Modification of Nursery Tree Architecture with Apple Rootstocks: A Breeding Perspective

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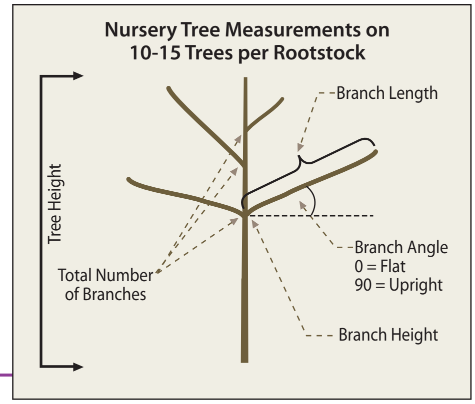

Figure 1. Data collected from two-year trees on different rootstocks budded with the same scion at two different nursery locations in the US.

Apple orchards have changed quite a bit in the past fifty years. The trees have gotten smaller and more productive; the rows are narrower, and the orchard systems more efficient. Scientific advances in physiology and horticulture have been critical for this transformation but the main factor that made this transformation possible is the genetics behind dwarfing–without them our orchards would still look like walnut orchards. The genetic components found in M.9, M.8, M.27, M.26, and other dwarfing parents have been used by the breeding program in Geneva, NY to incorporate these components into a new set of productive, disease-resistant rootstocks being planted in the U.S. and overseas. These rootstocks are now well known for their field resistance to the rootstock phase of fire blight and to replant disease.

> **"Tree quality is usually defined by tree caliper but the number of feathers and the angle of the feathers are important criteria in evaluating tree quality. Over the last few years we have observed that many of the Geneva® rootstocks have flatter branches and more feathers than similar commercial rootstocks. This would be a significant advantage in high–density systems such as the Tall Spindle since less labor would be required to tie feathers or branches down after planting. In addition, this trait might also be useful when pairing rootstocks with upright growth-habit scion varieties to decrease vigor and increase productivity."**

Tree Quality

We have been studying how other traits beyond dwarfing, precocity and disease resistance may impact production and profitability of a rootstock. A recurring theme has been the quality of trees that the nursery is able to provide to the orchardist and how that quality affects the early productivity of the orchard. For commercial nurserymen, tree caliper and the number of feathers are the two most important criteria in evaluating tree quality. Several studies have shown the early yield advantage of planting a large-caliper well-feathered tree when establishing an orchard versus less expensive whips, sleeping eyes or bench grafts which are planted in place. At the moment it appears that the yield advantage of feathered trees results in a significant economic advantage as long as tree density is not more than 1,300 trees/acre. Since the primary goal of an orchardist is to develop fruiting wood (spurs, flowering buds) and the infrastructure to support it, the sooner he gets the infrastructure in place the sooner he can start producing fruiting wood and therefore fruit.

