Theory and Practice of Genetically Manipulating Peach Tree Architecture

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Peach production world-wide relies on the use of vigorous, spreading scion cultivars grafted onto rootstocks of similar vigor. Regardless of the desired growing system, from low density to high density, from large open-center trees, to closely spaced tree walls, to "Y" trellis systems, the standard, vigorous tree type must be made to fit the system. For the development of high density peach production systems using the standard tree type, severe pruning is necessary. Pruning invigorates trees and leads to excessive vegetative growth, which may adversely affect fruit quality and subsequent flower bud formation due to shading. Summer pruning of excess regrowth can help to alleviate the problem, but the economic benefits of this practice are still not certain.

Peaches, as currently grown, produce rather poorly when compared with other tree fruits. The average production of peaches in the U.S. is approximately half that of apple on a per acre basis. The advantages of high-density fruit production have been clearly demonstrated in improving apple yields and reducing labor inputs. Over the last 50 years apple productivity on a per acre basis has increased 200-300% in the United States. The apple systems rely on the use of dwarfing rootstocks and spur-type varieties. Commercially acceptable dwarfing rootstocks are not available for peach (Marangoni et al., 1984) and, although spur-type peaches exist, they are not commercially available. While the possibilities exist for the development of dwarfing rootstocks for peach, there are opportunities for other approaches to growth habit manipulation through breeding scion varieties with new growth habits. These opportunities are based upon the existence of a great variety of naturally occurring peach growth habits. Also, unlike apple, the vast majority of commercial peach varieties have been developed through breeding programs. Therefore, the development of new varieties using germplasm with different growth habits is feasible within our current peach breeding programs.

Variation In Tree Growth - Vavilov's Law Of Homology

Clearly, as one walks through a tree filled landscape, the wide variation in tree growth forms is apparent. This is even more striking when we consider the array of growth forms used in the ornamental landscape, including dwarf, weeping, columnar, bushy, globose. In some cases these growth forms can be found within the same species. Nikolai I. Vavilov (1887-1943), noting the genetic variation in plant populations, put forward a theory stating that characters found in one species may be found in another, depending on their relationship. Vavilov's "Law of homology" has remained a principal that has proven to be useful to horticulturists for pointing the way to plant characteristics that may remain as yet undiscovered in a particular species by observing characteristics in a related, or perhaps unrelated, species. It was this law that provided the impetus for our search for alternate peach tree growth habits. Knowing that numerous tree forms exist in the family Rosaceae (stone fruits, apple, pear, quince and many other fruit and ornamental species) we surmised that many of these forms could be found in peach and, in fact, this is the case. In this report I outline the characteristics of the major classes of growth habit in peach and present information on the potential advantages and disadvantages of each type. The development of cultivars expressing alternate growth habits is also discussed.

Currently, peach growers can choose from an array of different peach fruit types (peach, nectarine, yellow flesh, white flesh, melting, non-melting, low acid, saucer shape, etc.). However, few choices exist in terms of tree form. No one form is ideal for all growers because each grower has different needs related to land area, available labor, and equipment. The columnar-shaped tree may be more suitable for high-density peach orchards than the standard spreading type. Such orchards could be trained as a tree wall and harvested using mechanized platforms.

Genetics Of And Breeding For Peach Growth Habit

Most of the peach tree growth habits are controlled by single genes (Table 1; Figure 1). These single genes control, for example, the number of lateral buds that are produced or that grow into branches. This affects canopy density. Some genes control the length of growth between nodes which affects branch length and therefore tree size. Other genes control branch angle and affect the form of the canopy, for example upright or spreading. Since most traits are controlled by single genes, the breeder can generally predict what percentage of seedlings from a cross will carry the new trait. Also selection for growth habit is relatively easy because many growth habits are readily apparent in the field as opposed to a trait like disease resistance that may require time-consuming inoculation tests to separate susceptible from resistant plants. Nevertheless, most breeding programs produce varieties exclusively of standard growth habit. Since no growth habit is perfect, perhaps there is comfort in working with the problems that one is familiar with versus new, unfamiliar problems that may result from the use of novel tree types.

