

Update on the USDA, ARS Citrus Scion Improvement Project

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Citrus breeding has been conducted by the USDA in Florida since 1893 when W.T. Swingle made his first crosses at the USDA Subtropical Laboratory in Eustis, FL. The initial emphasis was to develop disease-resistant cultivars. A second objective was to develop citrus fruit that were easy to peel; ease of peeling is still an important objective of the program. Swingle hybridized ‘Duncan’ grapefruit (*Citrus paradisi*) with pollen from ‘Dancy’ tangerine (*Citrus reticulata*), which resulted in the new citrus type known as tangelos, of which ‘Orlando’ and ‘Minneola’ are the most important commercially. Frank Gardner used ‘Orlando’ tangelo pollen in crosses with ‘Clementine’ mandarin and created the hybrids ‘Osceola’, ‘Lee’, ‘Nova’, and ‘Robinson’. Gardner pollinated ‘Minneola’ tangelo with ‘Clementine’ pollen, which led to ‘Page’. Jack Hearn began making citrus hybrids in the early 1960s and created ‘Sunburst’ (‘Robinson’ x ‘Osceola’) and ‘Fallglo’ (‘Bower’ x ‘Temple’). Several hybrids generated by Hearn have been identified as candidates for release, and numerous additional hybrids are in the early stages of evaluation. Many seedy but otherwise high quality hybrids have been irradiated in an effort to reduce seed production and thereby increase consumer demand. Recently, research to determine the components of fruit quality important to consumers, as well as to how new cultivars hold up in marketing channels, have been incorporated into the USDA scion improvement program. Continued development of new attractive, flavorful, and convenient citrus cultivars available over a wide season will enable the US citrus industry to remain competitive in the global marketplace.

The development and availability of improved citrus scion varieties are essential to the US citrus industry in order for it to remain viable and competitive in the world market. New varieties are needed to extend the harvest season, offer alternatives to consumers, and confer resistance to pests (Hearn, 1973). To become successful, a commercial variety must fulfill numerous requirements relating to production, marketing, and consumption. Growers are concerned with the amount and difficulty of cultural care needed to produce the variety, as well as characteristics pertaining to pest resistance, fruit production (bearing age, yield, longevity), and marketability of the fruit (extent and location of markets, season, and price). Marketers are concerned with suitability for harvesting, packing, processing, transportation and storage, season of availability, and access to markets. Consumer’s concerns include appearance, convenience, eating quality (amount and flavor of juice), dietary value, and cost. None of our current commercial citrus scion varieties can be considered ideal and even the best have serious defects.

Genetic improvements of citrus have been accomplished by: 1) identification and propagation of natural mutations or budsports; 2) natural hybridization; 3) hybridization by controlled pollination; 4) variation induced asexually via nucellar embryony or tissue culture; and 5) irradiation to induce desirable mutations. Although not genetic improvement in its strictest sense, the introduction of new germplasm can be considered improvement on a local basis, especially owing the vastly differing performance of citrus in different regions. Throughout its history, the USDA citrus scion improvement program has utilized plant introduction, hybridization, and irradiation in an effort to provide improved

citrus varieties to the US citrus industry. This program has been reviewed in these proceedings in 1962 by Cooper et al. and in 1973 by Hearn. As significant time has passed since the last review, it seemed timely to revisit this topic and give an update on the current status of the program.

USDA Scion Hybrids

The USDA citrus breeding program has been in existence since its inception in 1893 by W.T. Swingle and Herbert J. Webber at the US Subtropical Laboratory in Eustis, FL. Swingle and Webber’s initial objective was to develop varieties with resistance to the numerous diseases that plagued citrus in Florida, and by 1893 they had begun to make citrus hybrids at the Eustis lab. The citrus breeding program suffered a major early setback due to the severe freeze in the winter of 1894–95 which killed most of the USDA hybrids. Losses caused by this freeze were so devastating that it prompted Swingle and Webber to focus on breeding for cold hardy citrus and in 1897 they made crosses between sweet orange (*Citrus sinensis*) and trifoliolate orange (*Poncirus trifoliata*). From these crosses only a few true hybrids were identified; these came to be known as the citranges (Webber and Swingle, 1905). The citranges have proven valuable as rootstocks, but not as scions. Swingle and Webber (1897) also recognized hybridization as “probably the most satisfactory method of obtaining improved and unique flavor.” Starting in 1897 Swingle and Webber began making crosses between tangerine (*Citrus reticulata*) and grapefruit (*Citrus paradisi*); the fruit resulting from these crosses came to be known as “tangelos” (Webber and Swingle, 1905). ‘Sampson’ and ‘Thorton’ were the first of several tangelos to be selected for propagation and distribution, but these varieties never gained commercial success due to difficulty with produc-

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tion and poor shipping characteristics. Additional tangelos were generated by Swingle and co-workers E.M. and F.W. Savage and after evaluation, several selections were named and released, including 'Orlando' and 'Minneola' (Robinson, 1931; Swingle et al., 1931). 'Mineola' has proven to be the most commercially successful tangelo while 'Orlando' has proven to be a very valuable pollen parent for scion breeding.