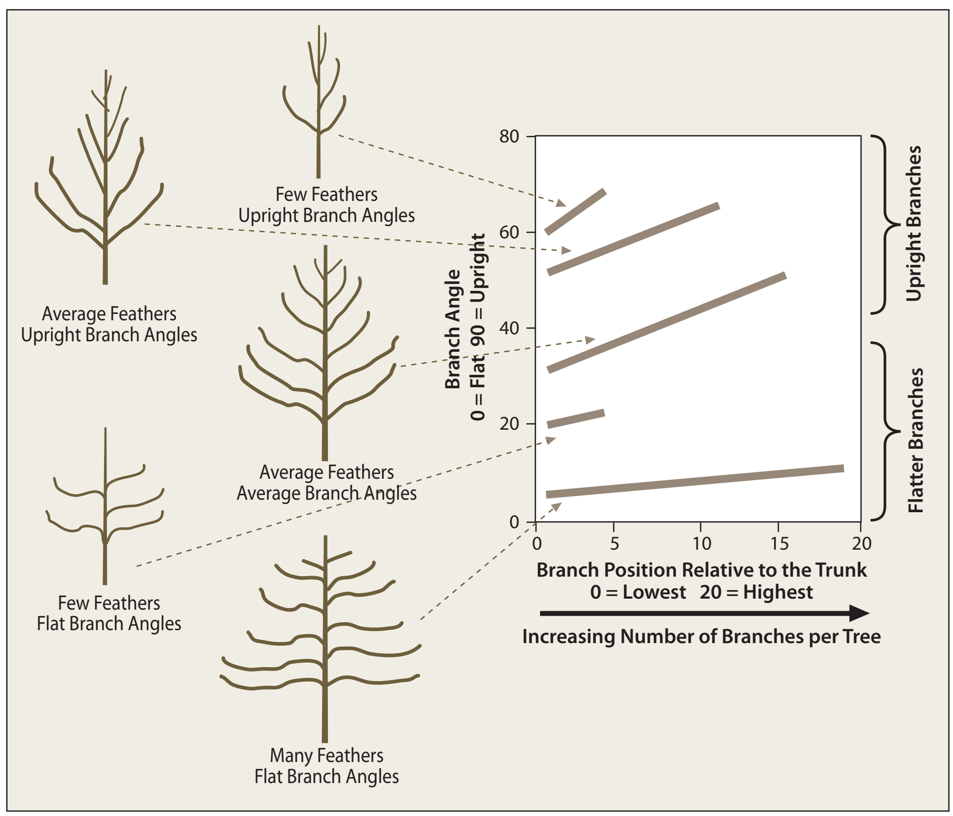

Figure 2. Classes of tree types produced by rootstock effects (same scion and different rootstocks) grouped by branch angles and number of feathers and a graphical representation in a Branch Angle Plot. In the plot the rootstocks producing trees with more feathers are represented with longer lines. The rootstocks in the lower half of the graph have flatter branches and the ones in the upper half have more upright branches. The slopes of the lines represent how the branch angle changes according to the order (position) of the branch on the tree.

When growers plant feathered trees at high tree planting densities, they plant a significant infrastructure that was formed in the nursery and have essentially an instant orchard with high potential yields in the second and third years. With whips or one-year bench-grafted trees, a large part of the infrastructure has to be developed in the orchard after planting and thus significant production is delayed until years four and five. With sleeping eye trees or plant-in-place bench grafts, all of the infrastructure must be developed after planting the tree in the orchard.

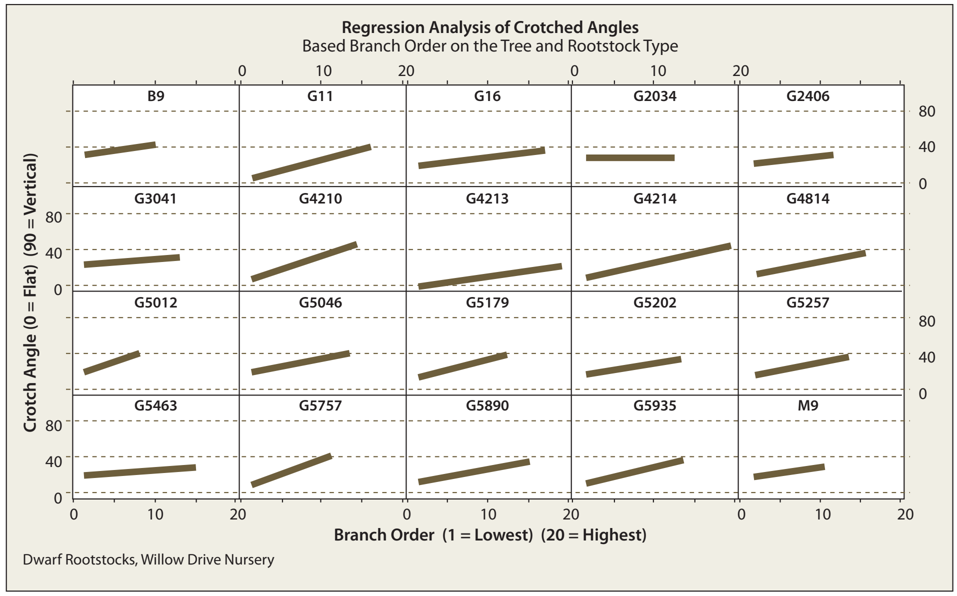

Figure 3. Branch angles and number of branches measured in Fall 2005 on a set of nursery trees budded with the same scion (Brookfield Gala) on several different dwarfing rootstocks. Refer to Figure 2 for an interpretation of this graphic.

