Citrus Scion Improvement Program

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United States Department of Agriculture Scientists, H. J. Webber and W. T. Swingle, thought that the prospects for improving citrus cultivars were better through breeding than through selections from seedling groves. They began hybridizations in 1893 when they used sweet orange (*Citrus* sinensis (L.) *Osbeck*), grapefruit (*C. paradisi* Macf.), and mandarin (*C. reticulata* Blanco) cultivars as breeding parents (8, 12). They planted the resulting seeds and the seedlings gave them their first encounter with what is now called nucellar embryony, an asexual method of seed production. Webber and Swingle (13) recognized that cold-hardy citrus trees were needed in the industry. In 1897, they used the trifoliate orange (*Poncirus trifoliata* (L.) Raf.) as the cold-hardy parent in crosses with the sweet orange. These hybrids (citranges) were cold hardy, but their fruit contained excessive amounts of the acrid oil derived from the trifoliate parent.

In 1897 and 1898, Webber and Swingle (13) made various crosses among oranges, grapefruit, tangerines, satsuma, lime, and lemon. Three tangelos (hybrids of 'Duncan' grapefruit (*C. paradisi*) X 'Dancy' tangerine (*C. reticulata*)), 'Sampson,' 'Thornton,' and 'Williams,' were released from these crosses. In 1904, 'Sampson' was the first scion hybrid released in the Florida citrus-breeding program. 'Thornton' was released shortly thereafter. 'Sampson,' 'Thornton,' and 'Williams' tangelos made little impact in the Florida citrus industry. A few trees of 'Thornton' remain in Florida today. An interesting point is that Webber and Swingle named and released these new hybrids about 7 years after the crosses were made.

In 1923, the 'Sustic,' 'Lakeland,' and 'Tavares' limequats, hybrids of lime (*C. aurantifolia* (Christm.) Swing.) and kumquat (*Fortunella*) were released (10). These were more cold hardy than lime or lemon and were possible substitutes. Today, they are occasionally found as dooryard trees.

Other new cultivars were released in 1931. 'Clement' tangelo ('Duncan' grapefruit X 'Clementine' (*C. reticulata*)) was released but received little attention. 'Umatilla' ('Ruby' orange (*C. sinensis*) X satsuma (*C. reticulata*)) never attained commercial importance. 'Orlando,' 'Seminole,' 'Minneola,' 'San Jacinto,' and 'Yalaha' tangelos, hybrids of 'Duncan' grapefruit and 'Dancy' tangerine, were released in 1931 (11). 'Orlando' tangelo is an important cultivar in Florida (1.2 million trees) and 'Minneola' is planted to a significant extent (200,000 trees) (2). 'Wekiwa' tangelo ('Savage' grapefruit X 'Sampson' tangelo), described in 1921, was never widely planted (9).

In 1942, Frank Gardner and Jack Bellows made a series of citrus crosses to produce early-ripening tangerines and tangelos that were easy to peel, attractive, and with cold hardiness (1). P. C. Reece and J. R. Furr assisted Gardner in evaluations of the hybrids. In 1946, Furr and Reece discovered

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that all progeny plants from crosses with either 'Temple' (*C. reticulata* hybrid?) or 'Clementine' as the seed parent were zygotic (3). This has encouraged their use in crosses since 1942. These crosses produced many progeny plants that produced only zygotic progenies and could also be used as seed parents. This greatly increased the genetic base and the ability to produce hybrids.

In 1959, three tangerine hybrids were released from the 1942 crosses—'Robinson,' 'Lee,' and 'Osceola' ('Clementine' X 'Orlando' tangelo) (5). 'Robinson' is the most widely planted with 548,000 trees (2) in Florida, where it is the earliest ripening tangerine. 'Lee' and 'Osceola' are planted to a limited extent.

'Page' ('Minneola' X 'Clementine') was released in 1963 (6). 'Nova' tangelo, another hybrid of 'Clementine' X 'Orlando,' was released in 1964 (7). There are now 166,000 'Nova' trees in Florida (2).

J. R. Furr was transferred to the USDA Date and Citrus Station at Indio, California, in 1946. He established a citrus-breeding program at that location. He also made crosses and sent the seeds to Florida where they were fruited in the USDA citrus-breeding program. This provided a wider genetic base of hybrids because more parental types were available. Seeds from some crosses made in Florida were sent to Furr for fruiting in California. The 'Fremont' tangerine hybrid released in California in 1964 resulted from a cross of 'Clementine' X 'Ponkan' by P. C. Reece in Florida. It was fruited and tested by J. R. Furr. 'Fremont' is not adapted to Florida conditions. The Date and Citrus Station in California was closed in 1982.

In 1979, the USDA released the 'Sunburst' citrus hybrid, a 1961 selection of the cross of 'Robinson' X 'Osceola' (4). This is the latest release from the USDA scion-breeding program. 'Sunburst' fruit ripen after 'Robinson' and before 'Dancy,' a desirable market period. 'Sunburst' fruit are more resistant to postharvest decay than those of 'Robinson' or 'Dancy.'

