Young-tree Performance of Juvenile Sweet Orange Scions on Swingle Citrumelo Rootstock

William S. Castle¹ and James C. Baldwin

University of Florida, IFAS, Horticultural Sciences Department, Citrus Research and Education Center, 700 Experiment Station Road, Lake Alfred, FL 33850

Additional index words. blood orange, *Citrus sinensis*, Cleopatra mandarin, interstock, Palestine sweet lime, 'Pera' orange, rough lemon, seedling propagation, 'Valencia' orange, vegetative incompatibility, Volkamer lemon

Abstract. A worldwide search was conducted for sweet orange [*Citrus sinensis* (L.) Osb.] selections with higher yield and better juice quality than existing commercial cultivars used in Florida primarily by the processing industry. Seeds of nearly 100 selections were introduced, germinated, and used as a source of buds for propagation. The scion selections were divided among six trials established by propagating juvenile buds from ≈12-month-old scion seedlings onto Swingle citrumelo [*C. paradisi* Macf. × *Poncirus trifoliata* (L.) Raf.] rootstock plants already in place in the field. Comparison trees using buds from mature sources were produced in a commercial nursery. The trials consisted of four to five replications of one- or two-tree plots with trees planted 4.3 × 6.7 m within and between rows, respectively. The scions were early-maturing (fall to early winter), midseason (winter to early spring), and late-season (early spring to early summer) common orange, blood orange, and 'Pera' orange selections. Data collected routinely included seed counts, standard measurements of juice quality, and yield during an ≈13-year period of evaluation. All trees exhibited typical juvenile traits such as vigor and thorniness; however, flowering and first cropping were not substantially delayed. Many selections began fruiting within 3 years after planting, which is the common commercial experience among trees propagated with mature bud sources. Many selections were low-seeded with counts of less than 10/fruit. Mean cumulative yield (8 years) among the early- and midseason selections in the first-planted trial was 1390 kg/tree and ranged to a high of 1751 kg/tree; for the late-season types, the mean was 947 kg/tree with little variability among eight selections. The yields of the early- to late-season selections in the other trials were similar. The blood orange selections proved to be mostly midseason in maturity. They lacked the deep peel and flesh coloration of blood oranges grown in a Mediterranean-type climate, but some selections did develop an enhanced orange color of the juice and the different flavor typical of blood oranges. 'Pera' orange selections exhibited a bud union incompatibility and subsequent decline with Swingle citrumelo rootstock and also when another sweet orange was inserted as an interstock. Their mean cumulative yield over six seasons was 797 kg/tree with an ≈30% difference between the lowest and highest values. Juice soluble solids, acid, and color values were typical of 'Pera' fruit grown in Brazil. The overall collection of sweet oranges displayed considerable diversity in their traits despite their supposed origin as a monophyletic group. Several early-season selections were released for commercialization, including 'Earlygold' and 'Itaborai', because of their better juice color and flavor. 'Vernia', a midseason selection, was released because of its high juice quality in late winter–early spring and its cropping precocity.

Sweet oranges [*Citrus sinensis* (L.) Osb.] are grown in many places throughout the world and are popular as fresh fruit, espe-

cially navel and 'Valencia' oranges (Saunt, 2000). Sweet oranges are also grown for processing primarily in Florida and Brazil. The principal oranges in Florida are 'Hamlin' and various 'Valencia' clones and 'Pera' in Brazil, but other orange cultivars are grown in both places so that once harvesting begins, fruit are available for an uninterrupted harvest season.

Oranges grown in Florida and Brazil must meet certain minimum maturity standards. Processed orange juices produced in Florida or imported for sale in the United States are rated on the basis of U.S. Standards for Grades for color, flavor, and defects using a 100-point scoring system (Fellers, 1990). In that system, 40 points each are assigned to

color and flavor. For a product to be graded A, it must score a minimum of 36 in each category. Therefore, the juice of different orange cultivars is often blended to meet those criteria because the juice of one or more of the individual cultivars may be inadequate to be used on its own.

The Florida citrus processing season begins with a relatively poor-quality orange, 'Hamlin', which is normally harvested in December and January. It is a very productive cultivar, but its juice has relatively poor color and flavor and typically must be combined with 'Valencia' and the juice of other cultivars to meet Grade A standards (Wutscher and Bistline, 1988). 'Valencia' fruit mature late in the season and are usually harvested in March to June. It is the standard cultivar for quality and easily meets the color and flavor criteria and the same is generally true for 'Pera' orange. These three cultivars have been the mainstay of their respective citrus juice industries for many years. However, because growers are compensated for yield and/or juice quality (usually soluble solids content), efforts to find improved selections have continued (Grosser et al., 2009). Moreover, single-strength pasteurized juice (also known as not from concentrate) has emerged as a popular product that has changed the processing industry by placing more emphasis on blending, juice flavor, and color. Therefore, we conducted a worldwide search with the objective of identifying, introducing, and evaluating new sweet orange selections with higher yield and better juice quality than the standard commercial cultivars.

Materials and Methods

Plant material and propagation. Various citrus collections throughout the world and locally were either visited to examine and identify sweet orange selections with promising attributes for the Florida processing industry or someone was contacted with specific requests for seeds. Many of the selections were named cultivars of some level of commercial interest and are described in various publications (Hodgson, 1967; Saunt, 2000). In some instances, fruit samples were collected and the juice extracted and analyzed. Seed counts were noted along with a visible determination of juice color. From that effort, ≈100 sweet orange selections were identified (Table 1). Some selections were introduced as seeds; others were available in Florida and also initiated from seed.

Approximately 100 seeds of each selection were germinated and seedlings grown for 1 year. Sweet oranges generally produce uniform seedling populations. The seeds have multiple embryos of which a high proportion is of nucellar origin (Frost and Soost, 1968). After 1 year, the occasional visible off-type was removed from each population of seedlings. Buds were taken from among ≈50 to 75 seedlings of each selection and used for propagation onto Swingle citrumelo rootstock seedlings being grown at the field site. The rootstock seedlings were either

Received for publication 30 Nov. 2010. Accepted for publication 24 Jan. 2011.

We are very grateful to Orie Lee and his family for their exceptional long-time commitment of land, tree care, and harvesting assistance that made the field trial possible and to Orie Lee for his intellectual contributions to interpreting the results while teaching us the grower perspective. We also extend our gratitude to Florida citrus growers who supported this work through a self-imposed tax for research funds granted by the Florida Citrus Production Research Advisory Council.

¹To whom reprint requests should be addressed; e-mail bcastle@ufl.edu.

Table 1. Expt. 1: Sweet orange scion selections.

Scion selection	Source ^z	Remarks
Early- and midseason (EM.1)		
Akay	Lindcove FS R ₄₃ T _{13, 20}	All trees removed early in trial because of poor cropping and fruit Trees were relatively less vigorous (smaller); fruit were noticeably rounder with thinner, paler peel than the fruit of other selections
Cadena Punchosa	USDA–Orlando	
Catlin	Lindcove FS R ₄₈ T ₁₅	Alternate bearing problem DPI old-line clone Trees propagated with buds from old-line mature trees of this clone Released as ‘Midsweet’ Susceptible to <i>Alternaria</i> stem-end rot (black rot) Leading midseason orange in China; trees were smaller than those of other selections and tended to crop well throughout the canopy; fruit were egg-shaped
Fiwicke	Lindcove FS R ₄₈ T ₅	
Hamlin	SPB 72-14-16	
Hamlin 1-4-1	SPB 1-4-1	
Homosassa	USDA–Orlando	
Jaffa	Lindcove FS R ₄₈ T ₉	
Jincheng	USDA–Orlando	
Joppa	Lindcove FS R ₄₉ T ₈	
Kona	USDA–Orlando R ₇ T ₁₅ (Whitmore)	Blood orange; removed five trees; <i>Phytophthora</i> rot on trunks; excessive vigor and fruit drop Heavy fruit drop before harvest Released as ‘Sunstar’ Blood orange
Mediterranean Blood	USDA–Orlando	
Mediterranean Sweet	DPI Arboretum R ₁₆ T ₁₃	All trees were removed early in the trial for low yield and very poor fruit quality Early-season commercial Florida selection Local selection; not commercial All trees were removed because of bud union creases and low yield Only one tree declined from bud union crease
Midseason	USDA–Orlando	
Moro	Lindcove FS R ₄₄ T _{1,2}	Trees were removed early because of bud union creasing ‘Perao’ is an old selection of ‘Pera’ that was selected because of greater tristeza tolerance; no bud union creases formed Seed collected from trees in an Orie Lee grove DPI old nucellar line Blood orange; all trees were removed because of low yield; however, fruit quality was excellent with melting flesh; only a few red flecks generally appeared in the fruit Blood orange, but rarely produced red pigment; mostly deeper orange flesh Released as ‘Gardner’
Necked Orange	Lindcove FS R ₄₆ T _{13, 16}	
Parson Brown	DPI Arboretum R ₁₅ T ₁₂	Seeds obtained by Heinz Wutscher; began flowering 1–2 years earlier than other selections
Partin Delicious	Cecil Whaley, St. Cloud	
Pera Sweet	Lindcove FS R ₄₉ T ₂	Commercial Brazilian selection; seeds obtained by Heinz Wutscher
Pera 7	USDA–Orlando R ₇ T ₃₉ (Whitmore)	
Pera 15	Lindcove FS R ₄₉ T ₂	
Perao	Lindcove FS R ₃₀ T _{15,30}	
Pineapple #8	Local selection	
Pineapple	SPB 150-10-3a	
Tarocco	Lindcove FS R ₄₉ T _{18–20}	
Ruby	DPI Arboretum R ₁₅ T ₁₁	
Sanford (Florida) Med. Sweet	USDA–Orlando	
Shamouti Masry (Khalily)	DPI Arboretum R ₁₇ T ₁₀	
Tahiti	Lindcove FS R ₄₉ T ₁₀	
Tobias	Brazil	
Torregrosa	USDA–Orlando R ₉ T ₇₃ (Whitmore)	
Westin	Brazil	
Late-season (V.1)		
Berry Valencia	Lindcove FS R ₄₇ T ₁₆	Deeper orange flesh/juice color DPI old-line nucellar selection; trees propagated with buds from old-line mature trees of this clone DPI old-line clone
Hart Late Valencia	Lindcove FS R ₄₇ T ₁₄	
Olinda Valencia	USDA–Orlando 9-8-58	
Rohde Red Valencia	DPI Arboretum R ₁₈ T ₁₃	
Valencia 1-14-31	SPB 1-14-31	
Valencia	SPB 10-12-7	
Valencia	USDA–Orlando 9-8-17	

^aLindcove Field Station (FS), Univ. California; USDA = U.S. Dept. Agric.–Orlando, FL; SPB = State Plant Board, now Bureau Citrus Budwood Registration, Div. Plant Ind. (DPI), Fla. Dept. Agric.; USDA–Orlando (Whitmore) = USDA Whitmore Foundation Farm, Leesburg, FL; DPI-Arboretum = collection at the Bureau Citrus Budwood Registration office in Winter Haven, FL.

grown in a nursery setting and ≈ 1 year later, the budded plants were moved to their nearby trial locations or the seedlings were started in their trial locations and budded in place. In some instances, extra trees from the first planted trials (EM.1 and V.1; Table 1) were moved after 1 year by tree spade to positions in EM.2 and budded with a new scion selection. In field trials started with trees produced in a commercial nursery, tree age is set at 0 years at planting. For our trees to be considered equivalent, we set tree age 0 as 1 year after budding. Certain common commercial selections were also propagated as standard

nursery trees using mature bud sources for comparison purposes.

