Plant Breeding

Investing in the Future of the California Avocado Industry

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Research projects on breeding, scion and rootstock evaluations, and genetics of avocado (hereafter, collectively referred to as plant breeding) have been a major part of the California Avocado Commission's production research program for more than 20 years.

Since 1991, the commission has spent about $7 million on plant breeding out of a total production research investment of about $17.6 million. Although plant breeding is very important, and can potentially solve critical industry issues, it is a long-term investment with significant risk. Given the limited production research budget, the Production Research Committee must always look at the opportunity costs of investing in plant breeding (and other long-term projects) instead of short-term projects that may have a more immediate benefit to the grower. For these reasons, it is important to periodically review the plant breeding program and make sure that it is on track to meet the industry's needs.

In general, plant breeding is a long-term commitment, and many plant breeders acknowledge that their successors will reap the benefits of their work. In annual crops, the time required to develop new varieties has been reduced by growing the crops in multiple locations around the United States or even in the northern and southern hemispheres. In so doing, breeders can produce two or three generations in one year, greatly reducing the time required to develop new varieties. Unfortunately, this is not possible for tree crops, and in general tree-fruit breeding remains a slow process. In light of this, it is crucial that the goals and objectives of a tree-fruit breeding program are well-defined and realistic.

It is easy to become excited about the potential for a

breeding program to develop a new fruit variety that will have some characteristic that consumers will love and create strong demand for; however, this rarely happens. This is largely due to the time required to bring a new variety to the consumer—usually at least 10 years, but often closer to 20 years for tree crops. In this time, consumer tastes change and what would have been a hit when a program started may be a flop because the consumer has moved on. The 'Gwen' avocado is a good example of how by the time a new variety is developed the market can shift, in this case from green skin to black skin fruit.

This is why many tree-fruits varieties are bred to extend the harvest season, but keep the product consistent over the season. Peaches are a perfect example of this—they are in the market virtually year-round, but the varieties are invisible to the consumer. Thus, most tree-fruit breeding programs are focused on more fundamental objectives (e.g., pest or disease resistance, cold tolerance) rather than creating wholly new varieties for which specific market development programs will be needed.

The Need for an Avocado Breeding Program

The California avocado industry has supported a plant breeding program for more than 50 years, and the original reasons for supporting a plant breeding program still apply in the 21st century. The development of new fruit varieties and rootstocks allows the industry to keep up with the changing avocado market across decades and adapt to pests, diseases and environmental stresses. The types or varieties of avocados grown determine the marketing needs and other industry activities. Therefore, changing the varietal mix can fundamentally change the nature of the industry, for example, by changing the timing of peak supply. Thus, breeding new fruit varieties can be a way to implement particular industry strategies. At the same time, breeding new rootstock varieties can allow growers to reduce input costs (e.g., through pest or disease resistance, or a dwarf tree to reduce harvesting costs) or grow their trees in new areas to expand the industry (e.g., through the development of cold tolerance).

Before the inception of a formal avocado breeding program, the California Avocado Society had a very active new varieties committee to evaluate the large number of seedlings being put forward as new avocado varieties. Many of the varieties discovered through this program are still available and in use today, most notably Hass. There is no question about the impact Hass has had on the world avocado market, and this variety is testament to the benefit that can come from a breeding and selection program.

Plant breeding as a tool can be an effective and worthwhile investment in the future of our industry, but it requires having a realistic vision of how the California avocado industry and market are going to change over the next 10 to 20 years, a challenge akin to choosing the winning lottery numbers. For example, before there were significant volumes of avocado imports, breeding was seen as a way to add varieties that could extend the avocado season, to develop the domestic avocado market and realize the opportunity of year round supply. It is unlikely that anyone would argue that this should still be the driving force for the current breeding program. More likely, long-term intractable problems such as salinity and Phytophthora should be a primary focus.

In deciding what the specific objectives of the plant breeding program should be it's helpful to determine the overall goal of the program. Three possibilities are:

Solve long-term problems through the development of new cultivars based on pest, disease and environmental stress resistance/tolerance, while maintaining the best characteristics of 'Hass', to reduce production costs, improve profitability and allow avocado production in new growing areas.

Anticipate and adapt to market changes by creating new cultivars based on improving 'Hass' to maintain current market position and develop a greater reputation for quality and reliability.

Create a new avocado market through the development of new cultivars based on taste, phytonutrient content or other characteristics believed desirable by the consumer.

Fruit Varieties or Rootstocks?

Commercial avocado groves are made up of grafted trees composed of two distinct cultivars: a rootstock with characteristics suitable to develop the root system and a scion to produce the fruit. Both components are necessary and considerable time has been spent discussing whether one should be emphasized over the other in the breeding program. Ultimately, the breeding program should result in the improvement of growers' financial well-being. Thus, the program's goal should focus on the trait(s) that would most improve profitability.