In 1909 Swingle introduced the 'Clementine' (*Citrus reticulata*) to the United States from Algeria (Webber, 1943), and this would prove to be an important parent in the future of the USDA scion improvement program. In 1942, John Bellows, at the USDA US Horticultural Field Station in Orlando, made 35 crosses utilizing 'Clementine' as the pollen parent and 'Orlando' tangelo as the seed parent. Bellows left the USDA in 1943, but his work was continued by Phillip C. Reece and Frank E. Gardner at the USDA Hiwassee farm in Orange County, and at field sites in Lake Mary, Seminole County and Ft. Pierce, St. Lucie County. A population of 327 seedlings resulting from the 'Clementine' x 'Orlando' crosses was evaluated; three promising individuals were identified and eventually released as 'Robinson', 'Oseola', and 'Lee' (Reece and Gardner, 1959). Another selection from the same 'Clementine' x 'Orlando' cross was eventually selected for release as 'Nova' (Reece et al., 1964). 'Clementine' was also used as a seed parent in crosses with 'Minneola' tangelo, and this cross resulted in the identification and release of 'Page' (Reece et al., 1963). Reece used 'Robinson' and 'Osceola' as parents in a cross in 1961, and in 1967 an individual seedling was selected by Jack Hearn for further evaluation. This selection was released in 1979 as 'Sunburst' (Hearn, 1979).

One of the progeny resulting from the 'Clementine' x 'Orlando' crosses made by Bellows in 1942, identified as 6-8-16, was introduced into Texas in 1955, and eventually released as 'Bower' (Wutscher et al., 1973). Reece used 6-8-16 (later known as 'Bower') in 1962 as a seed parent in a cross with 'Temple' (*C. reticulata* hybrid). Hearn evaluated the 376 seeds resulting from the 'Bower' x 'Temple' cross and from them made a selection that was eventually released as 'Fallglo' (Hearn, 1987).

The most complex scion hybrid, and last to be released from the USDA program, resulted from a cross made in 1963 by Hearn and Reece at Ft. Pierce using one of the 'Clementine' x 'Orlando' hybrids (1-3-54) as the seed parent and a seedling of a midseason sweet orange as the pollen parent. Hearn evaluated 712 seedlings resulting from this cross and selected one which was released in 1989 as 'Ambersweet' (Hearn, 1989).

Irradiation

One of the problems hindering the commercial potential for new citrus hybrids is the seed content of the fruit. It is widely accepted that the presence of seeds is undesirable to consumers. However, most of the citrus hybrids with outstanding fruit quality contain numerous seeds. One approach that has been taken to eliminate seeds is the use of irradiation. Hensz (1971) reported on the use of thermal neutron treatment of seeds of 'Hudson Pink' grapefruit that resulted in the development of 'Star Ruby' seedless grapefruit, which is not only seedless, but also has enhanced red color in the flesh. Hearn (1984) irradiated seeds of 'Pineapple' orange and 'Duncan' grapefruit and budwood of 'Foster' grapefruit (Hearn, 1986) in an effort to obtain seedless mutants of these varieties. Irradiation proved to be successful at eliminating seeds, and a seedless selection of 'Pineapple' orange has been evaluated and is near release (McCollum and Bowman,

2005). Irradiation was also used successfully to reduce the seed number in a grapefruit-like hybrid, USDA 1-77-19. Hearn crossed Pearl tangelo x Duncan grapefruit and identified a selection (5-75-8) that was early maturing, low in acid content and non-bitter, but seedy. Irradiation of seeds of 5-75-8 led to the identification of USDA 1-77-19, another selection that has received considerable attention and is near release. However, recent tests have revealed that USDA 1-77-19 is subject to postharvest deterioration problems (McCollum and Chaparro, 2004) and research will be necessary to develop appropriate handling practices for this selection. A seedless mutant of 'Fallglo' has been developed by irradiation of budwood and should be available soon. Budwood of 16 hybrids which have excellent fruit quality, but are seedy, has been irradiated and used to produce grafted trees. These trees have been established in the field and will be evaluated for seed content when they start to produce fruit. It is likely that seedless varieties of these selections will be identified.