Field trials. Our grower-cooperator provided an 8-ha site (lat. 28°15' 11.79'; long. 81°14' 19.30') in St. Cloud, FL, with standard grove microsprinkler irrigation, nutrient (Obreza and Morgan, 2008) (160 kg N/ha/year) and pest management and arranged for harvesting each season. The soil series at the site is mapped as Myakka fine sand, a Spodosol in the family of Aeris Haplaquods. The soil has a surface layer of very dark gray sand ≈ 18 cm thick underlain by 50 cm of light gray sand. Below those horizons is the spodic

horizon, which consists of sand cemented by organic material and is ≈ 12 to 25 cm thick. Site drainage was provided by a perimeter ditch.

Six trials were established with all trees spaced 4.3 $\times$ 6.7 m within and between rows, respectively. The first two trials consisted of selections maturing from early- to midseason (EM.1) to late (V.1), October to June, respectively (Table 1). The same range of selections was included in the third and fourth trials (EM.2; V.2; Table 2). ‘Pera’ selections were evaluated in the fifth trial (P.1) and one ‘Pera’ selection on several rootstocks was tested in

Table 2. Expt. 2 and 'Pera' sweet orange scion selections and experiment assignment.

Expt.	Scion selection	Source ^z	Remarks and field notes
Early- and midseason			
2	Aziza	UCR	
2	Bidwell's Bar	UCR	
2	Budd Blood	DPI	A local selection discovered as a dooryard tree in Florida; tends to produce anthocyanin color moderately but reliably
2	Cadena Punchosa	UCR	
2	Cadenera	UCR	
2	Capuchin	UCR	
2	Hamlin-1-4-1	USDA, Orlando	Trial trees grown from buds of a mature source
2	Hinckley	UCR	
2	Indian River	UCR	
2	Itaborai	Limeira	
2	Joao Nunes	Limeira	
2	Koethen	UCR	
2	Lima	Brazil	Acidless; seed arranged by Orie Lee ^y
2	Macetera	Lindcove FS	
2	Madam Vinous	Lindcove FS	
2	Mangaratiba	Limeira	
2	Marrs	Texas	Seeds provided by Dr. R.E. Rouse
2	Moro	Concordia	INTA Research Center, Argentina
2	Moro	USDA, Orlando	Seeds for USDA tree obtained from Indio, CA; trial trees grown using buds from a mature source
2	Natal	Limeira	Late-maturing
2	Olivelands	UCR	
2	Orange de Nice	UCR	
2	Orlando Blood	Orlando, FL, area	Seed collected by Orie Lee from backyard tree
2	Precoce de Valence	UCR	
2	Roble	DPI	Encountered problems with bud union creasing and tree decline
2	Rotuma Island	UCR	
2	Ruby (nucellar)	Limeira	
2	Ruby	UCR	
2	Salustiana	UCR	Spanish variety; early, seedless; very similar to Cadenera
2	Sanguine Grosse Ronde	UCR	
2	Sanguinea	Limeira	
2	Sanguinea de Mombuca	Brazil	Seed arranged by Orie Lee; blood orange
2	Sanguinello	UCR	Blood orange of Sicily
2	Sanguinello Riccio	Sicily	Blood orange; seed collected by Castle from fruit obtained in a commercial grove (Sicily)
2	Sanguinello Moscato	Sicily	Light-blood orange; seed obtained by Castle from a commercial grove in Sicily
2	Tarocco	Limeira	Blood orange
2	Trovita	UCR	Possibly originated as a navel orange seedling in California
2	Tomango	Limeira	Light (poorly colored)-blood orange; South African in origin
2	Vainiglia	UCR	Pink fleshed, acidless orange; lycopene pigment
2	Williams, 'X'	Davenport, FL	Midseason orange; trees growing in the yard of Charles Williams; DPI has some records; seedling tree
2	Williams Budded	Davenport, FL	Fruit collected from a budded tree in Williams' yard
2	Wetumpka	UCR	
2	#8	Limeira	Collected at experiment station but lost identity; possibly 'Seleta Vermelha'; released in Florida as 'Earlygold'
Pera selections			
P1	Pera, Acidless	Limeira	
P1	Pera, Bianchi 25	Sete Lagoas, Brazil	Collected from a private farm
P1	Pera, Bianchi 26	Sete Lagoas, Brazil	Collected from a private farm
P1; P2	Pera, Olympia	Limeira	
P1	Pera, Preimunizada	Limeira	
P1	Pera, Indiantown	Coca Cola, Indiantown, FL	Coca-Cola Company maintained a private collection from which this selection was obtained
P1	Pera, Rio	Limeira	
P1	Pera, Vacinada	Brazil	Seed arranged by Orie Lee
Late-season			
V2	Valencia, Folia Murcha	Limeira	Commercial plants in Brazil have a wilted-leaf appearance, but there is a question whether that trait is transmitted by seed
V2	Valencia, Frost	UCR	California nucellar seedling
V2	Valencia, Cutter	UCR	California nucellar seedling; very vigorous and slow to bear
V2	Valencia, Appleby	Australia	SunRaysia Hort. Res. Inst., Irymple
V2	Valencia, Casey	Australia	SunRaysia Hort. Res. Inst., Irymple
V2	Valencia, Jenner	Australia	SunRaysia Hort. Res. Inst., Irymple
V2	Valencia, Smith	Australia	SunRaysia Hort. Res. Inst., Irymple
V2	Valencia, Vernia	Coca-Cola, Indiantown	
V2	Valencia 1-14-31	DPI	Hughes nucellar. Buds taken from R ₅₄ T _{37, 38} of EM.1 trial
V2	Valencia, Bet Gourine	Israel	Local selection obtained from Volcani Center

^zUCR = collection at the Univ. California, Riverside; DPI = Bureau Citrus Budwood Registration, Div. Plant Ind., Fla. Dept. Agric., Winter Haven; Limeira = Citrus Research Center, Limeira, Brazil; LFS = Lindcove Field Station, Lindcove, CA; USDA = U.S. Dept. Agric.

^yGrower-cooperator.

the sixth trial (P.2). ‘Pera’ orange is a cultivar known to be incompatible with trifoliate orange and its hybrids (Table 2) (Salibe, 1963). A crease forms at the bud union; thus, in P.1, each two-tree plot had one tree propagated directly on Swingle citrumelo rootstock and the second tree was propagated on Swingle citrumelo also but with an interstock of another sweet orange selection, usually ‘Hamlin’. ‘Pera Olympia’ (P.2) was the only scion on four rootstocks: rough lemon (*C. jambhiri* Lush.), Palestine sweet line (*C. limettoides* Tan.), Cleopatra mandarin (*C. reshni* Hort. ex Tan.), and Volkamer lemon (*C. volkameriana* Tan. & Pasq.) (Table 2). All trials consisted of four or five replicates of one- or two-tree plots in a randomized complete-block design. The P.2 trees were planted on the ends of rows in single-tree plots.

Data collection and analysis. Tree height was measured periodically. Annual samples of 50 to 60 fruit for standard juice quality assessments were collected usually from three plots near the time of harvest. Juice was extracted and analyzed with commercial equipment at the Citrus Research and Education Center, Lake Alfred, FL. Juice color was measured in subsamples of extracted juice (Fellers et al., 1990). The color measurement is known as the color number. The number is allowed to be rounded off to generate the color score used in business. Fruit yield was measured annually during commercial harvest by placing fruit in tubs holding 400 kg and recording volume. Seeds were counted in samples of five fruit/tree in two separate seasons. Annual field notes were taken in the early and midyears of the trials to record observations of off-type trees, consistency among trees, fruit drop, peel and juice color, flavor, and any otherwise noteworthy traits. Data analyses were conducted according to the experiment design using analysis of variance with mean separation by the least significant difference test (PROC GLM; SAS Institute, Cary, NC). Some variables were compared by simple linear correlation analysis.