Peach Growth Habits

Dwarf. Dwarf trees vary in size but rarely reach over 2.45 m (8 ft) in height. There are at least two types of dwarf trees. Very short internodes, long leaves, and a dense canopy characterize the "brachytic" dwarf. The brachytic dwarf has received some attention in breeding programs and high fruit quality brachytic dwarf varieties have been released (Hansche, 1989; Fideghelli, 2002; Stanica, et al., 2002). The dwarf tree suffers from a number of difficulties beginning at the stage of nursery propagation. Internodes are very short, making propagation through bud-grafting difficult. Trees must be budded high on rootstocks to allow for orchard operations, rootstocks thus require an extra season of growth. In the orchard, the dense, shaded canopy is an ideal habitat for fungal and bacterial pathogens. It is difficult for chemical sprays to penetrate the canopy, and fruit are difficult to locate for thinning and harvesting. These characteristics detract from the commercial potential of the brachytic dwarf. We have evaluated the potential of the brachytic dwarf as a dwarfing rootstock and our results agree with those of Murase et al. (1990) in that it does not dwarf the scion.

Another dwarf type tree (A72) was reported by Monet and Salesses (1975) in France, but it has, surprisingly, received little attention. We have found that seedlings from open pollinations of A72 exhibit a wide range of sizes including those ranging from standard size, semi-dwarfs, full dwarfs, and extreme dwarfs that reach less than a foot in height after five years. Leaves are not""oversized" as they are in the brachytic dwarf and overall the canopies are more open than those of the brachytic dwarfs except in very dwarf seedlings. Fruit quality of A72 and its first generation progeny is poor and at least several generations of crossing to high fruit quality types will be necessary for variety development.

Compact. Examples of compact growth habit are 'Com-Pact Redhaven'

TABLE 1

Inheritance of peach tree growth habits (from Scorza and Sherman, 1996).

Character	Gene symbol	Remarks
Normal/weeping	*Pl/p*	Expressed in S2678
Normal/brachytic dwarf	*Dw/dw*	
Normal/dwarf	Dw_2/dw_2	Heterozygous in 'Kearney" 'Red Cal' and' 'Fire Red'
Standard/dwarf	*N/n*	Expressed in A72
Normal/bushy	*Bu1/bu1, Bu2/bu2*	*Bu1* and *Bu2* are duplicate independent factors
Compact/standard	*Ct/ct*	Expressed in 'Com-Pact Redhaven'
Standard/columnar	*Br/br*	Incomplete dominance

