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Founding Clones of Low-chill Fresh Market Peach Germplasm

DAVID H. BYRNE AND TERRY A. BACON

Abstract

The source of the low-chilling trait in peach breeding is low quality, soft fruited, small, white fleshed peaches from south China such as 'Peento,' 'Okinawa,' and 'Hawaiian.' These were intercrossed with local clones to develop commercially acceptable low-chill cultivars in the programs in the U.S. (Florida), Brazil (Pelotas and Sao Paulo), and Mexico (Queretaro and Chapingo). The work at these various sites except for the work between Chapingo and Florida, have developed independently with only an occasional exchange of germplasm. The founding clone analysis and data from isozymes, RAPDs, and morphological analyses indicate that this low-chill germplasm is more diverse than the U.S. high-chill germplasm since it combines the U.S. high-chill germplasm with local cultivars from Brazil and Mexico and the exotic low-chill south China germplasm.

Introduction

High-chill peach {*Prunus persica* (Batsch) L.} breeding and production throughout the world has, with the exception of Asia, relied chiefly on high-chill North American cultivars, most of which can be traced back to 'J.H. Hale,' and hence through 'Elberta' or 'Belle of Georgia,' to 'Chinese Cling' (26). This narrow genetic base has concerned breeders because of inherent limitations when trying to incorporate traits such as disease and pest resistance, unique flavor and nutritive components, and adaptation to different areas. In the process of developing cultivars for warmer climates however, breeders in North America, South America, and Australia introduced several sources of the low-chill trait into this germplasm. As a result, the low and medium-chill germplasm is now more diverse than North American high-chill germplasm.

In U.S. breeding programs, the low-chilling trait was initially derived from low quality, soft fruited, white-fleshed genotypes from south China such as 'Peento,' 'Okinawa,' and 'Hawaiian.' 'Peento' was utilized as early as 1907 in California at the University of California at Riverside, and at Chaffey Junior College in Ontario, California. These programs released 'Babcock,' which was later used extensively by Armstrong Nursery Company in California to develop peaches such as 'Flamingo,' 'June Gold,' 'Robin,' and 'Springtime,' and nectarines such as 'Armking,' 'Panamint,' and 'Palomar.' The University of Florida breeding program later used these materials in combination with 'Okinawa' and 'Hawaiian,' to develop a range of low-chill early-ripening cultivars that have in turn been used in breeding by other low and medium-chill efforts in Australia, Asia, South America, and the U.S. (Tables 1 and 2).

The programs in Brazil (Pelotas and Sao Paulo research programs) and Mexico (Queretaro and Chapingo research programs) intercrossed cultivars from Florida and other U.S. sources with local feral germplasm. This feral germplasm are locally adapted seed-propagated lines that date back to 16th century seed introductions by Portuguese and Spanish explorers. Cultivars derived from these programs have also been used in U.S. programs, especially in Florida, for development of non-melting fresh market cultivars.

This paper discusses low and medium-chill fresh market cultivar development in breeding programs in the U.S., Brazil, and Mexico, and compares their founding clones and relative contribution to these cultivars.

Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843-2133

Materials and Methods

Parentage of the cultivars in this study was obtained from the compilation by Brooks and Olmo (4, 5) and Okie (20) for U.S. released peaches, from Barbosa et al., (2), Bruckner (6), Nakasu et al. (19), and Raseira et al. (24) for Brazilian releases, and from Perez (21) and Rodriguez and Sherman (25) for Mexican releases. Questions of parentage were verified by direct communication with the breeders involved in development of the respective cultivars (see list of cooperating breeders).

The database was a compilation of historical parentage data obtained from Ralph Scorza (26, 27) supplemented with up-to-date parentage of recent cultivar releases. The data were analyzed with a computer program, written in 'dBase' (Borland International, Inc., Scotts Valley, CA), that calculated the percent contribution of each founding clone in the background of a cultivar. Since peaches are largely self-pollinating (10), open pollinations and unknown pollen parents were considered self-pollinations. Although this assumption is not completely true, given the biology of the plant, it will give a result closer to the actual situation than the alternative of assuming that these are crosses with unrelated genotypes.

Melting and non-melting fleshed germplasm was analyzed and discussed separately because the two have been developed independently and with different germplasm in some of the breeding programs.

Results and Discussion

Melting-flesh germplasm.