The citrus industry of the United States, as well as that of most other countries, has been developed on the basis of only a few scion types. These are largely the orange, lemon (*C. limon* Burm. f.), lime (*C. aurantifolia*), mandarin, grapefruit, pummelo (*C. grandis* (L.) Osbeck), and citron (*C. medica* L.). The sweet orange is the most important type and a significant number of cultivars are grown. However, the range of genetic variability is very narrow, indicating that the cultivars differ by only a few genes. Grapefruit is the second most important type of citrus fruit and two cultivars account for most of the fruit. The genetic range of variability is even less than that of the orange. In the U.S., the lemons are primarily the 'Eureka' and 'Lisbon' types and these are genetically very similar. The 'Persian' or 'Tahiti' lime (*C. aurantifolia* hybrid) is the only commercial lime cultivar grown in the U.S. The cultivars of mandarin (tangerine) and mandarin hybrids are more diverse genetically than those mentioned above. Pummelos and citrons are not grown commercially in the U.S.

Significant production problems occur with each of the citrus types grown in the U.S. The most efficient means of controlling these problems is the development of resistant cultivars. Chemical control of some problems is ineffective and the presence of the chemicals often causes environmental problems. Also, diseases and pests develop resistance to pesticides and biological control often is not available.

During the past 90 years, numerous hybridizations have been attempted in efforts to produce new citrus scions with desirable traits. The objectives included cold hardiness, pest resist-

ance, and various horticultural traits. Some of the seed parents in the early crosses produced nucellar seedlings and few, if any, zygotic progeny.

The only F_1 intergeneric hybrids that have produced edible fruit are the limequats (*C. aurantifolia* X *Fortunella*). These acid fruits have not attained commercial importance. The most valuable interspecific hybrids within *Citrus* have been those of *C. paradisi* X *C. reticulata* (tangelos). Hybrids of this parentage resemble the *C. reticulata* parent more than *C. paradisi*, but their fruit are often larger than those of *C. reticulata*.

The crosses made within the past 50 years which have produced the most promising scion hybrids have been those in which one or both parents were F_1 interspecific *Citrus* hybrids. Also, these hybrid progenies are composed of at least $\frac{1}{8}$ (12½%) or more of *C. paradisi*. Hybrids of *C. reticulata* X *C. sinensis* generally have produced relatively small fruit which are difficult to peel. These hybrids resemble the *C. reticulata* parent more than the *C. sinensis* parent. The flavor of the fruit and juice is also more like that of the *C. reticulata* parent. Desirable genetic traits such as cold hardiness, appealing fruit peel and early-to-late maturity are found in *C. reticulata*.

The fruit and juice of *C. reticulata* often are more flavorful than those of *C. sinensis*, owing to their prominent oils found in the rind and other fruit parts. Highly flavorful fruits are more likely to exhibit "off flavors" that can be a problem in fresh fruit as well as in processing.

'Clementine' mandarin and grapefruit have been desirable parents in citrus scion breeding but many hybrids from these parents are self-incompatible and weakly parthenocarpic. They require cross pollination for adequate fruit set. This usually leads to seedy fruits that are less desirable for the fresh market. Irradiation of seeds and budwood is being tested as a technique to produce citrus clones with fruit having reduced seed content.

Desirable citrus traits that are heritable and have been combined in new scion hybrids include resistance to cold, *Alternaria citri* Ellis and Pierce of foliage and fruit, snow scale (*Unaspis citri* (Comstock)), and a dieback of uncertain cause. Early fruit maturity and improved fruit color (rind and inside) have also been combined in new hybrids.

The objective of the current scion-breeding program is to develop tangerine, tangelo, orange, and grapefruit cultivars. Superior characteristics or objectives sought in new cultivars that apply equally to these four market classes of fruit include cold hardiness, disease and insect resistance, and consistent production of high-quality fruit with attractive appearance and good taste. The maturity season is an important characteristic. Classes of fruit for the fresh market should peel easily and ship with minimal losses. The juice should contain a high percentage of total soluble solids with a favorable level of acid, acceptable color, and no objectionable "off flavors" when proccessed. New, early-maturing cultivars would extend the harvest season and permit more efficient use of labor, packinghouses and processing equipment. The hazard of freeze injury to these fruit would be reduced because they could be harvested before the onset of cold weather. Development of late-maturing cultivars could extend the harvest season. However, superior cultivars that mature at the same time as existing cultivars, as well as adaptation of new cultivars to mechanized harvest methods, would be beneficial. New cultivars of grapefruit and oranges with diverse genetic makeup are needed for possible protection against disease hazards.

The scion breeding program consists of four steps: 1) hybridization, 2) culture of seedlings until they produce fruit, 3) propagation of superior types on several rootstocks and planting them at multiple locations, and 4) culturing the trees until they have produced several fruit crops. Evaluations for fresh fruit market are made during steps 2, 3 and 4. Characteristics include fruit quality, size, yield, maturity date, postharvest qualities, cold hardiness, disease resistance, pollination requirements and suitable rootstocks. Evaluation for processing is done in step 4.

The above steps were followed in the development of the 'Sunburst.' A period of 18 years was required before release, in contrast with the 7 years required for the release of 'Sampson' tangelo by Swingle and Webber. A period of 18 years or more is realistic in the development of a new citrus scion cultivar. Consequently, citrus breeding is a long-term program. A question that frequently arises is: How much information is required before a cultivar release is made? Perhaps this question has several answers, but it is obvious that the number of years is directly related to the amount of information desired.

The future of citrus breeding in Florida is encouraging because of the wider range of parental material available to breeders. In the past, only a few seed parents were available that produced zygotic progeny. However, the seed parents developed in recent years that produce monoembryonic seeds and zygotic progeny are of many types. The task will not be easy, because the requirements of new cultivars are more specific.

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