Rootstock Effect on Tree Quality

Although producing feathered trees is becoming more common for US nurseries, not all feathered trees are similar. Some have few branches and others have many, while in some cases the branches are too low and in others the branches are too high. The production of feathers is dependant on climate and on the cultural practices of the nurseryman. However, over the last few years we have observed that rootstock genetics has a significant effect on the number of branches and the angle of branches of nursery trees. As we visited the numerous cooperating nurseries that were growing trees for rootstock trials destined to be planted at several locations in the U.S. and around the world we began noticing that there were some consistent differences in the number of branches, branch angles, tree size and height that could only be explained by the influence of the rootstock on the same scion. We set out to measure these and in the fall of 2005, with the help of Dr. Bruce Barritt and other scientists we measured several architecture characters (see Figure 1) on a set of Brookfield® Gala trees budded on different rootstocks at Willow Drive Nursery destined for a replant trial in Washington State. These results showed there was a definite pattern of branching that was strictly explained by the rootstock. A year later my son Nick and I took similar measurements on a different set of Fuji trees budded on different rootstocks at the Adams County Nursery field in Delaware. The data from Delaware were correlated with what we saw the previous year at a different site and scion. The rootstocks that were common to both sites behaved similarly at the two sites, which shows the stability of the rootstock trait in different environments.

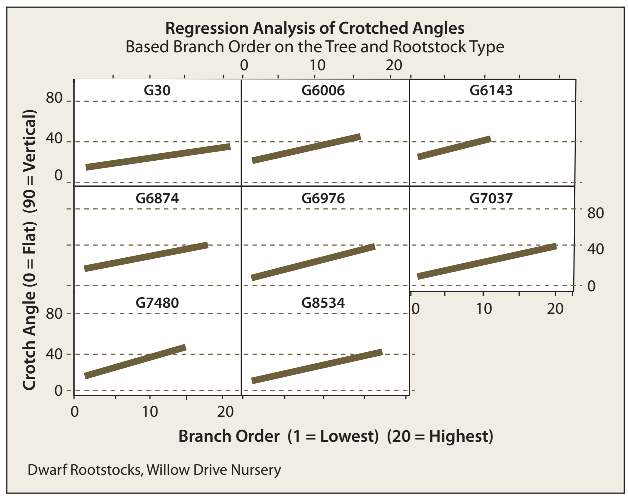

Figure 4. Branch angles measured in Fall 2005 on a set of nursery trees budded with the same scion on several different semi-dwarfing rootstocks. Refer to Figure 2 for the interpretation of this graphic.

When we analyzed the data we were able to describe the architecture of the tree influenced by rootstock in a graphical pattern that distinguishes the rootstock effects into several nursery tree types (Figure 2). We observed that rootstocks modified the number of feathers that the trees had and the crotch angles of those feathers. The tree types generated by these rootstocks ranged from upright trees with few feathers to flat branched trees with many feathers.

Flat Branching

Wide crotch angles and flat branches have been associated with higher productivity of the branch. In modern orchard systems flat or pendant branch angles are induced by tying the young branch down or by attaching weights to the branch as it is extending. The effect of tying the branch down is to reduce the vigor of that branch and increase the flowering then next year. This method to tame tree growth has been utilized in high-density systems in

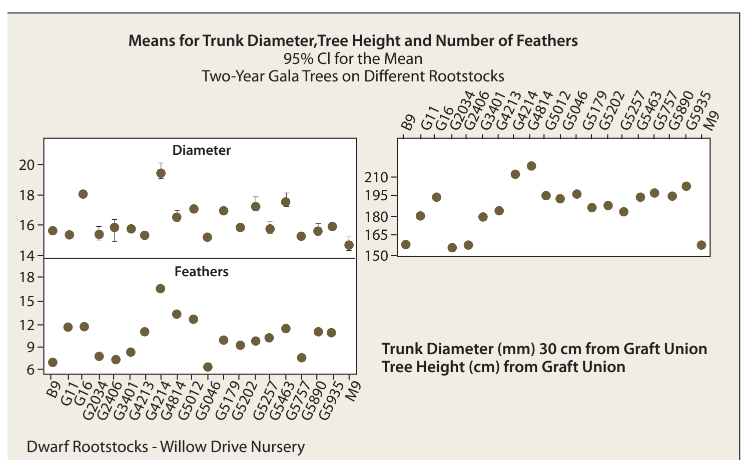

Figure 5. Nursery tree size measurements (height and diameter) of Brookfield Gala trees on several dwarfing rootstocks.