California. Fruit breeders in California in the early years of low-chill peach breeding relied predominantly on two south China derived genotypes, 'Peento' and 'Lukens Honey,' as sources of the low-chilling trait. It is understandable then that 'Peento' was identified as a primary founding clone in all six of the low-chill melting-flesh programs in the study (Figure 1). Hume (12) described 'Peento' as a very low-chilling peach with medium-to-large fruit that was oblate with thin, bitter, yellowish-green skin and yellowish-white flesh that was firm and clingstone. It is believed that this is the same 'Peento' imported to the U.S. by P. J. Berckmans of Augusta, Georgia as seed from Australia in 1869 (14, 15, 16). 'Lukens Honey' has been described as a medium-chill peach, named in 1920 in California, with white low-acid flesh (20). These two genotypes formed the foundation of much of the low and medium-chill breeding efforts of subsequent breeding programs and gave rise to many important breeding clones such as 'Babcock,' and its derivatives, 'Flamingo,' 'June Gold,' 'Robin,' 'Springtime,' 'Panamint,' and 'Palomar' (Table 2).

Florida. The University of Florida stone fruit breeding program built on the foundation of the early low-chill California breeders and introduced other sources of the low-chilling trait. The Florida germplasm was found to be 34% derived from low-chill materials, and 60% from high-chill materials (Figure 1). They began by intercrossing low quality, low-chill south China peaches such as 'Okinawa,' 'Hawaiian,' and 'Jewel' (derived from 'Peento') with peach germplasm from the northeastern and southeastern U.S. and California. Eastern U.S. germplasm was used for quality and disease resistance while California germplasm, from the early low-chill programs, was used as a source of quality and adaptation. 'Okinawa' was useful for overcoming problems inherent in higher-chilling parents such as blind nodes ('Springtime' and 'Armking'), and bud failure ('Loring'). 'Hawaiian' and 'Okinawa' are late-ripening, small, white, melting-fleshed peaches originally used as rootstock materials. Sharpe (28) reported that 3 generations were required, after initial crosses, to recover commercially acceptable early-ripening, low-chill genotypes. The improved germplasm has been utilized extensively by breeders and commercial growers throughout the world.

Additionally, in the mid 50s the Florida program began to introgress the nectarine gene into their breeding population using

'Panamint' and NJN21 ('Cardinal' and 'Flaming Gold' parentage) and more recently, 'Armking,' 'Armqueen,' 'Merrill Princess,' 'Mayfire' and others in their breeding program (29, 32).

Brazil. The breeding programs at Pelotas and Sao Paulo have advanced their germplasm by combining breeding materials from the U.S. with locally-adapted Brazilian germplasm believed to be derived from seed brought over by Portuguese explorers. The genetic background of the lower-chilling program at Sao Paulo was found to be 38% local Brazilian cultivars, 34% from low-chill U.S. materials, and 28% from high-chill U.S. materials. The Pelotas germplasm was 49% local Brazilian, 11% from low-chill U.S. materials, and 40% from high-chill U.S. materials (Figure 1). It is noteworthy that the Brazilian founding clone germplasm was different in each program, indicating these two breeding efforts progressed independently with locally adapted germplasm.

The Sao Paulo program used the local low-chill cultivars, 'Rei da Conserva,' 'Perola de Itaque,' and 'Taichi.' The first two were utilized because of their productivity and firmness although flavor was considered inferior. In the early years of the program these materials were crossed with the imported cultivars, 'Suber,' and 'Jewel' ('Peento' progeny selections) to incorporate better flavor (2). 'Rei da Conserva' is still used as a processing peach in the Sao Paulo region as well as seedling rootstock (23). 'Taichi' was utilized for its local adaptation, firmness, and flavor even though it was considered a small peach with a tendency for pronounced tips and sutures and greenish-white flesh (2). More recently, improved low-chill Florida cultivars such as 'Sunred,' 'Sunlite,' 'Maravilha,' and 'Columbina' have been imported and utilized in crosses. The latter two ('Maravilha' and 'Columbina') were initially sent to Brazil as numbered selections for evaluation where they were named (33).