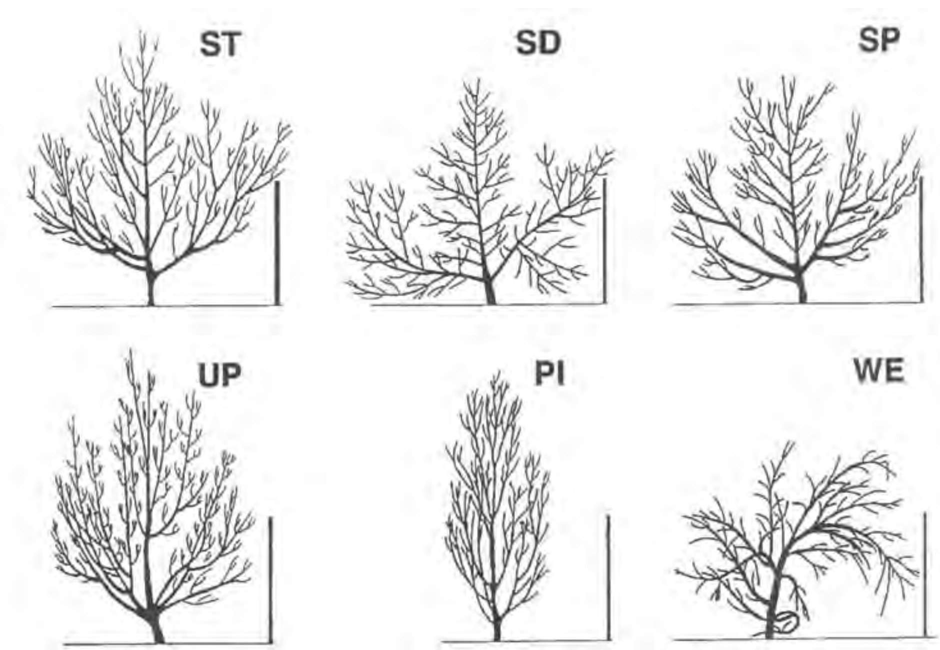

Figure 1. A selection of peach tree growth habits that can be developed through breeding: Standard form (ST), semi-dwarf (SD), spur-type (ST), upright (UP), columnar (PI), weeping (WE). From Bassi et al (1994).

and 'Compact Gold Medal,' which is sometimes marketed as 'Compact Elberta.' Both of these are presumed single gene mutations of their respective standard varieties (Mehlenbacher and Scorza, 1986). A third compact tree that has been identified is 'Elbertita,' presumably a mutation of 'Elberta,' Compact trees have shorter internodes than standard trees, wider branch angles, and a greater number of and longer laterals than produced on standard trees (Scorza, 1984). These characteristics make for a dense canopy and reduced light penetration (Scorza et al., 1984). While the reduction in tree size (20-50% smaller than standard) is desirable for peach production, the dense canopy and excessive pruning necessary for adequate light penetration would be disadvantageous for commercial growers. However, our observations suggest that if pruning is kept to a minimum 'Com-Pact Redhaven' will produce numerous spurs that produce fruit throughout the canopy. This reduces the need to prune for new fruiting wood and it may be possible to develop a new strategy of pruning compact trees that would reduce the density of foliage and still favor fruit production. In terms of rootstock potential of the compact genotype, the dense canopy is accompanied by high root system density that may increase exploitation of soil resources by compact trees and affect shoot development (Tworkoski and Scorza, 2001).

Semi-dwarf. Semi-dwarf trees are generally between compact and standard trees in overall size. Their branch growth is similar to standard trees so the dense canopy is not an issue. Breeders at the Istituto Sperimentale per la Frutticoltura, Rome, have obtained semi-dwarf trees from open-pollinated standard varieties such as 'Sentinal', 'Redhaven', and 'Southland' (Fideghelli et al., 1979). These semi-dwarfs vary in size but are generally about 50-60% the size of standard trees (Quarta and Scortichini, 1985), otherwise they are quite similar to standard trees in appearance. 'Gage Elberta', a variety no longer commercially grown, is another semi-dwarf tree. By simply selecting for reduced tree size and high fruit quality, progress in developing semi-dwarf peach trees is being made. Such trees may allow growers to space trees closer, reduce pruning, and increase yields per hectare.

Spur-type. Many stone fruit species including plum, apricot, and cherry produce fruiting spurs. The first report of spur-type growth in peach was published by Scorza in 1987. Spur- type growth peaches were found in exotic peach germplasm that had been imported into the U.S. Some were apparently peach-almond hybrids and their spurriness was most likely inherited from the almond parent. Yet, the trees that produced the greatest densities of spurs were dwarf (*dwdw*) x compact (*Ctct*) peach hybrids. The spur-type trees recovered were apparently heterozygous at the *dw* locus (*Dwdw*) and homozygous recessive (*ctct*) (standard growth type alleles) (Scorza, 1987). Spur-type peach trees require a completely different production strategy in order to take advantage of spurs. For example, severe pruning, as practiced on non-spur peach trees, induces vigorous shoot development and does not allow for the development of spurs. Pruning and production systems for fruits such as apricot, plum and cherry may be appropriate models for spur peach.

Weeping. Weeping peaches have generally been released as ornamentals. There are at least two programs in Europe, including one in Bologna, Italy and one in Bordeaux, France that currently are (Italy) or have in the past (France) worked on the development of weeping peach varieties for commercial fruit production. Bassi and co-workers (1994) in Italy have suggested that the weeping peach may be of interest for new training systems, similar to the Lepage system in pear with a zig-zag stem made from the scaffold branches alternately radiating from the trunk one above the other.