Results and Discussion

General tree performance. Virtually all trees grew to a height of ≈ 4 to 5 m within 6 to 7 years and were largely upright in growth habit with vigorous thorny branches typical of juvenile trees. Sweet orange trees propagated with buds from mature sources normally begin commercial cropping in Florida 3 years after planting. In our trials, cropping was delayed only 1 year in some selections, but most selections produced enough fruit to record yield in the third year and were producing commercial quantities of fruit in the fourth season after planting (Tables 3, 5, 7, 9, and 12). Cropping initially occurred in the upper portions of the canopy at the ends of vigorous, upright shoots. That cropping pattern confirms earlier observations that the least juvenile (first fruiting) part of a canopy is at the perimeter and upper extremities (Furr et al., 1947). Heavy cropping at the ends of branches among some selections led to bro-

Table 3. Mean yield (kg/tree; n = 5) of EM.1 early- and midseason sweet orange selections on Swingle citrumelo rootstock, St. Cloud, FL.^z

Scion	Tree age (yrs)								Cumulative yield
	3	4	5	6	7	8	9	10	
Midseason (Sunstar) ^y	113	127	237	216	270	335	123	330	1751
Mediterranean Sweet	54	154	245	182	276	290	183	301	1685
Joppa	108	136	267	194	246	261	124	331	1666
Homosassa (Midsweet) ^y	112	130	227	211	271	278	137	297	1663
Parson Brown	59	170	265	188	233	280	128	292	1615
Tobias ^x	38	115	231	185	265	293	202	286	1615
Hamlin	57	154	249	189	231	268	160	287	1594
Pineapple	44	125	178	196	158	245	101	525	1572
Ruby	63	152	189	211	168	295	99	332	1509
Partin Delicious	69	126	212	190	207	248	128	305	1487
Tahiti	86	135	223	136	256	217	176	252	1481
Fiwicke	112	124	250	125	259	155	177	195	1396
Kona	71	123	169	138	244	198	150	234	1327
Pineapple #8	71	99	171	181	211	259	109	220	1321
Perao	114	64	257	130	221	171	123	215	1296
Jaffa	87	109	171	158	185	225	118	219	1273
Cadena Punchosa	56	139	167	171	137	250	55	296	1270
Westin ^w	25	99	157	173	177	246	97	226	1201
Hamlin 1-4-1 ^v	61	85	157	120	203	183	205	180	1194
Sanford (Gardner) ^y	42	92	127	171	123	249	127	252	1183
Jincheng ^w	17	107	163	97	227	167	198	207	1183
Torregrosa	56	101	153	147	160	195	100	245	1156
Pera 7	48	63	194	156	173	166	112	242	1154
Mediterranean Blood	81	97	167	118	165	166	123	212	1129
Shamouti Masry	47	91	117	68	205	191	108	200	1027
Mean	67	115	198	162	211	234	135	257	1390
Least significant difference	30	36	51	47	68	59	61	80	

^zTrees budded in place in June 1986 at 4.3 × 6.7 m (348 trees/ha).

^yA seedling selection of the cultivar was later released under the name in parentheses.

^xStandard nursery trees planted in Mar. 1988.

^wTrees are 1 year younger.

^vTrees were propagated using buds from a mature source.

ken limbs as the trees aged. The damage was substantial in some cases and probably affected the yield data. Fruit also had juvenile characteristics, including an initial tendency to large sizes, puffiness, and thicker peel in some selections. After the trees had cropped for a few seasons, most fruit began to look more like fruit typical of trees grown from mature buds. Juice content and quality of the first crops were generally commercially acceptable.

Tree survival was essentially 100% with a few exceptions explained in the discussion of each trial. However, it was apparent after examining the trees over several seasons that there were some off-type trees based on their appearance. The typical tree judged to be an off-type was noticeably shorter with odd fruit, leaves, and shoots by comparison with the other trees of the same selection. The percentage of off-types varied from zero to $\approx 10\%$ among selections. The off-type trees were apparent within ≈ 3 to 5 years after planting and were removed to make way for new selections. The remaining trees within a selection were uniform in appearance and performance. In some instances, it was apparent within a few years that some selections were excessively vigorous, unproductive, or produced undesirable fruit and were removed from the trial.

EM.1: Early- and midseason selections. By the third season after “planting,” selections of a similar age were bearing a crop ranging from 44 (‘Pineapple’) to greater than 110 kg/tree (‘Fiwicke’, ‘Homosassa’, ‘Mid-

season’, and ‘Perao’) (Table 3). The ‘Jincheng’ trees had the lowest yield because they were planted 1 year later; however, their yield in the fourth year was comparable to or exceeded that of most of the other selections. During the eight seasons of measurement, mean yield/tree increased from 67 to 257 kg/tree with five selections yielding greater than 300 kg/tree in the eighth season and one selection, ‘Pineapple’, producing 525 kg/tree. Alternate bearing was evident after the third bearing year, but the degree appeared to be no more severe than that experienced among commercial Florida citrus groves (Fla. Agric. Stat. Serv., 2010). There were a few exceptions, primarily midseason-maturing seedy types like ‘Pineapple’, a cultivar well known for severe alternate bearing (Davies and Jackson, 2009). Cumulative yield ranged from 1751 kg for the ‘Midseason’ (‘Sunstar’) trees to 1027 kg for the ‘Masry’ trees, a 70% difference.

The mean seed count over two seasons was 10/fruit (Table 4). The seediest selections were ‘Sanford’ (21 seeds) and ‘Kona’ and ‘Pineapple #8’ (19 seeds). ‘Ackay’, ‘Moro’, ‘Pera 15’, and ‘Tarocco’ were virtually seedless with less than three seeds/fruit (data not shown). Those four selections were eventually removed as a result of excessive vigor, lack of productivity, or undesirable fruit. The ‘Pera 15’ trees were removed because of tree decline resulting from the bud union incompatibility well known to occur between selections of this sweet orange and trifoliate orange and its hybrids (Carlos and

Table 4. Mean seed number/fruit (n = 5) determined when the trees were 4 and 8 years old and juice quality (n = 3) of fruit harvested in late November to early December from EM.1 early- and midseason sweet orange selections budded in place on Swingle citrumelo rootstock in June 1986 at St. Cloud, FL.

Scion ^z	Season of maturity ^y	Seed count/fruit	Juice quality						
			Tree age (years)	Juice content (%)	Soluble solids concn (%)	Acid (%)	SS/A ratio	Juice color no.	Soluble solids (kg·ha ⁻¹)
Homosassa (Midsweet) ^x	M	11	5	58.2	12.0	0.84	14.3	34.7	5151
			8	61.0	10.4	1.07	9.7	32.3	6631
Midseason (Sunstar) ^x	M	13	5	58.4	11.7	0.87	13.5	34.5	5348
			8	62.1	10.0	1.11	9.1	32.3	6502
Ruby	M	12	5	56.7	11.3	0.74	15.4	36.4	4321
			8	63.7	10.2	0.99	10.5	33.2	6343
Tobias ^w	E-M	6	5	60.6	11.6	0.70	16.6	34.7	5592
			8	62.6	9.6	0.97	9.9	33.8	6195
Mediterranean Sweet	E-M	3	5	57.6	11.2	0.60	19.0	34.7	5835
			8	56.6	10.7	0.79	13.5	31.5	6092
Sanford (Gardner) ^x	M	21	5	58.8	11.4	0.74	15.3	35.7	2382
			8	60.9	10.2	1.10	9.3	32.9	6014
Pineapple	M	18	5	57.9	11.6	0.78	15.0	36.0	3977
			8	62.3	10.3	1.10	9.4	33.8	5984
Parson Brown	E	11	5	55.5	10.7	0.40	27.2	35.5	5532
			8	61.2	6.8	0.58	16.9	33.0	5883
Joppa	E-M	10	5	57.6	12.0	0.73	16.6	34.7	6816
			8	58.9	10.6	0.97	11.0	31.9	5688
Pineapple #8	M	19	5	59.2	11.8	0.85	13.9	35.2	4340
			8	62.1	9.8	1.12	8.8	33.1	5596
Partin Delicious	E	8	5	60.8	11.2	0.48	23.3	36.2	4845
			8	63.2	9.9	0.79	13.0	33.7	5586
Cadena Punchosa	E	13	5	58.0	12.4	0.74	16.8	34.4	4638
			8	57.9	10.7	0.92	11.7	32.2	5312
Westin ^v	E-M	3	5	58.5	12.1	0.53	23.0	35.8	3714
			8	61.2	10.5	0.70	15.1	33.0	5216
Jaffa	M	18	5	60.0	11.5	0.75	15.5	35.5	3855
			8	62.5	9.9	0.97	10.2	32.7	5164
Torregrosa	M	16	5	60.3	12.4	0.87	14.4	34.9	3712
			8	62.2	10.7	1.06	10.1	32.9	5087
Kona	E-M	19	5	58.9	12.3	0.73	16.9	35.0	4449
			8	62.4	10.4	0.88	12.0	32.9	4788
Tahiti	E	16	5	58.7	11.1	0.62	17.8	35.7	4554
			8	61.0	10.0	0.78	12.8	33.4	4737
Hamlin	E	4	5	56.3	11.3	0.53	21.2	34.8	5371
			8	54.9	10.1	0.73	13.9	31.4	4652
Shamouti Masry	M	8	5	61.4	11.9	0.86	13.7	35.3	3206
			8	64.4	10.2	1.07	9.5	32.6	4439
Perao	M	4	5	60.8	11.4	0.75	15.3	36.4	6248
			8	57.4	12.0	0.67	17.8	38.0	4242
Pera 7	M	7	5	62.1	10.9	0.74	14.8	36.7	4824
			8	60.6	11.7	0.73	16.4	36.9	3788
Hamlin 1-4-1 ^u	E	3	5	59.7	10.9	0.69	15.9	35.5	3667
			8	58.9	10.0	0.71	14.2	32.4	3700
Jincheng ^v	M	4	5	62.9	12.1	0.75	16.1	35.1	4540
			8	55.2	10.5	0.89	11.7	33.1	3237
Fiwicke	E-M	18	5	50.8	12.1	0.71	17.1	36.4	5103
			8	58.7	10.5	0.94	11.2	32.7	3073
Mediterranean Blood	M	8	5	60.7	11.6	0.66	17.8	34.6	4163
			8	59.5	9.9	0.80	11.8	33.7	3063
Mean			5	58.9	11.6	0.70	17.1	35.4	4645
Least significant difference			5	4.7	0.9	0.09	1.9	1.0	1711
Mean			8	60.5	10.2	0.90	12.0	33.2	5108
Least significant difference			8	3.8	1.7	0.13	2.0	0.7	1689

^zSorted according to soluble solids, kg·ha⁻¹, tree age 8 years.

^yPreviously established season of maturity based on commercial experience in Florida and/or elsewhere: E = early; M = mid.

^xA seedling selection of the cultivar was later released under the name in parentheses.

^wStandard nursery trees planted in Mar. 1988.

^vTrees are 1 year younger.

^uTrees were propagated using buds from a mature source.

SS/A = soluble solids/acid ratio.

Donadio, 1996; Salibe, 1963). The 'Pera 7' trees also declined later. The 'Perao' trees did not exhibit any decline although they are a supposed selection of 'Pera'.