The Pelotas program utilized mainly four local cultivars: 'Precoce Rosado,' 'Admiravel,' '15 de Novembro,' and 'Delicioso.' 'Precoce Rosado' is a yellow-fleshed, red-blushed (80%), freestone peach with superior flavor and occasional pronounced tips (Raseira, personal communication). '15 de Novembro,' and 'Delicioso' are low-chill (approximately 200 chill hours), white, melting-flesh peaches but the latter is considered superior as it is firmer and freestone. Moreover, 'Delicioso' has been a predominant founding clone in the Pelotas program and is in the background of half of the releases since 1976 (6). In the early years the Pelotas program intercrossed local cultivars with seedlings from the Florida program germplasm ('Southland X 'Hawaiian' derivatives), and several cultivars were named from those efforts, including 'Cardeal,' 'Premier,' and 'Princesa.' In succeeding years, germplasm from New Jersey, and several imported nectarines ('Sunred,' 'Panamint,' and 'Goldmine'), were incorporated into the breeding population.

Non-melting germplasm.

In the U.S., breeders have traditionally developed non-melting type peaches for the processing industry where value is placed on interior qualities such as flesh firmness and color, freedom from loose fiber, fine texture, and the lack of red coloration in the flesh. The growing demand for early-ripening peaches with 'tree-ripe' flavor however has led to a recent trend to develop non-melting cultivars for the fresh market. The non-melting flesh characteristics allow growers to harvest at a more mature stage with less bruising and longer shelf life. One concern with fresh market breeders was a tendency of some genotypes to develop off flavors, especially fermented flavors, as they ripen, or if stored too long. Several non-melting cultivars have been released that are less prone to this problem, including 'Davidsun,' 'Maysun,' 'Big Top,' 'UFGold,' 'Crimson Lady,' 'Delta,' 'Springprince' and 'Springbaby.' In other countries such as in Brazil, Mexico, and Spain non-melting genotypes have been used for fresh consumption for centuries.

Brazil. The Brazilian programs have worked for many years to develop non-melting peaches for processing as well as dual-purpose types, useful for both fresh and processing markets. The program in Pelotas has a major objective to develop processing cultivars and has released about 30 cultivars since beginning the program over 40 years ago (6). The germplasm is largely based (55%) on four Brazilian nonmelting processing cultivars: 'Aldrighi,' 'Ambrosio Perret,' 'Abobora,' and 'Intermediario' (Figure 2). The first two are the most prominent of these. 'Aldrighi,' a parent of 'Bolinha' (a dual purpose brown rot (*Monilinia fruticola* Wint.) resistant cultivar) (9) was derived from seed of fruit that was imported from Argentina for processing, and appears to be the parent of 'Intermediario.' 'Ambrosio Perret' is a selection of unknown origin that was in the 1937 catalog of the Quinta Bom Retiro nursery. It was a firm, non-melting yellow processing cultivar that transmitted good size to its progeny, but lost favor with growers and with breeders for inconsistent cropping and susceptibility to brown rot. Possibly the most important Brazilian release has been that of 'Diamante,' a major commercial peach in Brazil and in Mexico, and a principal breeding parent in all of the non-melting programs in the study. 'Diamante' is derived 50% from the Brazilian local cultivars 'Abobora' and 'Aldrighi,' 25% from the old variety 'Amsden,' a white, melting-flesh, mid-season variety selected in Missouri in 1868 (11), and 25% from the original Florida ('Southland' x 'Hawaiian') germplasm, and other U.S. cultivars.

