are certainly more tolerant of wet soil conditions than either Nemaguard or Lovell, but appear not quite as good as either Marianna 2624 or Myrobalan 29C. In orchard situations the lack of appropriate vigor problem seen with Queen Ann has not been observed. Apparently the vigor problem can be corrected with applications of additional water and nitrogen.

New Studies

In 1986 University of California pomologists planted a group of more than 80 size-controlling rootstock selections for evaluation. By 1996, eight of these rootstocks that exhibited promise for peach and nectarine were selected and planted in a new block for further, more intense screening. These rootstocks produce trees with a range of 20 to 50% size control potential. By 1998, 4 of the 8 selected rootstocks showed signs of incompatibility when used with different scion

cultivars. The remaining trees appear healthy. Further testing is required before field studies with growers can be performed.

SUMMARY

Peaches and Nectarines

The open vase with Nemaguard rootstock, planted at a 16 x 18 foot spacing and pruned using the minimally pruned method, is currently a very economically efficient training system for fresh-shipping stone fruits in most areas of California. The Quad V at 9 x 16 to 18 feet is a higher density system that works well for particular situations because of issues involving labor and tree uniformity. These choices are made primarily because of the high cost of trees. If tree cost were less, as it is in many other areas of the world, the Kearney V at a 6 x 16 foot spacing is probably the simplest and most efficient system.

Plums

Currently, Citation is probably the best rootstock for fresh market plums. The degree of dwarfism it provides seems to be ideal for California. We recommend planting trees at spacings of 14 x 16 feet in the row and 16 feet between rows, using tie down clips to secure the branches in the desired location and orientation, and practicing minimal pruning for the first few years. This procedure brings trees into bearing within 5 years.

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