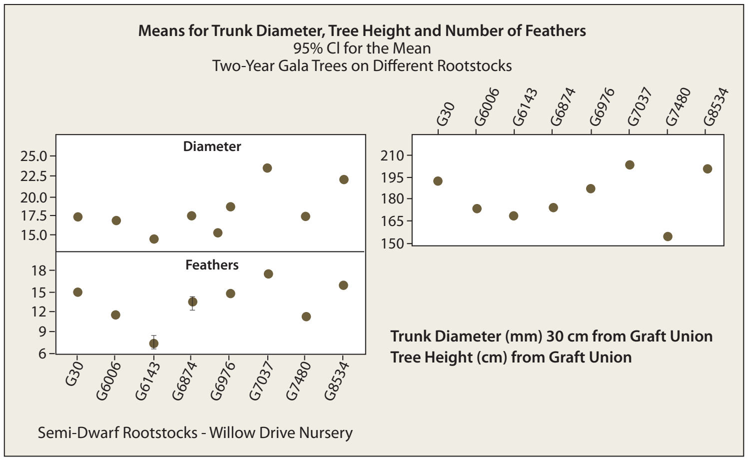

Figure 6. Nursery tree size measurements (height and diameter) of Brookfield Gala trees on several semi-dwarfing rootstocks.

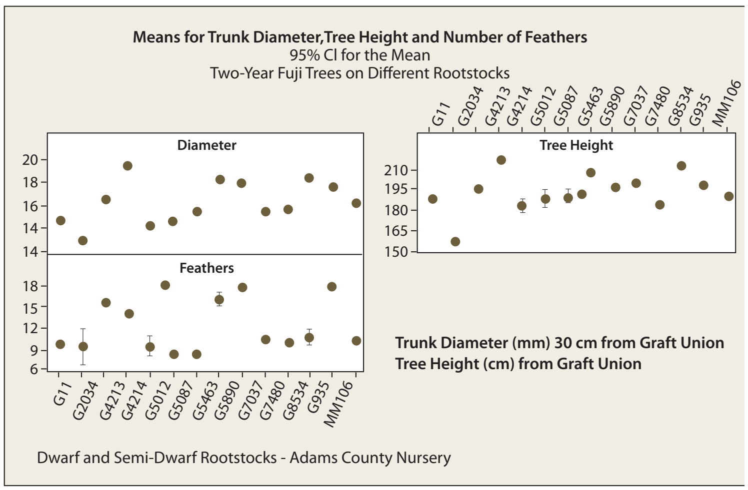

Figure 7. Branch angles measured in the Fall 2005 on a set of nursery trees budded with the same scion (Fuji) on several different semi-dwarfing rootstocks. Refer to Figure 2 for the interpretation of this graphic.

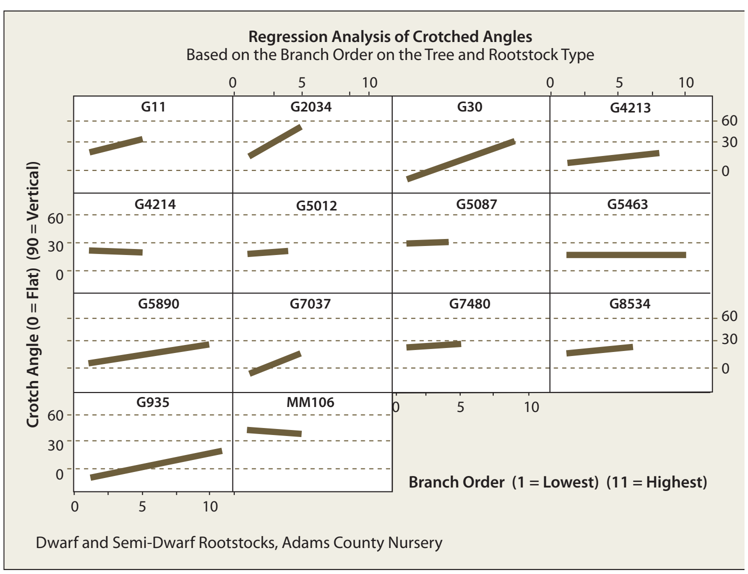

Figure 8. Nursery tree size measurements (height and diameter) of Fuji trees on several dwarfing rootstocks.

Northern Italy as some of you may have witnessed during IFTA tours in that region. If new rootstocks induced flatter branch angles it would be a significant advantage in high-density systems such as the Tall Spindle since less labor would be required to tie feathers or branches down after planting. When we compared branch angles of some of the Geneva rootstocks to B.9 and M.9 standards (Figures 3, 4 and 7) we noticed that the crotch angles were much wider (flatter branches) in some Geneva rootstocks (G.935, G.11, G.30, CG.4210, CG.4213, CG.4214) than the Malling or Budagovsky standards. When we visit orchards worldwide, we can easily distinguish the trees on these flat branching inducing rootstocks from trees on other rootstocks. This trait might also be useful when pairing rootstocks to specific upright growth habit scion varieties to decrease vigor and increase productivity.