The Future

Hearn retired from the USDA in 1995 and like his predecessors, left of wealth of citrus germplasm for evaluation by his successors. Prior to his retirement Hearn identified several selections as promising enough to consider releasing; some were hybrids and others were introductions. Among the selections near ready for release are: 'Thomson' navel orange – this orange was selected by Hearn in an attempt to provide a better quality navel orange for late season harvest. The resulting selection is not really a late navel in the strictest sense, since it meets fresh fruit standards at about the same time as other navels. It has, however, the ability to hold good quality and enough acid to retain good taste for up to a month longer than other navel varieties. It has more consistent yields than some of the more widely planted navels and does not seem to have any undesirable horticultural characteristics. Average fruit size is somewhat smaller than the DPI 56-11 series navels, but still large enough to be well received by the fresh fruit industry. 'Tresca' midseason orange – work with this selection has been ongoing since the 1960s due to an extremely long period of juvenility. It has about the same season as 'Pineapple' orange, but much better juice color and few, if any, seeds. The juice color is essentially equal to Valencia (CN 37-39) and in some years a small amount of lycopene or "blood" is present. This variety should supply very high quality fruit for both the fresh and juice markets. USDA 1-105-106 – this is a complex hybrid resulting from a cross of ('Clementine' mandarin x 'Orlando' tangelo) by a seedling sweet orange. This selection produces juice with outstanding color and flavor. Although not an orange, it may have utility for fresh juice and the mandarin background may improve its tolerance to citrus canker. Additional hybrids from the Hearn era are in various stages of evaluation and will no doubt lead to releases.

In 1996 Jose Chaparro was hired by the USDA to fill the position vacated by Jack Hearn. During Chaparro's tenure with the USDA he generated thousands of hybrids; however, Chaparro left the USDA in 2004 prior to his hybrids coming into fruit production. Currently the USDA scion improvement program has in excess of 10,000 hybrid seedlings growing in the field for evaluation. These hybrids are being grown at the A.H. Whitmore Citrus Research foundation farm in Lake County, FL, and at the USDA, ARS, US Horticultural Research Laboratory farm in St. Lucie County, FL. Many of these hybrids share parentage of successful varieties. There is great promise that selections will

be identified from the thousands of hybrids being evaluated, and that this will result in the release of new scions of value to the citrus industry. Recently, 46 hybrids have been selected based on fruit characteristics worthy for further evaluation.

In 2006 a new set of crosses was made using 'Lee', 'Robinson', and 'Clementine' as seed parents in combination with 'Orlando', 'Nova', 'Robinson', and 'Clementine' as pollen parents. These crosses resulted in the production of thousands of seeds which will be planted out for evaluation. These parents were selected as they represent crosses that have in the past produced large numbers of promising selections. Only time will tell if the next great variety is among them. As H.B. Frost (1943) stated "The extreme variability of citrus hybrids is both their greatest disadvantage and their greatest advantage; it makes nearly all hybrids worthless, and it presents the possibility of producing something that will be not only very good, but very distinct from existing varieties." By continuing to create new germplasm we will continue the possibility of identifying scions that are not only very good, but also very distinct from varieties that are currently available.

Although the development of new scion varieties with outstanding fruit quality is a paramount objective of the scion improvement program, historically, identification of selections with superior quality has been based on the subjective judgment of a very few individuals. Currently we are working to incorporate sensory evaluations by trained panelists to correlate with chemical composition of fruit. By identifying components which contribute to or detract from good flavor we hope to be able to develop genetic markers which could be used early in the scion evaluation program to eliminate all but the most promising selections early in the process.

The USDA citrus scion improvement program has a long and successful history of developing improved citrus scion varieties, and the potential for further improvements exists. However, recently huanglongbing (HLB) (citrus greening, causal agent *Candidatus Liberibacter asiaticus*), perhaps the most devastating disease of citrus, has become established in Florida. The effects of HLB and the current phytosanitary regulations established to manage the disease pose severe limitations on field evaluation, propagation, and distribution of citrus germplasm, and as a consequence, bring into question the viability of the scion improvement program as it has been traditionally conducted. At this time it is too early to predict exactly how HBL will impact the scion improvement program, but it is certain that the impact will be significant.

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