Narrow-leaf. Narrow-leaf or willow-leaf peaches represent a novel growth habit due to a genetic change in leaf width. Narrow-leaf trees produce leaves that may be less than half as wide as normal peach leaves (Glenn et al, 2000) (Figure 2). This may produce a more open canopy that would increase light penetration and potentially, improve color, favor more uniform ripening, and reduce disease incidence. Research has shown that narrow leaf trees are more efficient in their water use and may perform better under conditions of water stress than standard leaf peach trees (Glenn et al., 2000). Studies of the productivity of narrow-leaf trees as well as the pruning requirements for commercial production are underway at the USDA stations in Kearneysville, West Virginia and Byron, Georgia. Selection for variety development is also underway at these facilities (Okie and Scorza, 2001).

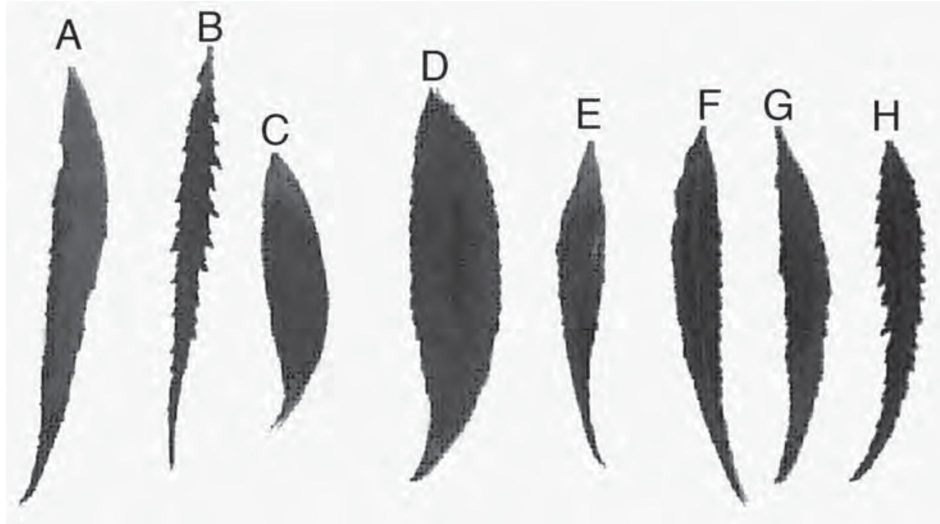

Figure 2. Leaves from narrow leaf peach seedlings. D is a leaf from a standard tree.

Columnar. Columnar trees appear to have a long history in Japan where they have been developed as ornamentals (Yamazaki et al., 1987). Left to grow naturally, they will attain a height of up to 5 m (16 ft) and a crown diameter of around 1.5m (5 ft). The most striking feature of the columnar tree is its narrow branch angles (Scorza et al., 1989) (Figure 3). The fruit quality of the columnar (also known as "pillar") tree that was originally available in the U.S. was poor and yields were low. The breeding program at USDA, Kearneysville and at several locations in Italy (Bologna and Forli) have significantly improved the fruit quality and productivity of columnar trees and several varieties suitable for commercial trials have been developed. These include, 'Crimson Rocket' released by R. Scorza USDA-ARS Kearneysville, WV and 'Alice-col' released by A. Liverani CRA, Forli, Italy, with new advanced selections under test in both programs. The fact that columnar trees have a naturally narrow canopy appears to make them ideally suited to high-density spindle tree or "wall" systems. The narrow canopy also fits well with mechanical harvesting technology or with picking platforms, since each side of the tree is naturally only several feet in width, making it easy to reach into the canopy to collect fruit. Clearly, the columnar tree presents a radically different approach to peach production. To address the need for information on columnar peach orchard management, pruning and spacing trials have been established in the U.S., Italy, and Canada (Miller and Scorza, 2001). Grower trials have also been established in the U.S. in collaboration with Adams County Nursery.


Figure 3. Columnar or 'pillar' peach trees.