Juice quality was assessed when the trees were 5 and 8 years old. The mean values were not markedly different between those years; however, they are not strictly comparable

because of different fruit sampling dates. Mean juice quantity across both years was typical for Florida-grown fruit and ranged from ≈55% to 62% by weight (Table 4). The soluble solids concentration ranged from less than 10% to a few values greater than 12% and acid concentration ranged from ≈0.5% to a few values greater than 1.0%. The soluble

solids:acid ratios reflect fruit maturity with the larger numbers indicating the most mature selections on a particular date. Mean ratio was 17.1 and 12.0 when the trees were 5 and 8 years old, respectively. Those values would ordinarily be considered typical of young versus older trees, but in this instance, the later sampling date (December versus

November, respectively) for the younger trees was responsible for the difference.

Juice color is an especially important attribute of early-season oranges. Their color is often below the minimum score of 36 required to make Grade A juice (Fellers, 1990). As a result, their juices must be blended with the juices of other selections with better color such as 'Valencia'. Juice color is not usually a concern with most midseason-maturing oranges. Their juice will achieve a color number greater than 36 by the time of harvest and likewise for 'Valencia' orange juices, which are usually 37 or greater. In this trial, only one of the six early-maturing oranges, 'Partin Delicious', had a juice color number greater than 36. The standard early-maturing orange, 'Hamlin', had color numbers below 36. Among the midseason selections, only 'Perao' and 'Pera 7' had a color number above 36 in both seasons (Table 4). However, the color numbers for the other midseason oranges may be misleading because those selections would normally be harvested later in the season and the numbers would then be above 36.

For Florida growers of oranges for processing, the quantity of soluble solids produced/ha (a combination of juice volume, soluble solids concentration, and tree yield) is the basis of a crop's monetary value. Today, $\approx 3000 \text{ kg}\cdot\text{ha}^{-1}$ is considered to be necessary for a profitable grove operation. That number was exceeded by most of the selections regardless of season of maturity. The 'Hamlin 1-4-1' trees propagated with mature buds had one of the lowest soluble solids production levels, $\approx 3700 \text{ kg}\cdot\text{ha}^{-1}$ (Table 4). Trees of 'Hamlin' propagated using juvenile buds produced 4652 and 5371 $\text{kg}\cdot\text{ha}^{-1}$ when they were 5 and 8 years old, respectively, or $\approx 30\%$ more soluble solids than the trees propagated with mature buds. That difference was not statistically significant, but it could be explained by the difference in canopy volume because the latter trees grew more vigorously and were clearly taller by the time the trial was 8 years old. Among the midseason oranges, 'Pineapple' is the commercial standard, but we did not include trees propagated with mature buds for comparison. There were a few selections such as 'Homosassa' ('Midsweet', presently a moderately important commercial cultivar) that produced larger amounts of soluble solids as 8-year-old trees than 'Pineapple', but the differences were generally less than 10% and not statistically significant.

V.1: Late-season selections. There were significant differences in fruit yield among selections in individual years with the highest cumulative yields being those of '10-12-7' and '9-8-17' (Table 5). Both of those selections are among the most popular and productive selections used commercially in Florida. Yield at first cropping was 20 kg/tree and increased to nearly 200 kg/tree (Table 5). Seed counts were not made of these selections because they are all 'Valencia' oranges, which usually contain only a few seeds. Juice content was $\approx 60\%$ by weight with no differences among selections (Table 6). Mean soluble solids concentrations were mostly between

Table 5. Mean yield (kg/tree; $n = 5$) of V.1 'Valencia' sweet orange selections budded in place on Swingle citrumelo rootstock in June 1986 at St. Cloud, FL.

Scion	Tree age (yrs)							Cumulative yield
	3	4	5	6	7	8	9	
10-12-7	17	96	143	111	176	197	115	221
9-8-17	12	82	137	112	175	194	112	230
Catlin	34	77	116	74	163	184	145	208
Berry	24	86	110	111	154	189	87	164
Rohde Red	13	82	108	103	144	166	97	196
Hart	6	70	102	91	160	172	101	201
Olinda	10	67	120	101	155	156	89	193
1-14-31 ²	45	67	104	82	146	118	107	152
Mean	20	78	118	98	159	172	107	196
Least significant difference	11	30	28	30	31	31	30	46

²Trees propagated with buds from a mature source.

Table 6. Mean juice quality ($n = 3$) of fruit harvested in early April (age 5 years) or early March (age 8 years) from V.1 late-season sweet orange selections budded in place on Swingle citrumelo rootstock in June 1986 at St. Cloud, FL.

Scion ²	Tree age (yrs)	Juice content (%)	Soluble solids concn (%)	Acid (%)	SS/A ratio	Soluble solids (kg·ha ⁻¹)	Juice color number
10-12-7	5	61.2	12.8	0.74	17.4	3543	38.8
	8	61.2	12.3	0.98	12.7	5204	37.2
Hart	5	59.4	13.0	0.81	16.0	2291	38.9
	8	60.8	12.7	1.05	12.2	4919	36.6
9-8-17	5	61.1	13.1	0.80	16.5	3698	39.1
	8	60.7	11.9	1.00	12.0	4815	36.3
Berry	5	61.9	12.5	0.70	17.7	2910	38.1
	8	60.7	12.3	1.05	11.8	4691	36.7
Rohde Red	5	62.5	12.8	0.79	16.2	2952	40.3
	8	61.1	12.3	1.04	11.9	4690	38.1
Catlin	5	58.3	12.1	0.70	17.2	2742	39.0
	8	62.9	11.5	0.95	12.1	4251	37.3
Olinda	5	60.5	12.7	0.75	17.0	3193	38.9
	8	60.8	12.3	0.93	13.4	4057	36.2
1-14-31 ²	5	58.5	12.7	0.88	14.4	2249	38.6
	8	62.6	12.3	1.04	11.9	3051	37.2
Mean	5	60.5	12.7	0.77	16.6	2978	39.0
Least significant difference	5	2.8	0.5	0.08	1.4	1379	0.5
Mean	8	61.3	12.2	1.01	12.2	4460	37.0
Least significant difference	8	3.8	0.5	0.16	1.7	1078	0.5

²Sorted according to soluble solids, $\text{kg}\cdot\text{ha}^{-1}$, tree age 8 years.

²Trees propagated with buds from a mature tree and planted in Feb. 1987.

SS/A = soluble solids/acid ratio.

12% and 13% and acid concentrations varied among the selections from less than 0.80 to greater than 1.00%. There were no differences in fruit maturity within either harvest season as indicated by the solids:acid ratios. Juice color numbers were mostly 37 to 40 and typical for Florida-grown 'Valencia' oranges. At tree age 8 years, soluble solids production ranged from 5204 $\text{kg}\cdot\text{ha}^{-1}$ to 3051 $\text{kg}\cdot\text{ha}^{-1}$. The production of all selections except 'Olinda' was significantly higher than that of the '1-14-31' trees, which were propagated using mature buds and included for comparison. The latter trees were smaller and, thus, less productive.

EM.2: Early- and midseason common and blood orange selections. To interpret the yield and juice quality data, note that tree ages are different among selections. Measurements were taken from the 1992–1993 through the 1997–1998 seasons when the majority of the trees were between the ages of 3 and 8 years, respectively. The yields of those selections budded 1 year later were measured over the same

seasons, so, e.g., the yield of 'Sanguinello Riccio' shown in Table 7 for tree age 3 years is actually for tree age 2 years, a difference considered in the discussion.

No selections were eliminated from this trial except 'Roble', which suffered decline from bud union creasing (Garnsey et al., 2001). The 'Roble' trees remained reasonably healthy during the evaluation period and declined afterward. The mean yield of the 41 selections increased from 78 kg/tree at age 3 years to 186 kg/tree after six cropping seasons, but there were few significant differences among selections in individual years (Table 7). Cumulative yield ranged from 1003 kg/tree ('Aziza') to less than 700 kg/trees among several blood orange selections. Most of the less productive selections were 1 year younger, but their yields still would be relatively low even if $\approx 100 \text{ kg}$ was added to their cumulative totals to compensate for their younger age.

The cropping of several selections at tree age 3 years was greater than 100 kg/tree.

Table 7. Mean yield (kg/tree; n = 4) of EM.2 early- and midseason sweet orange selections budded in place on Swingle citrumelo rootstock in May 1988.^z

Scion	Tree age (yrs) ^y						Cumulative yield
	3	4	5	6	7	8	
Aziza	139	122	199	200	139	204	1003
Sanguinea de Mombuca	74	125	233	181	154	211	977
Cadena Punchosa	122	123	147	215	112	239	959
Madam Vinous	98	128	157	229	84	231	926
Mangaratiba	88	109	147	208	148	219	920
Sanguine Grosse Ronde	134	96	184	178	132	167	890
Rotuma Island	115	91	183	183	105	211	887
Homosassa	92	111	152	201	128	203	887
Olivelands	112	78	231	178	113	160	872
Koethen	80	88	161	185	80	259	853
Salustiana	62	111	147	242	118	158	839
Sanguinea	97	117	132	208	107	178	839
Earlygold (#8) ^x	107	61	147	209	112	199	836
Hinckley	96	80	154	213	72	217	832
Roble	125	123	61	200	101	214	824
Lima	91	96	132	143	147	204	813
Ruby	89	119	117	216	86	179	807
Precoco de Valence ^w	22	81	158	176	125	244	804
Budd Blood	58	81	164	183	115	199	800
Vainiglia	122	89	76	238	37	237	799
Tomango	84	88	110	213	106	195	797
Marrs	139	104	155	167	106	109	781
Capuchin	83	84	107	199	101	206	780
Bidwell's Bar	55	91	137	202	106	186	777
Sanguinello	80	102	112	211	116	152	774
Macetera	29	58	197	162	130	189	765
Wetumpka	67	70	142	200	89	194	762
Itaborai	95	65	141	160	104	196	761
Cadenera	38	107	170	188	88	169	761
Indian River Sweet	61	86	120	190	104	155	716
Moro 18	20	71	194	109	129	184	708
Ruby (nucellar)	94	61	130	163	122	133	704
Joao Nunes	51	64	108	208	114	157	703
Hamlin 1-4-1 ^v	90	94	140	155	172	188	700
Trovita	44	88	127	186	96	140	680
Tarocco	75	93	156	116	86	125	651
Orange de Nice	71	41	70	163	67	199	612
Williams 'x' ^w	4	26	98	138	162	181	608
Orlando Blood ^w	No data	65	127	157	63	186	598
Sanguinello Riccio ^w	8	37	111	130	121	163	570
Sanguinello Moscato ^w	11	18	84	111	111	119	455
Mean ^u	78	87	142	183	110	186	781
Least significant difference	41	38	68	47	51	71	

^xYield measurement began in the 1992–1993 season when the trees were 3 years old.

