Physiological and Technological Barriers to Increasing Production Efficiency and Economic Sustainability of Peach Production Systems in California

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Abstract

During the past two decades California fruit growers have faced dramatically increased production costs associated with increases in field labor wages and availability. Correspondingly, the primary research interest of most California peach growers is to develop viable techniques to reduce labor costs while maintaining orchard productivity and fruit quality. The majority of labor costs associated with peach production in California are associated with tree pruning, fruit thinning and harvest operations. There have been numerous attempts to mechanize each of these operations; however each has resulted in limited success. Developing new orchard systems to address these problems is very attractive because new systems could make incremental increases in efficiencies of all three operations. However, successful introduction of new systems requires understanding of factors controlling tree growth and productivity and the physiological responses to management techniques. This paper will focus on attempts to adopt new orchard systems and tree-based physiological and developmental barriers to increasing peach orchard efficiencies encountered in California.

INTRODUCTION

With its Mediterranean type of climate; rich, deep soils; relatively abundant supply of high-quality water, ready access to relatively inexpensive, high quality labor and proximity to markets; the Central Valley of California has been a near ideal place to grow stone fruits. Indeed California is one of the world's leading producers of both fresh market and processing peaches and nectarines. However, with changes in labor laws and worker safety policies, increased wages, decreased migration of laborers from Mexico and Central America, increased competition for hand laborers from other sectors of the economy and increased labor insurance rates; the costs of labor have dramatically increased and the availability of workers to work in orchards has decreased.

Growers have long recognized that labor was one of their highest input costs and have been trying to make adjustments in orchard systems to increase fruit yields and quality or improve efficiencies in orchard operations, but they are now more keenly interested in simply reducing labor costs. The objective of this paper will be to review some of the attempts to increase the productivity and efficiency of California peach orchard systems and comment on the limitations of those systems so that we can learn from those attempts and make some suggestions about what might be possible in the future.

CALIFORNIAN PEACH ORCHARD PRODUCTION SYSTEMS

The standard open vase system (Micke et al., 1980) has been the backbone of the California peach industry for the past century and continues to be the most widely used system in the state. While it varies somewhat depending on locality, grower, peach scion cultivar and market objectives (fresh market or processing) trees trained to this system generally have 3-5 primary scaffolds emanating from a short trunk that branches to form the circular "walls" of an open vase (Fig. 1). This tree shape can provide excellent light distribution to most areas of the fruiting canopy while allowing easy access from a ladder to fruiting shoots for pruning, fruit thinning and harvest operations. However, the trees are large (generally requiring them to be planted at less than 300 trees/ha), take several years to grow and train into their desired shape before reaching full production, and are generally 4-5 m tall at maturity. When managed optimally, this system can produce yields of high quality fruit as great as any other system in California but most of the hand labor must be done from ladders.

In the 1970s, there were several attempts to develop hedgerow orchard systems that could be managed with moving platforms, using moderately high densities and which had the potential to come into production earlier than the standard open vase. The most popular of these systems was the California palmette or parallel “V” system. It was an adaptation of the Italian palmette system but rather than having a central scaffold with tiers of secondary scaffolds oriented along the tree rows it was trained with a short trunk and two primary scaffolds oriented parallel to the tree row (Fig. 2). Fruit were primarily produced on fruiting shoots (hangers) emanating from as close to the scaffolds as possible. The trees were planted at 2.5-3.0 m apart down the rows with about 3.5-4.0 m between rows.

A system that had similar structural characteristics as the parallel “V” system was the central leader system. Trees in this system had one central axis with no other permanent branches and fruit shoots emanating from as close to the central scaffold as possible. The trees were planted at 1.5-2.0 m between trees in the row and 3.5-4.0 m between rows. There was a variation of this system that was grown on very tall (~5.0 m) vertical trellises with lateral shoots tied to wires and side shoots that were vertically hedged but this proved too costly to establish and maintain, and the idea was quickly abandoned.

The light distribution patterns in these systems were not very good because the vertical orientation of the canopies dictated that most of the light during the mid period of each day was intercepted by the top of the trees or the row middles (DeJong and Doyle, 1985) and this over-stimulated vegetative growth in the top of the trees while shading lower fruiting wood. Lower fruiting positions were dependent on lateral light in the morning and afternoon and adequate light exposure could only be achieved by controlling the height of trees in adjacent tree rows. Thus, extensive summer pruning in the tops of these canopies was necessary and this could only be done effectively from ladders making labor demands greater instead of simpler. Mature orchard yields in these systems were generally less than in the open vase system (DeJong et al., 1992) and the vision of using mechanically moving platforms in these orchards to decrease the amount of ladder work was not realized because at the time it was more efficient to find and pay workers who could work from ladders. Due to the changing labor situation, in the past two years there has been a slight resurgence of interest in using moving platforms as an adjunct to some labor operations, particularly assisted pruning, but few if any growers are planting these types of systems.