Finished Tree Size

The vegetative vigor in the nursery is generally inversely correlated with the dwarfing ability of that rootstock. Therefore a dwarfing rootstock will in general produce a smaller tree than a semi- or non-dwarfing rootstock. There are, however, several exceptions in rootstocks from the Geneva breeding program. For example, Figure 5 shows nursery trees on G.16 rootstock are much larger and have more feathers than rootstocks in the similar dwarfing class M.9, B.9 and G.41. Similarly CG.4213 produces a larger tree than other rootstocks in the same size class (Figures 5 and 6). Among more vigorous rootstocks, G.30 produces a larger tree than other Geneva stocks in its size class (Figure 8). G.16 is well known among nurserymen to produce a large caliper, high-quality finished tree and when planted in the orchard to become productive and switch resources to fruit growth maintaining dwarfing. So another characteristic of a good rootstock is the ability to fill its space quickly and then to slow its vegetative growth in favor of production. This ability is particularly important in high-density orchards and very valuable when exploited properly.

Number of Feathers

The number of feathers on a tree is generally thought to be correlated with vigor (i.e. the larger the tree the greater the number of feathers). It is also possible to induce branching by stimulating vegetative buds with exogenous hormone treatments such as Promalin® or Maxcel®. This technique is used by commercial nurseries to produce better quality trees and induce branching in specific zones along the leader. Interestingly, some Geneva rootstocks have the ability to induce a higher level of branching in the scion whether treated with hormones or not. This ability is not necessarily correlated with vigor, as a matter of fact, fully dwarfing rootstocks like G.935 and CG.4213 can produce more feathers than vigorous rootstocks such as CG.7037 or CG.8534 (Figs. 5, 6 and 8). Other examples of this ability are CG.4214, G.16, and G.30. In contrast some vigorous stocks produce fewer feathers such as CG.5757, CG.6143, CG.7490 or MM.106. With G.935 we have been able to observe that this trait is carried into the orchard throughout the life of the tree stimulating the production of renewal wood. This capability may partially explain the high productivity that researchers worldwide have witnessed from this rootstock. This ability to induce new branching is very important in high-density orchard production systems like the Super or Tall Spindle and the Vertical Axis where the goal is to maintain one major trunk and small new productive branches emanating from it.

Where Does It All Come From?

In this study we have identified two new traits beyond dwarfing and precocity that are controlled by rootstocks: flat branching and number of feathers. These new traits come largely from the *Malus robusta* parent that was used in the Geneva breeding program. As many of you know, the Geneva breeding program has focused on disease resistance since its inception, and in particular on fire blight resistance. As it turns out *Malus robusta* cv. "Robusta 5" was used as a major source for fire blight resistance in the breeding program. Its tree architecture (growth habit) was described in a 1970 National Arboretum Bulletin as "tall and spreading"—thus, the spreading habit was in the genes of "Robusta 5", and is probably responsible for the flat branching of many of the Geneva rootstocks.

The productivity of some Geneva rootstocks has now been well established, and their field resistance to fire blight and replant disease has been proven in several experiments. This would have never been possible without the vision of people like Jim Cummins, Herb Aldwinckle and Randy Gardner who many years ago decided to go against the practice of crossing within the Malling rootstock gene pool and use the wild genetic resources available then to accomplish the goal of generating new productive and resistant rootstocks. We also have to thank the people that collected those genetic resources around the world; without them and the institutions that maintain the resources like the National Germplasm System of the USDA ARS, the U.S. apple industry would be in a worse position today without having solutions for the fire blight epidemic that is rampant in apple orchards and responsible for millions of dollars in losses every year. Rootstocks in the future are going to play an increasingly important role as we continue to move into different and more specialized production paradigms.

Conclusions

Although tree quality is usually defined by tree caliper, the number of feathers and the angle of the feathers are important criteria in evaluating tree quality. We have shown that branch angle and number of branches varies with rootstock. Many of the Geneva rootstocks have flatter branches and more feathers than similar commercial rootstocks. This would be a significant advantage in high-density systems such as the Tall Spindle since less labor would be required to tie feathers or branches down after planting. In addition, this trait might also be useful when pairing rootstocks with upright growth-habit scion varieties to decrease vigor and increase productivity.

Acknowledgements

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Gennaro Fazio is research scientist with the USDA-ARS Plant Genetics Resources Unit located on the campus of Cornell University's NY State Ag. Exp. Station. He leads the Cornell/USDA apple rootstock breeding and evaluation program. **Terence Robinson** is a research and extension professor at the Geneva Experiment Station who leads Cornell's program in high-density orchard systems and assists with the rootstock breeding and evaluation program.