^yNursery trees normally are moved to the field within 1 year after budding. Tree age is conventionally set as 0 at transplanting. Because our trees were budded in place, tree age was set at 0 during the 1989–1990 season to make our trees essentially equivalent to trees produced in a normal nursery.

^zTrees budded in place Oct. 1988.

^wTrees are 1 year younger. Yield was first recorded when these trees were 2 years old.

^vTrees propagated with buds from a mature tree and planted in Mar. 1989. Trees are 1 year younger.

^uExperiment means and data analyses do not include 'Lima' or 'Vainiglia' because these were acidless selections of little interest for producing orange juice.

Especially notable were the 'Aziza', 'Sanguine Grosse Ronde', 'Roble', and 'Marrs' trees, which all produced greater than 125 kg/tree, yield values well above normal for commercial trees in Florida. Those selections cropped substantially more than the comparison selection 'Hamlin 1-4-1', (700 kg/tree), which was propagated using mature buds. The productivity of the highest yielding selections can generally be explained by one or both of two factors: precocity and a resulting propensity to heavy early bearing, e.g., 'Aziza' and 'Marrs', or above average tree vigor/canopy volume (data not given), e.g., 'Sanguine Grosse Ronde' and 'Roble', or a combination of those factors, e.g., 'Olivelands' and 'Rotuma Island'. The trees of selections like 'Aziza' and 'Marrs' exhibited juvenile

traits, but less so than many of the other selections. Shoots of 'Aziza' and 'Marrs' were less thorny and vigorous and the trees seemed to require fewer shoot flushes before their shoots took on a less juvenile nature. As a result, flowering began sooner after budding leading to heavier, early cropping that also tended to reduce tree canopy growth.

Mean fruit seed count was nine but varied from virtually seedless ('Salustiana', 'Cadenera', 'Marrs', and 'Moro #18') to 20 or more seeds/fruit, e.g., 'Bidwell's Bar' and 'Indian River Sweet'. Mean fruit juice content was 61.2% by weight, soluble solids concentration was 9.8%, and acid concentration was 0.79%. Most juice content values were greater than 58%, typical for Florida fruit. Soluble solids concentrations are not strictly compa-

table because the trial consisted of early- and midseason-maturing selections all harvested at one time, which was not optimal for all selections. Among those considered to be early-maturing, 'Roble' had the highest soluble solids concentration (11.7%) followed by a group with values $\approx 10\%$, but they were not significantly different from 'Hamlin 1-4-1'. Exceptions to the preceding results were the mid- to late-season selections 'Wetumpka' and 'Bidwell's Bar' that had soluble solids values of 10.0 and 10.1, respectively, on 14 Nov. 1995. Season of maturity classification is largely based on soluble solids:acid ratio. Notable values were those of 'Vainiglia', 'Lima', and 'Mangaratiba'. The former two selections are acidless, which explains their high ratios. 'Mangaratiba' proved to be a selection that matured very early primarily because of low acid concentrations. The range in juice color numbers was small and there were few differences among selections. Most selections had values below the desired color number of 36. The highest values were those of 'Ruby Nucellar'.

For the year presented, the juice data combined with yield resulted in greater than twofold difference in soluble solids/ha among the selections (Table 8). Seventeen of 42 selections produced greater than 4000 kg-ha⁻¹ and two selections, 'Salustiana' and 'Vainiglia', produced greater than 5000 kg-ha⁻¹.

During the trial or soon after data collection was completed, the 'Cadenera', 'Joao Nunes', 'Macetera', 'Ruby', 'Sanguinello Moscato', 'Tarocco', 'Tomango', and 'Trovita' trees were removed at the suggestion of the cooperator because of excessive vigor and poor yields. Other selections such as 'Aziza', 'Budd Blood', 'Earlygold', and 'Itaborai' were further evaluated elsewhere in Florida (Castle and Baldwin, 2008).

V.2: Late-season selections. Mean yield was 31 kg/tree when they began cropping after 2 years in the field and increased to ≈ 160 kg/tree (Table 9). 'Vernia' and the selection for comparison, '1-14-31', were precocious in that they produced well in the first year of cropping but fell behind in subsequent years leading to average cumulative yields after six seasons. Several selections produced cumulative yields greater than 700 kg/tree of which 'Williams Budded' was the largest. Included in that group were 'Appleby', 'Smith', and 'Jenner', selections that had been previously tested in Australia and found to be among the best producers. Fruit samples were collected in April when the trees were 4 and 8 years old. Mean juice content was 62.2% and 56.3%, soluble solids concentration was 11.2% and 12.2%, and acid concentration was 0.79% and 0.65%, respectively (Table 10). Most selections did not differ significantly in these variables and all selections produced commercially acceptable quality juice. The higher soluble solids concentration and soluble solids:acid ratio of the 'Vernia' trees suggested that it matures at the beginning (February) of the Florida late season. 'Natal' is one of the latest maturing orange selections in Brazil and it appeared to perform similarly in our trial (Donadio et al., 1995).

Table 8. Mean seed count and juice quality (n = 4) of EM.2 early- and midseason sweet orange selections budded in place on Swingle citrumelo rootstock in May 1988.^z

Scion	Season of maturity ^y	Seed count	Juice content (%)	Soluble solids concn (%)	Acid (%)	SS/A ratio	Juice color	Soluble solids (kg·ha ⁻¹)
Salustiana	M	<1	63.3	9.6	0.76	12.8	33.6	5150
Vainiglia	E	14	60.4	10.2	0.15	69.1	33.7	5101
Madam Vinous	M	12	63.3	9.7	0.90	10.8	32.5	4885
Roble	E	14	59.0	11.7	0.64	18.2	32.2	4821
Sanguinello	M-b	7	65.1	9.6	0.90	10.6	33.1	4599
Cadena Punchosa	E-M	12	58.7	10.4	0.85	12.3	32.5	4591
Ruby	E-M-b	13	62.8	9.6	0.78	12.3	33.2	4548
Earlygold (#8)*	E	9	60.4	10.0	0.62	16.4	34.1	4438
Sanguinea	M-b	6	63.5	9.6	1.02	9.6	33.0	4433
Tomango	M-b	15	60.4	9.8	0.98	11.0	33.6	4428
Wetumpka	M-L	17	62.6	10.0	1.22	8.2	33.1	4391
Hinckley	M	11	60.8	9.7	0.83	11.7	32.7	4390
Bidwell's Bar	M-L	20	61.4	10.1	1.14	8.9	33.4	4386
Capuchin	M	18	62.2	10.0	1.03	9.7	33.1	4322
Aziza	E	5	60.5	9.9	0.75	13.5	33.9	4187
Homosassa	M-L	8	61.8	9.6	1.10	8.7	32.8	4172
Indian River Sweet	E	21	60.2	10.4	0.76	13.6	34.2	4147
Cadenera	M	1	63.2	9.5	0.92	10.5	33.1	3935
Koethen	M	14	60.7	9.8	0.94	10.5	33.3	3842
Budd Blood	M-b	7	63.2	9.5	0.88	10.9	33.6	3816
Joao Nunes	E	2	56.1	9.3	0.47	20.6	33.5	3797
Sanguine Grosse Ronde	E	21	58.4	9.9	0.78	12.7	33.1	3728
Precoco de Valence ^w	E	11	62.5	9.7	0.73	13.3	33.6	3719
Olivelands	M	14	63.2	9.5	0.94	10.2	33.3	3719
Mangaratiba	E	4	57.2	8.9	0.36	24.9	33.5	3692
Rotuma Island	M	15	60.7	9.5	0.99	9.6	33.0	3682
Orlando Blood ^w	E-b	14	64.0	9.9	0.76	13.1	33.7	3623
Orange de Nice	M	20	64.8	10.1	1.12	9.1	32.9	3601
Marrs	E	0	58.7	10.0	0.58	17.4	34.0	3564
Sanguinea de Mombuca	E-b	11	61.2	9.1	0.50	18.3	34.3	3510
Ruby Nucellar	E-M-b	8	59.3	10.1	0.69	14.9	35.1	3428
Itaborai	E	9	59.2	10.0	0.81	12.5	34.8	3318
Trovita	E	5	56.4	9.0	0.51	17.8	33.4	3301
Hamlin 1-4-1 ^v	E	3	60.4	9.8	0.73	13.6	33.7	3221
Williams 'x' ^w	E	15	63.3	10.2	0.82	12.5	33.0	3110
Macetera	E	2	57.0	9.3	0.66	14.1	32.5	3094
Lima	E	8	59.5	9.9	0.15	69.1	31.3	2937
Tarocco	M-b	2	66.6	10.2	0.94	10.8	33.8	2754
Sanguinello Riccio ^w	E-b	6	63.8	9.3	0.74	12.5	33.6	2689
Sanguinello Moscato ^w	M-b	<1	63.7	9.3	0.97	9.5	33.2	2292
Moro #18	E-b	1	61.6	9.3	0.77	12.3	33.0	2192
Mean		9.0	61.2	9.8	0.79	15.4	33.4	3843
Least significant difference		4.7	2.8	0.5	0.14	5.1	1.0	

^zJuice data were collected for all selections for 6 years total. One representative year was chosen for this table. Fruit sampling began in the 1992–1993 season. The juice data are for samples harvested 14 Nov. 1995 when the trees were 6 years old.

^yDetermined from published information and/or this trial. E = early; M = midseason; L = late; b = blood orange.

*Trees budded in place Oct. 1988.

^wTrees are 1 year younger. Juice data are for trees at age 5 years.