For rootstock varieties that are bred for tolerance to Phytophthora and salinity, it is relatively easy to calculate the financial impact on the industry. Some experts estimate that Phytophthora costs the California avocado industry as much as $30 million in lost production annually and $40 million is lost due to saline irrigation water. It is clear that investing in the development of a new rootstock that would halve the losses from just one of these factors would result in a significant financial gain for growers. And such a rootstock would require little marketing effort to get growers to test it and begin using it.

The financial benefit of developing a new fruit variety is not as easy to see as it is for rootstocks. This is partly because of the broader range of traits that are needed to make a fruit variety successful, and also because there are many

factors out of growers' control that determine the success or failure of a fruit variety. A new fruit variety would need to complement Hass so as not to compete with it (assuming the goal of the program is not to replace Hass), but rather to increase California's share of the avocado market. Enough growers would need to take the risk of planting the variety so that there would be adequate supply for it to gain a foothold in the market. A retailer or retailers would need to be willing to sell the fruit. And consumers would have to be willing to try the fruit.

In addition, there need to be agreements in place regarding the intellectual property of a new variety so that it is not made available to our competitors immediately, possibly defeating the purpose of having that new variety be a means of differentiation from imports. Of course this is an oversimplification of what would be needed to make a fruit variety successful, but it highlights the challenges involved. In addition, a new fruit variety may initially cost growers money if they plant it in lieu of 'Hass', which has a known market and earning potential.

A Refocus and New Direction

In 2011 a review of the CAC-sponsored plant breeding program found that only a small number of potentially commercially viable rootstock and fruit varieties have been developed in the program's more than 50 year history. The California-developed varieties being planted in the greatest numbers are 'Lamb Hass' and 'Toro Canyon'. The apparent lack of new varieties coming online illustrates the high risk nature of plant breeding.

The CAC Board and Production Research Committee have spent considerable time during their past few meetings trying to determine a path forward for plant breeding that takes into account grower needs, the future direction of the industry, and the risks and difficulties of developing new fruit and rootstock varieties. This has not been an easy task and the work will continue in the coming months; however, a path forward has been identified.

The plan that is taking shape has four primary areas of emphasis: rootstock breeding and selection; horticultural evaluation of new rootstocks and existing fruit varieties; preservation of existing germplasm; and development of genetic tools.

The first of these, rootstock breeding and selection, is relatively straight forward. This involves expanding the existing rootstock program to germinate and screen more seedlings each year for Phytophthora and salinity tolerance. The best selections may become viable rootstocks, but there also needs to be a plan in place to incorporate the best selections back into the blocks from which seeds are collected so that over time the population of seed source trees becomes more Phytophthora and salt tolerant. This will increase the chances of producing an ideal seedling to develop into the industry's new standard rootstock.

Horticultural evaluation of new rootstocks and existing fruit varieties is slightly more complex than rootstock selection. There needs to be a clearly defined point at which a rootstock moves from the initial screening process to more intensive field testing. Field testing would best be done in two phases. First is a high density, short-term planting in a Phytophthora infested soil that is irrigated with saline water. The purpose of this phase is to ensure that the tolerance observed during initial greenhouse screening tests holds up in the field. From here, the best selections should be propagated and moved on to more commercial-scale testing where traits such as tree growth, size, and yield can be evaluated, and the trees can be tested on different soil types and in different microclimates. In addition to rootstocks, existing fruit varieties and selections from within California and around the world should be evaluated for their potential to complement the 'Hass' market. These varieties should be planted under commercial conditions in a location where growers can periodically observe them and decide if they want to try some of them in their own grove.

The preservation of existing germplasm is important so that genetic diversity is not lost. Both fruit and rootstock varieties, as well as unnamed advanced selections should be planted in a location that is isolated from other avocados and is safe from development for the foreseeable future. Isolation is necessary to prevent the introduction of pests (e.g., shot hole borer) or diseases (e.g., sun blotch) that could cause this material to be lost. As molecular and genetic capabilities advance this germplasm may have traits that can be efficiently and quickly introduced into existing rootstock and fruit varieties.

The last part of a new program should be the development of genetic tools. Currently, it is not possible to genetically engineer the perfect avocado tree, and that is not what this part of the program is about. Rather, as our knowledge of the avocado genome increases it may become possible to identify the genes that are involved in certain desirable characteristics (e.g., Phytophthora and salinity tolerance). Continuing with this example, material in the germplasm preservation program could then be screened to identify which trees possess these traits. Those trees could then be propagated and planted in a block to allow for crosspollination, resulting in a better chance of finding a selection with both Phytophthora and salinity tolerance. In this way, genetic tools are used to focus the parental lines to more rapidly advance the program.

