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Florida Citrus Rootstock Selection Guide, 5th Edition[1]

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This updated 5th edition of the Florida Citrus Rootstock Selection Guide (FLCRSG) is a revision of the 2019 publication. The guide is a convenient, easy-to-use reference to 33 characteristics of over 50 rootstocks. The first group of rootstocks are 15 time-honored commercial rootstocks and those that have risen to the top rootstocks adopted by growers in the HLB environment, which are the most reliably characterized. The second group of rootstocks are minor commercial ones that are less frequently used today in Florida but may have been prominent at one time. The third group consists of the most recently released rootstocks for which there is limited commercial experience and are under scientific evaluations in field trials and commercial blocks.

Much has changed within the Florida citrus industry since the discovery and spread of the disease huanglongbing (HLB). Rootstocks were not initially part of the discussion related to managing HLB, but that too has changed, particularly given the accumulating evidence that trees on various rootstocks may differ in the incidence or tolerance of the disease and even possibly resistance with new hybrids. Therefore, the authors have prepared this timely and necessary update of the former editions and expanded the list of rootstocks to include three new rootstocks (US Super Sours) from the USDA breeding program, a new genetically modified, gene-edited rootstock and two new selections from UF/IFAS that have not yet undergone the usual extensive field evaluation in Florida. These new rootstocks offer potential improvements of many meaningful traits that appear essential to the future of our citrus industry, among them tree size, root volume, high yield and juice quality, and possible HLB tolerance.

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Note: Print the Rootstock table on 11'' x 17'' paper.

Preface

First published in 1989 as *Rootstocks for Florida Citrus*, the work of Dr. William Castle and his colleagues remains relevant over 30 years later. The purpose of the Florida Citrus Rootstock Selection Guide is to provide timely and useful citrus rootstock information to help Florida citrus growers make well-grounded, practical decisions. New problems with abiotic factors, pathogens, and diseases make the FLCRSG a standard document for the Florida citrus industry. Initially published as a book, it was integrated into an informative wheel and then a web-based expert system with an interactive table. Today, it is being developed into an Artificial Intelligence (AI)-powered interactive chatbox. Originally, 12 rootstocks were assessed, and now that number has increased to beyond 50, with the newest addition being the first genetically modified, gene-edited citrus rootstock to be approved by the United States Environmental Protection Agency.

The 3rd edition of this guide was published in 2016. The authors updated the 4th edition in 2019 by adding three rootstocks (US Super Sours) that have not yet undergone the usual extensive field evaluation in Florida, as well as by updating the information on the UFR series. These new rootstocks offered what were believed to be improvements at the time regarding HLB tolerance and several other meaningful traits, such as tree size, high yield, and juice quality that appear essential to the future of the Florida citrus industry. This 5th edition includes new selections from USDA, UF/IFAS, and private companies.

How to Use the Rootstock Selection Guide

[1] General

The rootstock information provided is a broad-based compilation of Florida information collected from field trials and commercial situations. The information is general in nature as it represents essentially "average" rootstock behavior across a range of conditions related mostly to scion variety and site conditions.

The quality of information varies due primarily to the time period of evaluation. Thus, the rootstocks have been grouped accordingly into three categories: 1) **MOST USED**, which are commercial rootstocks with a long history of use, are most widely adopted by growers, and are the ones for which the descriptions are the most reliable (first group); 2) **MINOR USE** rootstocks, which are ones that have been in minor commercial use for a while and others that were prominent at one time but whose importance has faded as newer rootstocks were introduced and adopted commercially (second group). The information presented for most of the rootstocks in this category is reliable but is sometimes not as fully developed as with the most used commercial rootstocks and the effects of HLB on these rootstocks is poorly characterized thus far; and 3) **RECENTLY RELEASED** rootstocks, which were more recently created in breeding programs and have been under evaluation in Florida for only a few years or not at all (third group), eventually selected from field trials and small commercial cooperative trials. Recently released rootstocks have limited commercial experience.

It is also important to note that in rating rootstocks, the differences for a stated factor are sometimes based on a quasi-qualitative comparison and in other cases a more quantitative basis. **Tree height**, for example, is essentially a relative rating based on the standard of comparison: a tree on a rootstock rated as "Large" would be equivalent in height to a mature tree on rough lemon rootstock. On the other hand, a rootstock's rating regarding citrus nematode or Phytophthora tolerance is fundamentally based on quantitative screening trials plus commercial experience. With many grapefruit going into citrus under protective screen (CUPS) grow facilities, rootstock performance may not be what is expected compared to when these selections are planted in the open grove in the HLB environment. When trees are planted in the HLB environment, their growth rate is often greatly reduced; however, in CUPS, growth rates are much higher than even in the non-HLB environment.

[2] Year of First Commercial Availability

The year of first commercial availability is when the rootstock first appeared in the nursery use records of the Florida Department of Agriculture & Consumer Services, Division of Plant Industry, Bureau of Citrus Budwood Registration or when they were approved for commercial production by the United States Government.

Information on rootstock use can be found in the annual reports of the Bureau.

[3] Horticultural Traits

Seed germination. Germination is the growth of a seed into a young plant or a seedling. This parameter is important for plant propagation in the nursery. Some rootstocks, like Rusk Citrange and 1584, have a high seed germination rate (80%–90%) but usually produce fruit with few to no seeds.

Seedling uniformity. This variable indicates the percentage of true-to-type seedlings. Most common citrus rootstocks produce polyembryonic seed that yields true-to-type plants, that is, seedlings that are the same type of plant as the original plant. However, a few rootstocks will differ based on the parental pedigree used for crossings. Rootstocks like Smooth Flat Seville produce lots of seeds, but the seeds do not germinate well, and the seedlings are highly variable, with 50% or more discarded as off-types. UFR-15 and UFR-16 present 80%–90% germination, but seedlings are also highly variable.