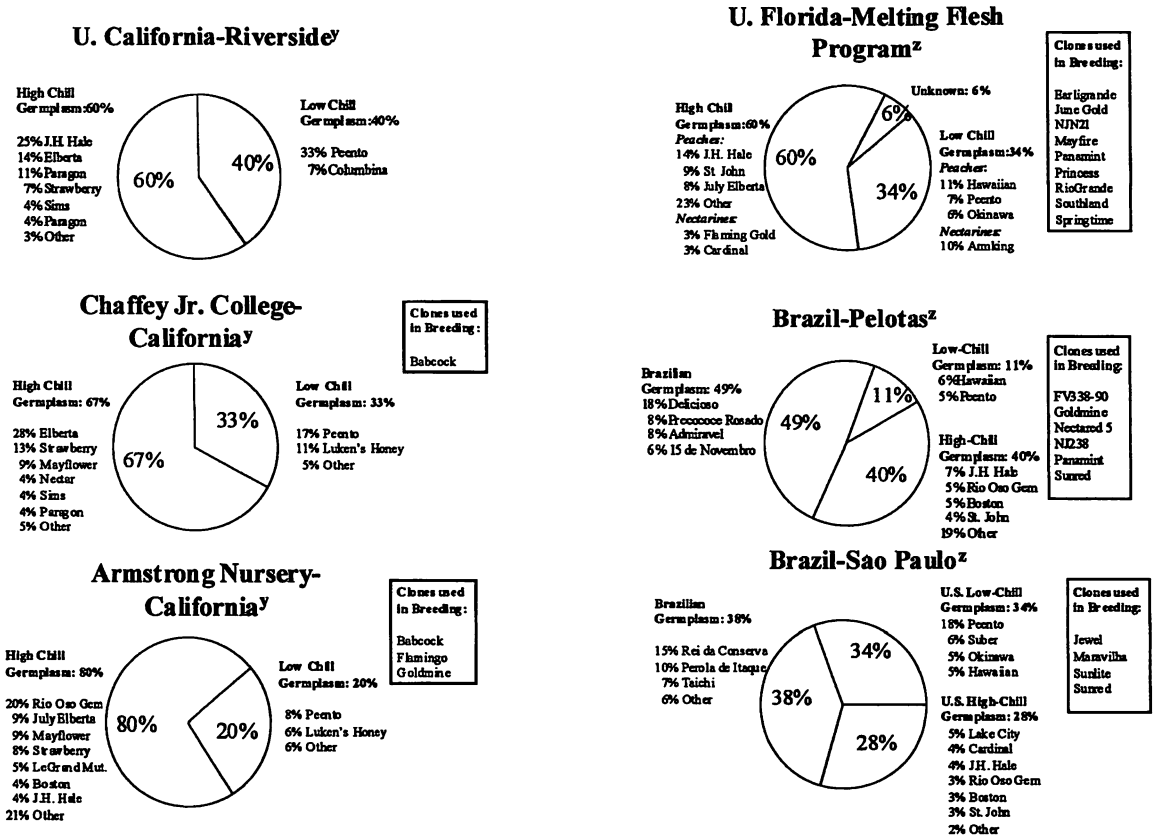
'Lake City,' a cultivar apparently introduced from Spain via St. Augustine, Florida (Sherman, personal communication), has been used repeatedly in Brazil. This cultivar is a very productive, mid to late season, orange fleshed, non-melting peach with medium size, conical shape, and a tip (Raseira, personal communication).

Mexico. Growers in Mexico have continued to utilize seedling trees since the introduction of peach seed by Spanish explorers in the 16th century. Moreover, after many generations, individual feral populations are now adapted to a wide range of environments from subtropics to the cool highlands (1800-2450 meters above sea level) (22). In Mexico as in Spain, the traditional peach fruit is a dual purpose non-melting type with yellow or orange flesh and no red overcolor. Fruit size is not as critical as in the U.S. because fruit not sold in the fresh market are sent to processors. The Mexican cling (referred to as "criollo") populations exhibit a range of ripening time but due to the nature of seedling populations, these are mid-to-late season ripeners (fruit development period greater than 150 days) since peach seeds require over 100 days from full bloom to mature and germinate well.

Breeders at Chapingo and Queretaro have selected local germplasm from orchards throughout Mexico. Both programs have actively intercrossed these local selections with the Brazilian non-melting cultivar 'Diamante,' a major commercial peach in Mexico that is highly regarded for its productivity, fruit quality, and moderate resistance to powdery mildew (*Sphaerotheca pannosa* Lev.), a major disease problem in the highland growing regions. Additionally, the Chapingo program has incorporated U.S. germplasm.

The Chapingo germplasm was found to be 20% local Mexican genotypes, 20% Brazilian non-melting, 45% U.S. high-chill, and 15% U.S. low-chill (Figure 2). The program has worked closely with the Florida program although Florida germplasm, in contrast with traditional Mexican fruit, is highly blushed and early-ripening. They have utilized the Florida selections FLA9-20C and FLA9-26C and have made several joint releases including 'OroA' and 'Aztec Gold.' FLA9-20C is derived from the same non-melting northeastern U.S. germplasm from which the U.S. non-melting cultivars 'Delta' (Louisiana) and 'Spring Baby' (USDA, Fresno, CA) were developed.