In the mid 1970s, researchers in Australia popularized the Tatura trellis (Chalmers et al., 1978) which was an attempt to develop a high density peach system that could be pruned and harvested mechanically. This system had an open “V” shape that had excellent light distribution characteristics. While there were a few California growers who experimented with this system, most avoided it because of the trellis. The associated mechanical pruning and harvest system proved inefficient and the establishment and orchard replacement costs were too high to make it practical for an industry that replaces trees after an average of about ten years. However, the idea of the Tatura trellis gave rise to the perpendicular “V” system (DeJong et al., 1994) that was fairly widely planted in the 1980s and 90s. This system consists of trees with a short trunk and two scaffolds oriented perpendicular to the tree row that extend at an angle into the alleyway between rows. Trees are planted at 2.0 m in the row and 5.0-6.0 m between rows.

The perpendicular “V” system maintains and even improves upon the light distribution characteristics of the open vase system because only two scaffold converge from the branching point on each trunk and thus the scaffolds are distributed more evenly through the orchard. The system is also easier to manage than open vase trees because the scaffolds are not branched and thus each main scaffold can be treated similarly. Fruit wood density and crop load can be adjusted on a scaffold basis during pruning and fruit thinning operations, respectively. Yields with this system are often higher than with either the open vase or hedgerow systems (DeJong et al., 1992), and it has been one of the most economically efficient systems grown in California (DeJong et al., 1999). However, the trees in this system are generally 4.0-5.0 m tall, requiring ladders for hand operations. Furthermore, the trees in this system tend to be more vigorous that in the open vase system because there are fewer scaffolds per rootstock and attempts to control tree size by heavy pruning tend only to stimulate vegetative growth. In deep, rich, irrigated, California soils there is not enough inter-tree competition even in these relatively high density plantings to have a sufficient effect on tree vigor to control tree size and prevent overcrowding of canopies.

The "quad V" system (Day et al., 2005) was developed to address some of the vigor issues inherent in the two-scaffold perpendicular system as well as to reduce planting densities and orchard establishment costs. In this system the open "V" structure of each tree is similar to the perpendicular "V" system but two scaffolds project into the alleyway between rows on each side of the tree. Thus, it is sort of a compromise between the perpendicular "V" system and the traditional open vase system. It is generally planted with 2.5-3.0 m between trees in a row and 5.0-6.0 m between rows. Because there are four scaffolds for each rootstock the trees are not quite as vigorous as two leader trees but tree heights are generally still between 4.0 and 5.0 m and most hand labor must be performed from ladders. It is possible to train the scaffolds so they have flatter angles and keep tree heights below 3.0 m (Day et al., 2005) but this requires extensive summer pruning and more horticultural care than most growers wish to provide.

Another system becoming increasingly popular with growers because of its lower tree density, is the "Hex-V" or 6-leader V. Similar in most respects to the Quad V, it is planted at 3.5×5.0-6.0 m. The additional scaffolds further help reduce tree vigor, but system regimentation is kept and trees display excellent light interception characteristics.

One orchard system that was specifically designed to eliminate the need for ladders in the orchard was the cordon system (Rogers, 1986). This system was similar to the French "solen" system for apples (Lespinasse, 1989) and was mainly employed in processing peach orchards in the Northern San Joaquin Valley. During the first year after planting the tree was reduced to two vigorous shoots that were bent across one another in opposite directions down the tree row and wrapped around a horizontal rope that was ~1.5 m above the ground (Fig. 3). The concept behind this system was to stimulate vigorous shoots from the horizontal scaffolds that would bear fruit and bend over one year and be replaced by similar shoots on an annual cycle. This system was maintained at less than 2.5 m tall and required no ladder work. However, productivity was not consistently high because some cultivars did not set well on the highly vigorous shoots and the system actually favored vegetative growth over fruit growth (Grossman and DeJong, 1998). Also, while ladders were eliminated from the orchards, a labor savings was not realized because of the increased management costs associated with keeping the trees under control (DeJong et al., 1999), demonstrating the importance of viewing the orchard as a system rather than merely focusing on the single goal of eliminating ladders.