^vTrees propagated with buds from a mature tree and planted Mar. 1989. Trees are 1 year younger.

SS/A = soluble solids/acid ratio.

There were virtually no differences among the selections in juice color. All color numbers were mostly between 38 and 39, typical for Florida late-season oranges. Soluble solids production at age 8 years ranged from 4442 kg·ha⁻¹ ('Williams Budded') to 2055 kg·ha⁻¹ ('Frost'), but there were no differences among the top 11 of 13 selections. Soluble solids production/ha differences were largely explained by yield ($r = 0.72$; $P < 0.01$).

P.1: 'Pera' orange selections. All the P.1 'Pera' selections without an interstock, except 'Pera Acidless', eventually exhibited a bud union crease, declined, and were removed (Table 11). However, by the end of the trial period, an interstock did not ensure longevity because among all the selections, survival varied from 25% to 75%.

As observed in Brazil (Carlos and Donadio, 1996), there were no effects among the trees with and without an interstock on yield and juice quality over the course of 3 years when the trees in each two-tree plot were measured separately; thus, the data were combined within each plot in all years. Also, the 'Pera' trees had a more mature tree (rounder rather than upright) appearance soon after they began cropping with less vigorous shoots, reduced thorniness, and the fruit had smoother, thinner peel than the oranges of the other selections. The trees began to crop well when they were 3 years old, which coincides with the apparent quick loss of juvenility compared with the other sweet oranges in EM.1 and EM.2. Mean yield was 86 kg/tree in the first cropping year and increased to 240 kg/tree

when the trees were 8 years old (Table 12). There were significant differences among selections only when the trees were 6 and 8 years old. More apparent was the alternate bearing, particularly in the last three measured crops when yield varied among 162, 96, and 240 kg/tree, respectively. However, alternate bearing is considered to be related to juvenility and may explain the performance of the 'Pera' selections and those in the other trials (Cameron and Frost, 1968). Mean cumulative yield was nearly 800 kg/tree over six crops with 'Bianchi' selections producing two of the largest cumulative values and some of the largest and smallest annual values.

The fruit were moderately seedy with approximately five to 10/fruit. Samples for juice quality measurements were collected in January, which is midseason when 'Pera' selections are typically harvested in Brazil. Fruit juice content was $\approx 58\%$ (Table 13), which is lower than the values of the early- and late-season selections. Mean soluble solids concentration was ≈ 11.7 with some significant differences in each year. At age 4 years, the fruit from the 'Vacinada' (12.3) and 'Olympia' (12.2) selections had the highest and those from 'Acidless' (11.0) had the lowest soluble solids, a similar situation when the trees were 8 years old. The mean soluble solids:acid ratios were skewed to high values because of the low acid-high ratio values of the 'Acidless' fruit. Juice color numbers were ≈ 37 except for the low values of the 'Acidless' fruit. The numbers were one or two units below many of those for the 'Valencia' selections as is commonly observed for 'Pera' as indicated by juice importers who bring juice from Brazil to Florida. The significantly higher yields of the 'Bianchi 26' and 'Pre-munizada' selections when those trees were 8 years old, combined with average juice quality, resulted in the highest soluble solids/ha.

P.2: 'Pera' orange selections. These 'Pera Olympia' trees were grown in a field nursery and all were set on the ends of the rows where other trials were located. They were less crowded and, thus, by the end of the measurement period, the trees were greater than 6 m tall. Cropping began when the trees were 3 years old and increased to 240 kg/tree by age 8 years (Table 14). The trees on Cleopatra mandarin rootstock produced the lowest yields and those on rough lemon had the largest yield, a significant difference among rootstocks that was first apparent when the trees were 5 years old. Because of their larger size and position at the ends of rows, these trees produced 6% (Cleopatra mandarin) to 35% (rough lemon) more fruit than the 'Pera Olympia' trees in the P.1 trial on Swingle citrumelo rootstock.

Trees on Cleopatra mandarin rootstock are well known to produce fruit with higher juice quality (Castle, 1987; Castle et al., 1993, 2006; Wutscher, 1979) as evident in P.2 (Table 15). Fruit from the trees on Cleopatra mandarin had higher juice quality than that of fruit from trees on the other three rootstocks in this trial. However, as we have reported previously (Castle, 2010; Castle et al., 2010a,

Table 9. Mean yield (kg/tree; n = 4) of V.2 late-season sweet orange selections budded in place on Swingle citrumelo rootstock, May 1988, St. Cloud, FL.

Scion	Tree age (yrs) ^z						Cumulative yield
	2	3	4	5	6	7	
Williams Budded	5	33	208	184	102	200	732
Appleby	43	69	152	169	119	171	725
Smith	38	65	148	167	114	192	725
Jenner	41	53	158	165	140	166	723
Murcha	33	89	135	199	72	185	713
Vernia	87	77	76	182	89	177	686
1-14-31 ^y	82	62	101	158	102	167	673
Natal	48	43	140	144	109	171	656
Bet Gourine	19	48	176	141	134	134	651
Cutter	19	48	142	140	103	175	627
Murdia	7	48	181	150	111	129	626
Frost	5	49	118	153	93	108	527
Casey	31	45	113	114	68	129	500
Mean	37	57	139	158	105	160	659
Least significant difference	35	44	62	40	44	57	

^zNursery trees normally are moved to the field within 1 year after budding. Tree age is conventionally set as 0 at transplanting. Because our trees were budded in place, tree age was set at 0 during the 1989–1990 season to make our trees essentially equivalent to trees produced in a normal nursery.

^yTrees propagated with buds from a mature tree.

Table 10. Mean juice quality (n = 3) of V.2 late-season sweet orange selections budded in place, May 1988, on Swingle citrumelo rootstock, St. Cloud, FL.^z

Scion ^y	Tree age (yrs)	Juice content (%)	Soluble solids concn (%)	Acid (%)	SS/A ratio	Juice color	Soluble solids (kg·ha ⁻¹)
Williams Budded	4	65.4	9.7	1.19	8.2	34.4	730
	8	56.9	11.0	0.65	17.1	38.6	4442
Appleby	4	63.7	12.5	0.83	15.1	38.0	1982
	8	58.8	11.5	0.72	15.9	38.2	4342
Natal	4	60.0	10.3	1.34	7.7	37.9	784
	8	60.0	11.8	0.73	16.2	39.1	4236
Murcha	4	63.3	12.4	0.73	17.0	37.8	2435
	8	57.9	10.4	0.63	16.5	39.5	4094
Smith	4	65.3	12.4	0.81	15.4	38.0	1852
	8	56.2	11.0	0.68	16.2	38.6	4080
Val 1-14-31 ^x	4	65.1	12.3	0.76	16.2	37.4	2260
	8	60.5	11.7	0.80	14.7	38.2	3886
Cutter	4	61.0	12.4	0.76	16.3	38.1	1291
	8	58.6	11.4	0.64	17.8	39.3	3838
Vernia	4	60.4	13.5	0.61	22.3	39.3	2215
	8	58.4	11.7	0.62	18.8	39.2	3693
Jenner	4	63.9	12.4	0.70	17.9	38.2	1464
	8	53.0	11.1	0.58	19.7	39.0	3435
Casey	4	58.7	12.5	0.80	15.8	37.1	1151
	8	51.0	12.4	0.69	18.0	38.2	3134
Bet Gourine	4	62.6	11.9	0.77	15.6	37.7	1245
	8	58.6	11.1	0.70	15.9	38.3	2966
Murdia	4	60.7	12.4	0.73	17.2	37.6	1276
	8	55.7	10.1	0.57	17.8	38.9	2571
Frost	4	59.4	12.1	0.59	22.9	37.6	1209
	8	46.2	10.8	0.45	23.9	39.0	2055
Mean	4	62.2	12.2	0.79	16.5	37.7	1573
Least significant difference		3.4	0.6	0.08	2.9	0.6	1142
Mean	8	56.3	11.2	0.65	17.6	38.8	3576
Least significant difference	8	5.2	0.9	0.08	2.8	1.4	1628

^zFruit samples were collected in Apr. 1994 and 1998 when the trees were 4 and 8 years old, respectively.

^ySelections ranked by their soluble solids/ha at tree age 8 years.

^xTrees propagated with buds from a mature tree.

SS/A = soluble solids/acid ratio.

2010b), yield was the primary factor that determined soluble solids production/ha with the trees on rough lemon having the highest value in Year 8 with a maximum difference of 39% among rootstocks.

Our results have both a research and commercial component. The first issue faced in

this project was the matter of introducing the selections to Florida in a timely manner such that a proper replicated trial could be established quickly, an objective also highly desired by the grower-cooperator. Plant introduction of a clonally propagated tree fruit species is normally by some means other than

Table 11. Tree survival (n = 4) among P.1 'Pera' sweet orange selections budded in place on Swingle citrumelo rootstock, May 1988, St. Cloud, FL.

Scion	Interstock ^z	Tree survival (%)
Acidless	Y	75
	N	100
Bianchi 25	Y	75
	N	0
Bianchi 26	Y	50
	N	0
Indiantown	Y	0
	N	0
Olympia	Y	25
	N	0
Premunizada	Y	75
	N	0
Rio	Y	75
	N	0
Vacinada	Y	25
	N	0

^zIn all cases, the interstock was a sweet orange, but not 'Pera' and not the same interstock selection. Y = yes; N = no.

seed. Seeds could be of questionable usefulness. Many, but not all, citrus species produce apomictic seeds and the degree of polyembryony varies. Also, seedlings have different lengths of juvenility. Therefore, from a research standpoint, it is noteworthy that our sweet orange selections produced visually uniform seedling populations. Their use in the young seedling stage as a source of buds for propagation did not seriously lengthen the time to bearing compared with trees produced using buds from mature trees. Furthermore, our project trees fruited earlier than if our trial consisted of seedlings only. Sweet oranges are reported to have juvenile periods as long as 15 years, but that is not well documented (Cameron and Frost, 1968).

In our trials, we did not compare seedlings with budded trees within selections, but the comparison was made in EM.1 between 'Hamlin' trees propagated using either juvenile (young-line) buds or a mature (old-line) source. In that comparison, the young-line trees were more vigorous and productive. We did not have the same result among the V.1 selections.