At Queretaro, local peaches collected from the traditional highland production



[Y] Based on all information available.

[Z] Based on releases between 1976 and 1997.

Figure 1. Percent contribution of major founding clones, and important clones used in breeding, of six low-chill fresh market breeding programs (melting flesh).

Table 1. Public peach and nectarine breeding programs in the world classified by activity and adaptation zone.

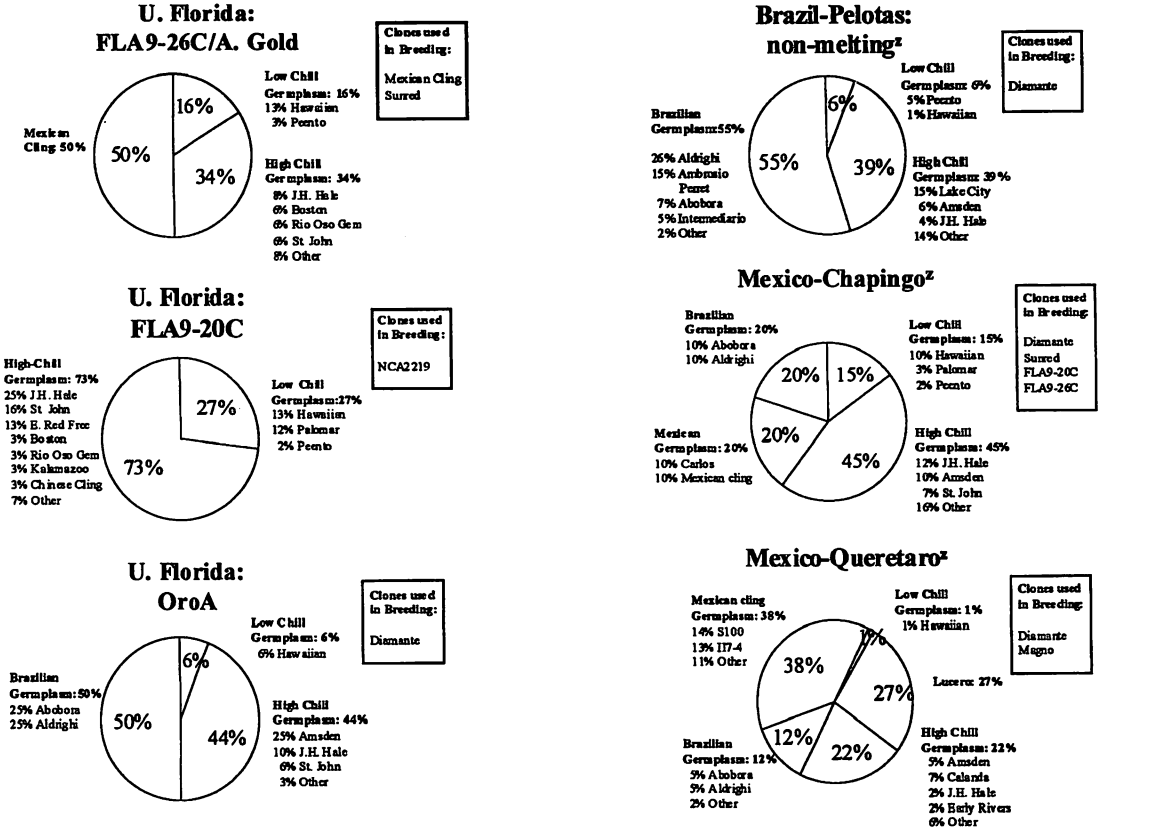
Activity level	Low-chill (< 450 CU)	Medium-chill (450 - 700 CU)	Marginal medium-chill (600 - 850 CU)
Active	Florida - UFL - Gainesville	Texas - TAES, College Station	California - USDA, Fresno
	Brazil - Pelotas, RS	Mexico - Chapingo	Georgia - USDA, Byron
	Brazil - Sao Paulo, Campinas	Mexico - Queretaro	Australia - Tatura, Victoria
		South Africa - Stellenbosch	
New	Texas - TAES, Weslaco	Georgia - USDA, UGA and UFL - Attapulgus	
	Australia, Queensland, New South Wales, and Western Australia	China - Zhengzhou, Henan	
	Taiwan - TARI, Taichung		
	Thailand - Kasetsart Univ., Bangkok		
Inactive		Louisiana - LAES, Idlewild	California - Chaffey Jr. Coll.
			California - USDA, Palo Alto
			California - UC, Riverside