Californian Attempts to Deal with Excessive Tree Vigor

All of the orchard systems described above were planted using vigorous, seedling rootstocks, primarily Nemaguard, and to a lesser extent Nemared, or Lovell. Although several other rootstocks have been tried, until recently no suitable size-controlling rootstock that would yield consistently positive results have been available. Therefore, a number of other approaches to deal with excessive tree vigor have been tried. In the 1970s and 80s, there was an extensive attempt to improve the fruit quality of dwarf scion cultivars (Hansche, 1978) and although the project was successful in releasing a couple of cultivars with improved fruit quality characteristics, the dwarf orchard system was never accepted because of numerous cultural and management issues. Some of the significant problems were: developing fruit of consistent quality because of the dense intra-canopy shading, increased cost of fruit thinning because of difficulties in finding the fruit, the tendency for wasps to build nest in the trees, problems with mildew because of intra-canopy shading and limb breakage because of brittleness of branches.

In the 1980s, there was substantial activity in assessing the potential of vegetative growth retardants (particularly, paclobutrazol or Cultar®) (DeJong and Doyle, 1984b). While it was shown that chemical compounds could be used successfully in California to decrease excessive vegetative vigor (especially water sprouts), none were never registered for commercial use in peaches because of environmental concerns and thus virtually all research on these types of products ceased.

The one management tool extensively used to control or decrease tree height is mechanical topping. This practice is widely recognized as far from optimal because it involves the indiscriminate use of heading cuts to eliminate the tops of branches and thus stimulates as much, if not more, regrowth than it removes with its concomitant reduction in light. However, it is regularly used in many orchards to arbitrarily reduce tree height and temporarily "open up the canopy to sunlight" because it is quick and relatively inexpensive. Growers recognize the need to try to "correct" the damage done by the topping machines by removing many of the headed shoots by hand pruning during dormancy - this is acceptable because it reduces the need for hand summer pruning during the busy harvest period.

In the past five years, there has been a rapid increase in availability of and interest in using size-controlling rootstocks to control peach tree vigor in California. However, actual adoption by growers has been slow for several reasons. Prior to the recent upsurge in availability of size-controlling peach rootstocks there were several attempts to introduce new rootstocks to California growers with very poor results. For instance, Citation rootstock was introduced as a size-controlling rootstock for peaches in the early 1980s and numerous growers tried it but it was later found to be incompatible with most peach and nectarine cultivars.

Recently a joint effort between USDA and UC Davis researchers has identified three size-controlling rootstocks (Controller 9, Controller 5 and Hiawatha) with commercial potential for peach that reduce tree trunk cross-sectional areas of mature trees by 10 to 50% and substantially reduce pruning requirements (DeJong et al., 2005). It is believed that Controller 5 and Hiawatha can reduce tree vigor enough to feasibly reduce tree height in commercial orchards to less than 3.0 m. Extensive research into the size-controlling mechanism has indicated that these rootstocks control scion vigor by having reduced root hydraulic conductance (Solari et al., 2006ab; Solari and DeJong, 2006). Additional studies also revealed that dwarfing rootstock affects are cumulative and that vegetative growth in any given year is a function of previous growth history in addition to current growth conditions (Pernice et al., 2006).

Additional size-controlling rootstocks are currently being developed in a program at UC Davis and numerous other rootstocks from other parts of the world are being tested but none have been extensively planted in commercial orchards. The spotty performance of previously introduced rootstocks in addition to high establishment costs of planting trees at higher densities has limited grower enthusiasm for adopting this new technology. However, as labor costs rise and the availability of the traditional orchard work force declines, use of size-controlling rootstocks will become an increasingly attractive option to deal with the supra-optimal growing conditions for peach production in California.

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Figures

Fig. 1. California standard open vase system.

Fig. 2. Hedgerow central leader and California palmette systems and the panel on the right show the tendency for the top of the tree to outgrow and shade the bottom.

Fig. 3. The California perpendicular “V”, “Quad V” and “Hex V” system tree structures.

Fig. 4. Trees in the cordon system and a genetic dwarf scion cultivar.

Fig. 5. A mechanical topping machine in a peach orchard and the types of heading cuts the machine leaves in the top of the tree.

Fig. 6. Mature Loadel cling peach trees on Controller 9 (aka P30-135, left) and Controller 5 (aka K146-43, right) size-controlling peach rootstocks.