If clonal senescence occurs as proposed by some authors (Cameron and Frost, 1968), then our results support the contention that sweet orange cultivars be periodically restored to a more juvenile, i.e., vigorous and fruitful, condition by occasional regeneration through some means such as seeds or possibly tissue culture (W.P. Bitters, personal communication). Clonal restoration through seed may also add a measure of cold-hardiness because juvenile trees, especially seedlings, have greater tolerance to cold weather than trees grown from old-line tree bud sources (Yelenosky, 1985).

The performance and phenotypic variability among the selections in the field trials illustrate the diversity among sweet oranges and suggests genetic variability. However, citrus systematics is complicated by apomixis and hybridization. Furthermore, *C. sinensis* is not considered to be a true species. Evidence

Table 12. Mean yield (kg/tree; n = 4) P.1 'Pera' sweet orange selections budded in place on Swingle citrumelo rootstock, May 1988, at St. Cloud, FL.^z

Scion	Tree age (yrs) ^y						Cumulative yield
	3	4	5	6	7	8	
Bianchi 26	74	113	82	255	61	327	912
Premunizada	102	112	102	225	61	286	887
Bianchi 25	60	106	94	181	102	323	867
Rio	78	94	79	133	107	276	767
Vacinada	92	100	99	167	104	194	755
Olympia	114	122	84	110	101	176	706
Acidless	75	80	82	110	117	224	688
Mean	86	104	89	162	96	240	797
Least significant difference	50	58	63	92	56	93	

^zPlot size was two trees, one with and one without a sweet orange interstock. The interstock had little effect on yield and juice quality; thus, no distinction was made in data collection or analysis between the two trees in each plot.

^yNursery trees normally are moved to the field within 1 year after budding. Tree age is conventionally set as 0 at transplanting. Because our trees were budded in place, tree age was set at 0 during the 1989–1990 season to make our trees essentially equivalent to trees produced in a normal nursery.

Table 13. Mean juice quality (n = 3) of P.1 'Pera' sweet orange selections budded in place on Swingle citrumelo rootstock, May 1988, St. Cloud, FL.^{zy}

Scion ^x	Tree age (yrs) ^w	Juice content (%)	Soluble solids concn (%)	Acid (%)	SS/A ratio	Color number	Soluble solids (kg·ha ⁻¹)
Bianchi 26	4	56.9	11.8	0.75	15.8	37.6	2028
	8	58.8	11.1	0.61	18.4	37.5	7500
Premunizada	4	60.6	12.0	0.89	13.6	37.7	2311
	8	61.0	11.5	0.69	16.8	37.3	7014
Rio	4	55.1	11.9	0.77	15.5	37.9	2025
	8	58.1	11.7	0.61	19.2	37.2	6496
Bianchi 25	4	57.0	12.0	0.77	15.9	37.4	2267
	8	59.5	11.5	2.66	18.4	36.7	5612
Acidless	4	53.8	11.0	0.15	80.6	35.5	1468
	8	54.4	11.4	0.18	63.5	34.5	4848
Vacinada	4	59.8	12.3	0.85	14.6	37.5	2513
	8	59.9	11.3	0.70	16.1	36.7	4592
Olympia	4	60.3	12.2	0.86	14.1	37.5	3236
	8	59.2	12.4	0.88	14.4	37.1	4506
Mean	4	57.7	11.9	0.72	24.6	37.3	2273
Least significant difference		5.8	0.6	0.08	14.4	0.82	1520
Mean	8	58.7	11.6	0.61	24.6	36.6	5707
Least significant difference		4.6	1.2	0.11	5.8	0.76	2464

^zFruit samples were collected in Jan 1994 and 1998.

^yPlot size was two trees, one with and one without a sweet orange interstock. The interstock had little effect on yield and juice quality; thus, no distinction was made in data collection or analysis between the two trees in each plot.

^wSorted according to soluble solids, kg·ha⁻¹, at tree age 8 years.

^xNursery trees normally are moved to the field within 1 year after budding. Tree age is conventionally set as 0 at transplanting. Because our trees were budded in place, tree age was set at 0 during the 1989–1990 season to make our trees essentially equivalent to trees produced in a normal nursery.

SS/A = soluble solids/acid ratio.

Table 14. Mean yield (kg/tree; n = 4) of P.2 'Pera Olympia' sweet orange trees on four rootstocks planted in Mar. 1989 at St. Cloud, FL.^z

Rootstock	Tree age (yrs)						Cumulative yield
	3	4	5	6	7	8	
Rough lemon	82	116	192	241	122	337	1091
Volkamer lemon	68	104	143	229	112	245	901
Palestine sweet lime	66	107	147	233	71	265	889
Cleopatra	61	94	135	147	145	171	752
Mean	69	105	154	212	111	240	892
Least significant difference	42	52	52	62	72	114	

^zTrees were set on the ends of rows planted 4.3 × 6.7 m. All trees were standard nursery-grown plants.

from studies of morphological, biochemical, and molecular characteristics indicates that sweet oranges comprise a monophyletic group,

i.e., all the descendants originated from a single ancestor perhaps by mutation (Barrett and Rhodes, 1976; Moore, 2001; Potvin et al., 1983).

The combined research and commercial objective was to search for new sweet orange selections that would be suitable for the Florida citrus juice processing industry, but candidates for fresh use were not excluded from the evaluations. The initial round at identifying selections with commercial potential included the assessments of a professional fruit buyer from a nearby citrus grower cooperative and data developed by a major juice processor. Among the early-maturing selections, emphasis was placed on yield and juice quality, especially color and flavor (Wutscher and Bistline, 1988). On that basis, 'Westin' was chosen in EM.1 and 'Earlygold' (tested as selection 8), 'Ruby', and 'Itaborai' in EM.2. Those selections became commercial selections, especially 'Earlygold', mostly because they fit the particular juice profile of the processor involved and offered advantages over the standard selection, 'Hamlin'. Other selections with commercial potential were 'Tobias' and 'Cadena Punchosa'. The former selection was very productive and exhibited one trait of special interest: it was the first selection to flower. Sporadic flowering began ≈2 years before the other selections and only on short shoots with single apical flowers. 'Cadena Punchosa' was only moderately productive but yielded large, nearly perfectly round fruit (data not given) that were found to be attractive as a fresh fruit in 2 subsequent years by the fruit buyer assisting in the evaluations.

The importance of midseason oranges has declined in Florida. However, among the selections we tested, our results confirmed the reported performance and subsequent release of 'Sunstar' (tested by us as 'Midseason'), 'Midsweet' ('Homosassa'), and 'Gardner' ('Sanford') that led to their release (Hearn, 1988). 'Pineapple' was the standard midseason orange in Florida for many years and is the comparison selection in our trials but has been supplanted in recent years by 'Midsweet'. The local selection, 'Pineapple #8', did not perform as well as the standard 'Pineapple'. There were no other midseason selections in EM.1 that exceeded the performance of those already mentioned; however, 'Jincheng', a popular midseason orange in China, was notable (Deng et al., 2008). The trees were 1 year younger, which contributed to their lower yield. They were more compact trees and yielded efficiently making them suitable for planting as a juice orange in combination with a size-controlling rootstock and higher density planting (Boswell et al., 1975; Wheaton et al., 1991, 1995). Also, the fruit would be attractive for the fresh market because they were low-seeded with good juice quality although our samples were harvested in most years before peak maturity.

In the EM.2 group of midseason selections, 'Salustiana' ranked high in the results. It is an old established variety and its known traits were repeated in our trial, i.e., modest yields of excellent internal quality and large, seedless fruit. The combination of yield and juice quality placed this selection at the top of the results across all selections in EM.2 for soluble solids production when the trees

Table 15. Mean juice quality (n = 4) of P.2 'Pera Olympia' sweet orange fruit from trees on four rootstocks planted in Mar. 1989 at St. Cloud, FL.^{zy}

Rootstock ^x	Tree age (yrs)	Juice content (%)	Soluble solids concn (%)	Acid (%)	SS/A ratio	Color number	Soluble solids (kg·ha ⁻¹)
Rough lemon	4	61.4	10.2	0.82	12.5	36.4	2520
	8	56.7	9.8	0.63	15.6	35.0	6554
Palestine sweet lime	4	60.3	10.4	0.78	13.4	36.7	2342
	8	58.0	10.1	0.63	16.0	36.2	5423
Volkamer	4	60.8	10.6	0.79	13.4	36.9	2351
	8	58.5	10.6	0.68	15.6	36.4	5328
Cleopatra	4	62.9	11.5	0.86	13.4	37.7	2354
	8	59.5	11.0	0.70	15.7	36.7	4045
Mean	4	61.4	10.7	0.81	13.2	36.9	2394
Least significant difference		3.8	0.5	0.07	1.1	0.4	1221
Mean	8	58.4	10.5	0.66	15.8	36.2	5110
Least significant difference		5.2	0.7	0.05	0.7	1.1	2793

^zFruit samples were collected in Jan 1994 and 1998.

^yTrees were set on the ends of rows planted 4.3 × 6.7 m. All trees were standard nursery-grown plants.

^xRootstocks are listed according to soluble solids production in Year 8.

SS/A = soluble solids/acid ratio.

were 6 years old. 'Madam Vinous' trees also placed high in the results, but the fruit were undesirably seedy, which would limit its commercial appeal as a fresh fruit.

The main practical result among the late-season selections in V.1 was that those propagated from juvenile sources were no different from those propagated using the mature buds. No selections offered any particular advantage over the standard tree, which would be favored because of its statistically comparable yield but smaller canopy size and thus higher yield efficiency. The same general results were obtained in V.2; however, in a subsequent larger-sized trial conducted by us with Carrizo citrange rootstock, 'Appleby' was one of the top performing selections after 9 years. 'Natal' remains of interest because of its very late maturity, which explains its commercial use in Brazil and 'Vernia' has become a commercial variety in Florida because of its excellent flavor and juice color (traits determined by the cooperating commercial juice processor).