regions were intercrossed among themselves and crossed with 'Lucero' (a local selection named by A. Vega Leyva in Aguascalientes), two Brazilian cultivars ('Diamante' and 'Magno'), and with other commercial cultivars ('Allgold,' 'Flordaprince,' 'Oom Sarel'). The germplasm was found to be 38% local Mexican germplasm, 12% Brazilian non-melting, 22% U.S. high-chill, and 27% derived from 'Lucero.' 'Lucero' is not included with other local Mexican germplasm based on a phenotypic study by Perez et al. (22) that found it was more similar to South African non-melting material than the Mexican criollo germplasm. In fact, seedling populations of 'Lucero' and 'Neethling,' a South African cultivar, are very similar. This would suggest that although 'Lucero' was selected in Mexico, it is actually derived from a South African processing cultivar (Perez, personal communication) which is derived from 'Kakamas' and 'Early Dawn' which trace back mainly to 'Chinese Cling.'

Florida. The University of Florida program has recently released several low chill non-melting peaches for the fresh market (30). As in other U.S. programs, non-melting efforts were initiated in order to develop cultivars that would enable growers to harvest at a more mature "tree ripe" stage (32, 34). They have developed non-melting germplasm from three sources: Mexican cling, northeastern U.S. non-melting materials, and Brazilian non-melting germplasm (Figure 2).

FLA9-26C and 'Aztec Gold' were developed from feral Mexican cling material (50%) combined with U.S. low-chill (16%), and U.S. high-chill (34%). The Mexican source goes back to seed collected by Jim Pittman (Gerber Co.) in 1969 from a seedling orchard in Aguascalientes, Mexico of a late ripening (150 days FDP), large, nonmelting criollo peach. He sent the seed to Ralph Sharpe who planted it, and although too high-chilling (650 CR) to fruit well in Gainesville, its pollen was used in a cross with 'Sunred.' This, after several generations, has yielded selections with lower chilling requirement (<300 CU), earlier ripening (78 to 115 days), and good size and quality (3).

Fla. 9-20C is derived from low-chill materials of south China descent (27%) combined with northeastern U.S. germplasm (73%), most notably the North Carolina selection (NCA2219) that goes



[z] Based on releases between 1976-1997.

Figure 2. Percent contribution of major founding clones, and important clones used in breeding, of four low-chill fresh market breeding programs (non-melting flesh).

Table 2. Principal low-chill founding clones and derivatives that are noteworthy for breeding and/or commercial purposes.

Founding Clones	Derivatives	Notes
Peento	Jewel, Suber	Peento progeny selections
	Babcock	Peento X Strawberry
	June Gold, Panamint, Maravilha, Sunred, Sunlite, NJ238	Babcock derivatives
Lukens Honey	Springtime	Lukens Honey derivative
	Flordaking, June Gold, Springcrest, Earligrande	Springtime derivatives
Hawaiian	Flordaprince, Flordaking, FV338-90, Sunred, NJ238, Maravilha, Earligrande, RioGrande	
Okinawa	Sunlite, Maravilha, Flordaprince	

back to 'Chinese Cling' and its many derivatives (26). This is the same germplasm from which the early ripening nonmelting varieties 'Delta' (Louisiana) and 'Spring Baby' (USDA, Fresno, CA) were developed.

'OroA' was selected in Florida from a population of seedlings of the Brazilian cultivar, 'Diamante.' 'Diamante,' as previously stated, is derived 50% from the Brazilian local cultivars 'Abobora' and 'Aldrighi,' 25% from the old variety, 'Amsden,' and 25% from the original Florida, 'Southland' x 'Hawaiian' germplasm and other U.S. cultivars.

Contribution of the high-chill germplasm. Among the founding clones of these low-chill germplasm are a series of high-chill cultivars that are the common founding clones of the high-chill germplasm: 'J. H. Hale,' 'Rio Oso Gem,' 'St. John,' and 'July Elberta' (Figures 1 and 2). In the early California programs this consisted of 60-80% of their genetic background. In the Florida program it ranges from 34% to 73% depending on the germplasm. In the germplasm developed in Brazil and Mexico, it is from 22% to 45% of the background. Thus the important founding clones of the high-chill Eastern U.S. fresh market peaches have contributed significantly to the development of low-chill germplasm, although to a lesser extent than seen in the higher chill germplasm (26).