Conclusion

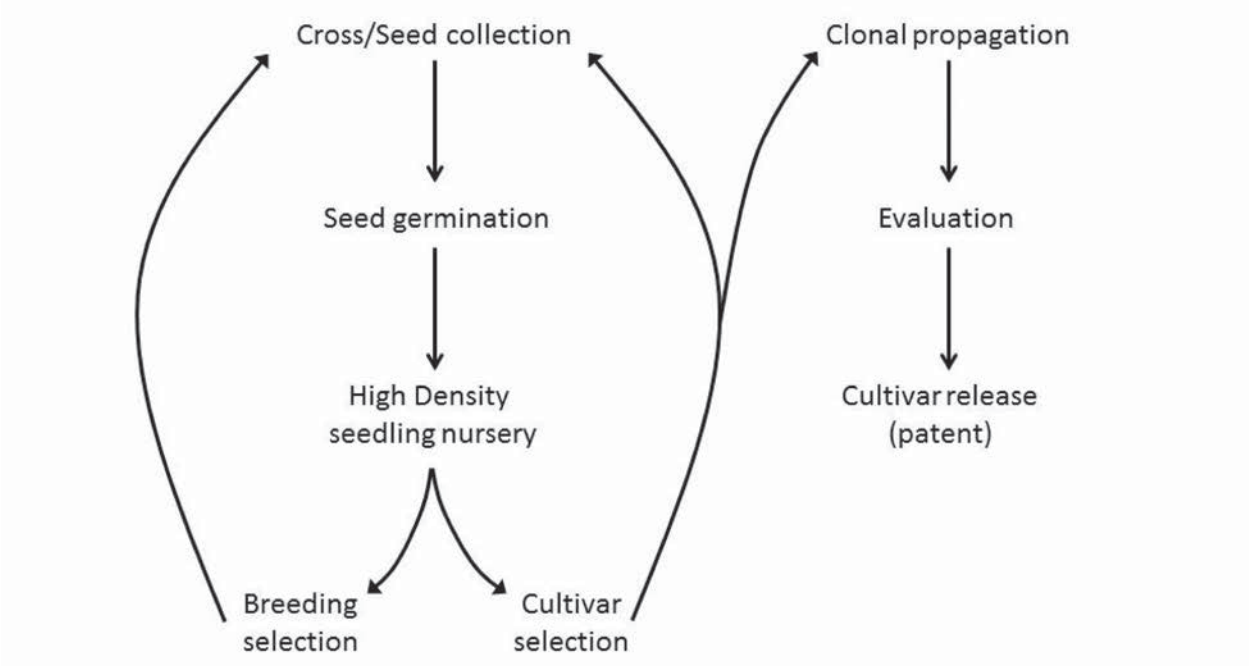
For a plant breeding program to be successful its goals and direction must be well-defined and be of a nature that is still pertinent in 10 or more years' time when the program starts to produce results. CAC has recognized that this stra-

tegic vision does not start with the plant breeding program, but rather with the challenges facing the marketing and maintenance of a credible presence in the overall U.S. avocado market. For this reason, the CAC Board of Directors, not without dissent, has defined their vision for the future as using plant breeding to address the long-term problems facing profitable avocado growing rather than to create a new avocado market based on new varieties.

Moving the California avocado industry away from a 'Hass' monoculture does have merit, but is viewed as a lesser priority in light of the challenges presented by salinity and high chloride water. In addition, there are a number of quality avocado varieties that, for whatever reason, have failed to attract the necessary interest to make them commercially viable. There currently exists an opportunity to use this backlog of varieties, some of which were once commercial varieties, to develop new niche markets for California avocados.

In summary, the recommendations of the Production Research Committee for a refocused plant breeding program are:

- To focus the program on developing rootstocks which are root rot resistant and salt/chloride tolerant
- To ramp down to a very low level of activity the breeding of new fruit types
- To collect information on the horticultural performance of existing fruit varieties and new rootstocks to allow California avocado growers to make rational investment decisions
- To commercially develop the existing backlog of fruit varieties already available to California avocado growers
- To continue to support the development of new genetic tools
- To preserve the existing avocado germplasm as the source of useful genetic diversity for future breeding efforts.



A schematic representation of how a breeding program flows. Seeds are collected, either from controlled or open crosses, and germinated to produce a seedling. The seedlings are planted into a high-density nursery for rapid screening of the desired trait(s) (e.g., salinity tolerance). This process takes from 1.5 to 3 years depending on the species. From here seedlings have three fates: discarded, have some positive traits worth keeping but not good enough to become a variety for release (breeding selection), have good potential to be a new cultivar and improve breeding stock (cultivar selection). Seedlings moving to cultivar selection are propagated (2 years) and then planted out for more detailed evaluation (may take 6 to 10 years). Those varieties making the final cut are patented, licensed for propagation and released to the industry. Depending on the species and the goals of the breeding program it may take from 2,500 to 10,000 seeds and 10 to 15 years to select one cultivar.