The two remaining groups, the blood oranges and 'Pera' selections, are treated separately here because diverse selections of each group have not been formally compared in Florida. Blood oranges are not considered to be suitable for Florida's subtropical climate because of inadequate cool temperature during ripening to bring forth the anthocyanin pigments that give those selections their well-known red to purple coloration. 'Moro' and 'Tarocco' were included in EM.1 but removed early because of the poor performance described. Anthocyanin pigment never appeared in the peel in the first few cropping years, but light flecking was present in the flesh. Cropping was light in both selections and seeds were rare. In EM.2, there were 12 blood orange selections plus 'Vainiglia', which is an acidless, seedy orange, which had very pronounced red coloration in the flesh from lycopene pigment. None of the true blood orange selections in EM.2 are commercially important in Florida and did not produce fruit with typical coloration. In general, there were similarities among the selections. The fruit

were moderately seedy except for the nearly seedless selections, 'Tarocco', 'Sanguinello Ricco', 'Sanguinello Moscato', and 'Moro'. All selections had soft flesh easily consumed along with the segment membranes. Blood orange cultivars are normally midseason in maturity, but in EM.2, fruit of some selections, e.g., 'Orlando Blood', tended to produce fruit with low acidity and were classified as early-maturing. That trait may change as the trees age.

The blood orange selections we tested have no potential in Florida if evaluated according to their production of typically colored fruit. However, we conducted a short seasonal tracking study in two seasons (data not given) to determine the quality of the blood oranges when allowed to remain on the trees into midwinter, their normal season of maturity. Later harvest had little impact on most selections, but the juice color of 'Budd Blood' improved 1.0 to 2.0 points on the 100-point system not because of red pigmentation, but because of enhanced orange coloration. Also, judging from causal sampling in the field, flavor changed from the typical experience of orange juice to the more distinctive flavor of a blood orange with a raspberry note.

The 'Pera' orange is the principal cultivar in Brazil and is thought to be similar to an old Florida variety, 'Lamb's Summer', that never became established commercially in Florida (Hodgson, 1967). In our trials, no compelling reasons emerged to support adding 'Pera' to the Florida citrus industry. The general 'Pera' results were typical for the cultivar and would be commercially acceptable (Bassanezi et al., 2009; Cavalcante et al., 2006). However, the 'Pera' selections had midseason maturity, which is not an important seasonal niche for new selections, and rootstock compatibility would be a serious issue in any industry using trifoliate orange-based rootstocks.

Conclusions

An important question to the project participants was: Given that our project was a

large undertaking involving considerable time and resources on the parts of the grower-cooperator and the research team, was it worthwhile? The answer is yes, for the biological and practical reasons presented in the discussion. Comparative evaluations of large numbers of scions are uncommon. The project showed that sweet orange selections could be easily assembled and propagated from seed without a significant loss in time resulting from juvenility. The nearly 100 selections in the project demonstrated sweet orange diversity and, as a resource beyond the original objective, they proved useful for making rootstock crosses, e.g., we selected 'Tobias' as a parent for short juvenility and early flowering.

The scope and size of the project attracted considerable citrus industry attention and input leading to the commercialization of several selections. Like in our previous experience with rootstock trials (Castle, 2010), it is difficult to develop a data set that provides all of the information needed in selecting cultivars for particular commercial uses. Thus, there was not a perfect match between our data and the initial choices of selections for commercialization. Furthermore, field trial constraints in a grower-cooperator situation precluded massive seasonal tracking to learn the full potential of each selection. Nonetheless, the value of conducting such large and time-consuming trials is apparent from the interest growers have shown for these new selections.

Literature Cited

- Barrett, H.C. and A.M. Rhodes. 1976. A numerical taxonomy study of affinity relationships in cultivated *Citrus* and its close relatives. *Syst. Bot.* 1:105-136.
- Bassanezi, R.B., L.H. Montesino, and E.S. Stuchi. 2009. Effects of Huanglongbing on fruit quality of sweet orange cultivars in Brazil. *Eur. J. Plant Pathol.* 125:565-572.
- Boswell, S.B., C.D. McCarty, K.W. Hench, and L.N. Lewis. 1975. Effect of tree density on the first ten years of growth and production of 'Washington' navel orange trees. *J. Amer. Soc. Hort. Sci.* 100:370-373.
- Cameron, J.W. and H.B. Frost. 1968. Genetics, breeding, and nucellar embryony, p. 325-370. In: Reuther, W., L.D. Batchelor, and H.J. Webber (eds.). *The citrus industry*. Vol. 2. Univ. Calif., Berkeley, CA.
- Carlos, E.F. and L.C. Donadio. 1996. Interstocks between Pera sweet orange and Rangpur lime. *Proc. 1996 Intl. Soc. Citricult.* 1:221-224.
- Castle, W.S. 1987. Citrus rootstocks, p. 361-399. In: Rom, R.C. and R.F. Carlson (eds.). *Rootstocks for fruit crops*. Wiley, Hoboken, NJ.
- Castle, W.S. 2010. A career perspective on citrus rootstocks, their development, and commercialization. *HortScience* 45:1-5.
- Castle, W.S. and J.C. Baldwin. 2008. Tree survival, growth, and juice quality of early-season sweet orange selections on eight rootstocks in Immokalee. *Proc. Fla. State Hort. Soc.* 121:145-147.
- Castle, W.S., J.C. Baldwin, and R.P. Muraro. 2010a. Rootstocks and the performance and economic returns of 'Hamlin' sweet orange trees. *HortScience* 45:875-881.
- Castle, W.S., J.C. Baldwin, R.P. Muraro, and R. Littell. 2010b. Performance of 'Valencia' sweet orange trees on 12 rootstocks at two

- locations and an economic interpretation as a basis for rootstock selection. *HortScience* 45: 523–533.
- Castle, W.S., K.D. Bowman, J.H. Graham, Jr., and D.P.H. Tucker. 2006. Florida citrus rootstock selection guide. Univ. Fla. Coop. Extension Publ. SP-248.
- Castle, W.S., D.P.H. Tucker, A.H. Krezdorn, and C.O. Youtsey. 1993. Rootstocks for Florida. 2nd Ed. Univ. Fla. Coop. Ext. Publ. SP-42.
- Cavalcante, I.H.L., A.B.G. Martins, and E.S. Stuchi. 2006. Fruit characteristics of eighteen orange cultivars. *Rev. de Biol. Ciencias da Terra* 6:72–77.
- Davies, F.S. and L.K. Jackson. 2009. Citrus growing in Florida. Univ. Press Fla., Gainesville, FL.
- Deng, X., C. Peng, Z. Chen, Z. Deng, and J. Li. 2008. Citrus varieties in China. China Agr. Press.
- Donadio, L.C., J. Orlando de Figueiredo, and R. Pio. 1995. Variedades citricas Brasileiras. Funep and Unesp, Campinas, Brazil.
- Fellers, P.F. 1990. Florida's juice standards for grades and their differences from United States standards for grades and United States Food and Drug Administration standards of identity. *Proc. Fla. State Hort. Soc.* 103:260–265.
- Fellers, P.F., D.R. Petrus, K.K. Nyhof, and A. Powell. 1990. Flavor and color profiles of frozen concentrated orange juice and orange juice from concentrate samples submitted for Florida's seal of approval or Sunshine tree programs, 1986 through 1989. *Proc. Fla. State Hort. Soc.* 103:265–268.
- Fla. Agr. Stat. Serv. 2010. Florida citrus statistics 2008–2009. Fla. Dept. Agric. Consumer Serv. and USDA Agric. Marketing Serv.
- Frost, H.B. and R.K. Soost. 1968. Seed reproduction: Development of gametes and embryos, p. 290–324. In: Reuther, W., L.D. Batchelor, and H.J. Webber (eds.). The citrus industry, Univ. Calif., Berkeley, CA.
- Furr, J.R., W.C. Cooper, and P.C. Reese. 1947. An investigation of flower formation in adult and juvenile citrus trees. *Amer. J. Bot.* 34:1–8.
- Garnsey, S.M., W.S. Castle, R.E. Rouse, H.K. Wutscher, and M.C. Kesinger. 2001. Budunion incompatibilities and associated declines observed in Florida among trees on Swingle citrumelo and other trifoliolate-related rootstocks. *Proc. Fla. State Hort. Soc.* 114:121–127.
- Grosser, J., B. Castle, F. Gmitter and P. Ling. 2009. What's new in sweet orange improvement? *Citrus Industry* 90:12–15, 27.
- Hearn, C.J. 1988. The performance of 'Sunstar', 'Midsweet', and 'Gardner' oranges. *Proc. Fla. State Hort. Soc.* 101:33–36.
- Hodgson, R.W. 1967. Horticultural varieties of citrus, p. 431–591. In: Reuther, W., H.J. Webber, and L.D. Batchelor (eds.). The citrus industry. Vol. 1. Univ. Calif., Berkeley, CA.
- Moore, G.A. 2001. Oranges and lemons: Clues to the taxonomy of *Citrus* from molecular markers. *Trends Genet.* 17:536–540.
- Obreza, T.A. and K.T. Morgan (eds.). 2008. Nutrition of Florida citrus trees. 2nd Ed. Univ. Fla. Coop. Ext. Publ. SL-253.
- Potvin, C., Y. Bergeron, and J.-P. Simon. 1983. A numerical taxonomic study of selected Citrus species (Rutaceae) based on biochemical characters. *Syst. Bot.* 8:127–133.
- Salibe, A.A. 1963. Studies on budunion crease of citrus trees. *Proc. Intern. Org. Citrus Virol.* 3:187–191.
- Saunt, J. 2000. Citrus varieties of the world. Sinclair International, Norwich, UK.
- Wheaton, T.A., W.S. Castle, J.D. Whitney, and D.P.H. Tucker. 1991. Performance of citrus scion cultivars and rootstocks in a high density planting. *HortScience* 26:837–840.
- Wheaton, T.A., J.D. Whitney, W.S. Castle, R.P. Muraro, H.W. Browning, and D.P.H. Tucker. 1995. Citrus scion and rootstock, topping height, and tree spacing affect tree size, yield, fruit quality, and economic return. *J. Amer. Soc. Hort. Sci.* 120:861–870.
- Wutscher, H.K. 1979. Citrus rootstocks. *Hort. Rev.* 1:237–269.
- Wutscher, H.K. and F.W. Bistline. 1988. Rootstock influences juice color of 'Hamlin' orange. *HortScience* 23:724–725.
- Yelenosky, G. 1985. Cold hardiness in citrus. *Hort. Rev.* 7:201–238.