Upright or Semi-Columnar. **Columnar growth habit is semi-dominant with homozygous *brbr* producing columnar and *BrBr* producing standard tree forms (Figure 4, Table 1). The heterozygote (*Brbr*) produces a unique upright or semi-columnar growth habit. This phenotype is neither columnar nor standard but possesses an intermediate growth habit. The upright cultivar 'Sweet-N-UP' was released from ARS-Kearneysville. In experimental trials it has shown good fruit quality and size with high productivity. Upright trees can be readily trained to central leader and "Y" systems. The upright tree, while notably different from the standard peach tree, presents a less radical departure from the standard when compared to the columnar tree.**

"Mixed" Growth habits. We have hybridized a number of different growth habits such as pillar x dwarf, pillar x compact, dwarf x compact, narrow leaf x pillar, etc. Many of these crosses have produced predictable combinations of traits, and others have produced unique new types. It is clear that desirable growth traits can be mixed and combined in new ways to produce a range of growth habits that are limited only by the imagination.

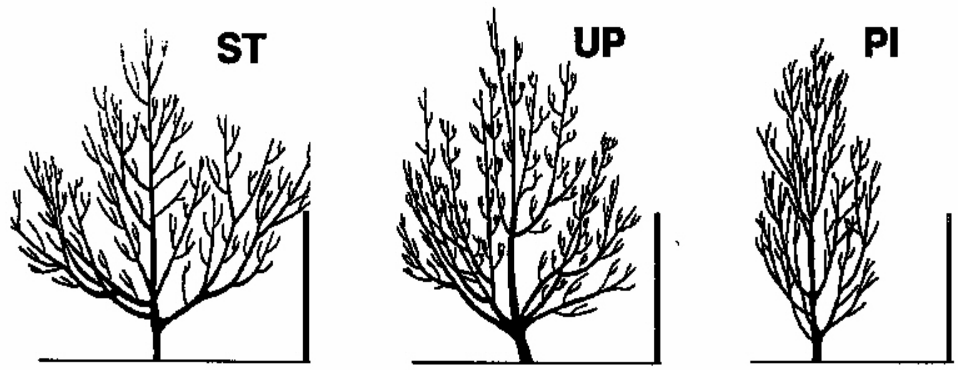

Figure 4. Standard peach tree (BrBr), upright peach tree (*Brbr*), columnar or "pillar" peach tree (*brbr*).

The Future

Breeders have the potential to develop a number of different growth habits with relative ease due to the single gene nature of most growth habits studied thus far. This does not mean that the process of combining high fruit quality, productivity and new growth forms is a simple, short-term task. Currently, peach growers can choose from an array of different peach fruit types (peach, nectarine, yellow flesh, white flesh, melting, non-melting, low acid, saucer shape, etc.). Few choices exist in terms of tree form. No one form will be ideal for all growers because each grower has different needs related to land area, available labor, and equipment. Real progress lies in making available to growers a variety of growth types that produce high quality fruit from which they can choose. Input from, and collaboration with growers, the nursery industry, and extension and research scientists along with careful study, critical observation, and rigorous testing will decide which traits and combinations of traits are most beneficial for commercial peach production in the future.

NOTE: for a comprehensive summary, including illustrations, and germplasm resources, of stone fruit growth habits see Bassi (2003).

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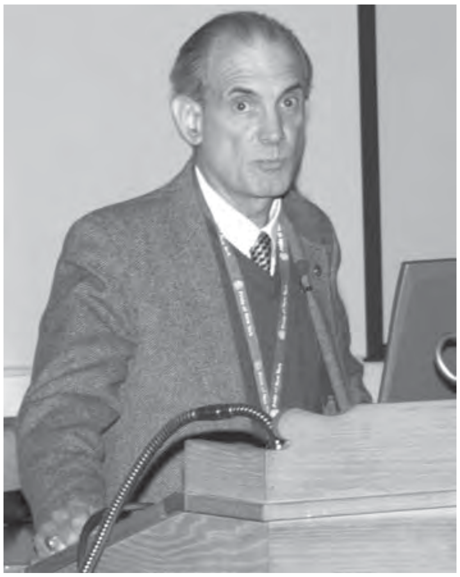

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