General conclusions on peach germplasm. The low and medium-chill germplasm appears to be quite diverse. All the programs in the U.S. have founding clones that are integral to the development of high-chill commercial peach cultivars ('J. H. Hale,' 'Elberta,' 'Fay Elberta,' 'July Elberta,' 'Boston,' 'Mayflower,' 'St. John') in their background because these were used as source of fruit quality (26, 27). The low-chill types used were 'Peento' (early Californian programs), 'Okinawa,' and 'Hawaiian.' All three of these are low quality, soft, small fruited, white fleshed peaches from south China. In Brazil, although these and a similar type, 'Suber' (a seedling of Peento), are among the founding clones, six local cultivars also figure prominently as founding clones. Local selections and cultivars are also important among the founding clones for the breeding in Mexico (7 clones). The relationships among these 3 low-chill Chinese peaches and 13 local selections are not well understood. The clones from Latin America were brought over from Spain and Portugal beginning in the 1600s and propagated for many generations via seed. This resulted in a series of geneti-

cally uniform populations adapted to a wide range of environments ranging from tropical to medium to high-chilling highland climates.

Unfortunately there is little research on the variability within and among these populations. Perez et al. (22) studied the morphological and phenological polymorphisms in peach germplasm from Mexico and compared it to peaches from U.S., Brazil, Europe, and South Africa. This analysis clustered the Mexican and other central American criollos into one large group, indicating some cohesiveness but much variability. Other groups were formed by the South African peaches, the evergreen and related peaches, and the Brazilian with the low-chill U.S. cultivars. The high-chilling cultivars from Europe and Pakistan clustered very loosely but apart from the low and medium-chill peaches studied.

Work with isozymes has found few polymorphisms among peaches (1, 7, 8, 17, 36) although polymorphisms have been more common among those clones from China or other countries (18, 36) as compared to the commercially important melting-flesh varieties of the United States. In a study in Spain, the nonmelting types had more polymorphisms than the U.S. fresh market melting type varieties (13, 17).

A study of peach germplasm using RAPDs generally confirms the conclusion arrived with isozyme data, that the peach germplasm from the U.S. is relatively homogeneous as compared to the germplasm collected from China and other parts of Asia (35). This data also indicates that the low and medium-chill germplasm derived from the Florida breeding program is more diverse than the germplasm developed in the higher chill areas, probably due to the more recent incorporation of exotic germplasm ('Okinawa' and 'Hawaiian').

Contributors

Wilson Barbosa, Secao de Fruticultura de Clima Temperado, Caixa Postal 28, 13001-970 Campinas, SP, Brazil (wbarbosa@barao.iac.br)

Thomas Beckman, USDA-ARS, PO Box 87, Byron, GA 31008, USA (tbeckman@byronresearch.net)

David H. Byrne, Department of Horticultural Sciences, Texas A&M University, College Station, TX 77843-2133, USA (d-byrne@tamu.edu)

Mario Ojima, Head, Secao de Fruticultura de Clima Temperado, Caixa Postal 28, 13001-970 Campinas, SP, Brazil (pommer@cec.iac.br)

W. R. Okie, USDA-ARS, SE Fruit and Tree Nut Research Lab, 111 Dunbar Rd. Byron, GA 31008, USA (a0dokie@attmail.com)

Salvador Perez, Prol. Zaragoza 408, Jardines de la Hacienda, Queretaro, Qro, 76180, Mexico (sperezg@sunserver.uaq.mx)

David Ramming, USDA-ARS, Horticulture Crops Research Laboratory, 2021 South Peach Ave., Fresno, CA 93727, USA (dramm@qnis.net)

Maria do C. Bassols Rasiera, CPACT-EMBRAPA, Caixa Postal 403, 96001-970 Pelotas, RS, Brazil (bassols@cpact.embrapa.br)

Jorge Rodriguez, Centro de Fruticultura, Colegio de Postgraduados, Chapingo, 56230, Mexico (joroal@colpos.colpos.mx)

Wayne Sherman, Horticultural Sciences Department, University of Florida, Gainesville, FL 32611 USA (wbs@gnv.ifas.ufl.edu)

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