Tree survival. This variable indicates the percentage of trees that will survive in a commercial block.

Tree size. Tree size refers to the size of the canopy of a mature tree. The ratings indicate relative tree vigor. A tree on a selected rootstock would be rated large [Lg] if it was comparable in vigor and size to one on Cleopatra mandarin or rough lemon, i.e., perhaps 14–20 ft tall. A small tree [Sm] would be less than 8 ft tall at maturity, and an intermediate tree [I] would be like one on C-35 citrange and range in height from 8 to 14 ft tall.

Suggested in-row spacing. This is the appropriate spacing without excessive crowding given the expected vigor and growth to maturity of common commercial scion varieties. Spacing would change according to the selected scion/rootstock combination. Between-row spacing would be dictated mostly by cultural and harvesting machinery used.

Yield/tree. This term is related to the amount of fruit on an individual mature tree at a recommended spacing but recognizing that the bearing habits of different scion-rootstock combinations vary. For example, some are more precocious (early bearing) than others. Comparisons of rootstocks for effects on tree yield should consider canopy size. Small trees usually produce less fruit per tree than larger trees, but the smaller trees can be planted at higher densities.

Yield/acre. Yield per tree times the number of trees per acre will ultimately determine the yield per acre. Generally, the relationship between these two variables (yield per tree and yield per acre) is directly proportional. However, there are situations where a tree has only intermediate yield per tree because of a smaller canopy but yield per acre is high because more trees of smaller stature can be planted per acre.

Juice percent. The average percent of juice per fruit for 'Valencia' sweet orange.

Juice Brix. The average Brix for a 'Valencia' fruit picked at peak maturity in the HLB environment and outside of the HLB environment.

Juice acidity. The average titratable acidity in citric acid equivalents of juice expressed from a 'Valencia' sweet orange fruit at peak maturity in the HLB environment and outside of the HLB environment.

Juice color. The average juice color of juice expressed from a 'Valencia' sweet orange fruit at peak maturity in the HLB environment and outside of the HLB environment.

Fruit size. Refers to a relative rating based on US market size standards in and outside of the HLB environment.

[4] Tolerances

Salinity. Salty waters in Florida containing high levels of NaCl are problematic because rootstocks vary in their absorbance and translocation of the Na^+ and Cl^- ions. This rating indicates how much a given rootstock can tolerate high-salinity irrigation water.

High pH. Rootstocks vary in their tolerance of calcareous soils mostly because of the $CaCO_3$ in the soil and/or the irrigation water. Such conditions commonly lead to calcium-induced Fe chlorosis. New evidence suggested that HLB-affected trees may also suffer stresses related to high bicarbonate in the irrigation water.

Clay soil. Refers to soils with horizons containing >20% clay or loamy materials, and especially soils where such horizons are close to the soil surface. These soils are generally unsuitable for Swingle citrumelo, Carrizo citrange, and other citrumelo, citrange, and trifoliate orange rootstocks.

Wet soil (flooding). Wet soils are poorly drained, chronically wet, or subject to extended periods of flooding. For additional soils information, see *Field Guide to Soil Identification for Florida's Citrus-Growing Regions*, SP 362 (http://ifasbooks.ifas.ufl.edu/p-266-field-guide-to-soil-identification-for-floridas-citrus-growing-regions.aspx).

Drought. With the advent of generally practiced irrigation, drought is no longer considered an important rootstock factor.

Freezes. The threat of a seriously damaging cold event remains. Few stressful freeze events have occurred since the 1980s. Thus, the tolerance of many of the minor and recently released rootstocks has not been adequately determined.

[5] Diseases and Pests

HLB (Huanglongbing) tolerance. This trait resists the relative severity of canopy health and crop symptoms on infected trees.

Blight. As with HLB, rootstock tolerance to blight, a disorder of unknown cause, is based on field observation in research trials and commercial groves. It is a combined rating for overall incidence and rate and time to first losses. Thus, Cleopatra mandarin is rated "S-T" because while the incidence of blight is low among young trees, substantial losses can occur when the trees reach 12 to 15 years of age.

Phytophthora nicotianae ratings are a combination of foot- and root-rot tolerances that are similar within a rootstock, but may differ; for example, sour orange has good foot-rot tolerance but mediocre root-rot tolerance.

P. palmivora/Diaprepes weevil complex. Rootstocks vary in their tolerance to *P. nicotianae* and *P. palmivora*, but when *P. palmivora* is present, it is not ordinarily problematic unless Diaprepes weevils are also present (*Phytophthora/Diaprepes* Complex). Most rootstocks are susceptible to this complex, but the ratings may vary depending on soil type.

Burrowing nematodes. All rootstocks are susceptible except for selections of Carrizo citrange, Ridge Pineapple sweet orange, Milam lemon, and Kuharske citrange.

Citrus nematodes. Trifoliate orange has tolerance to citrus nematodes. That trait is inherited by many of its hybrids including Swingle citrumelo.

Sting nematode is a pest in some instances, especially in soils with high sand content. There are no known tolerant rootstocks.

Xyloporosis and Exocortis. These virus and viroid diseases, respectively, can be problematic for trees on certain rootstocks. However, they have been virtually eliminated from Florida because of clean budwood programs. Therefore, they are not included in this guide.

Tristeza (mild Florida strain). This disease is mild and is caused by an aphid-transmitted virus. Some rootstocks are more susceptible than others.

Tristeza (severe stem-pitting strain). This disease is severe and is caused by an aphid-transmitted virus. Some rootstocks are more susceptible than others.

Graft compatibility with Valencia. This information is whether the rootstock has a compatibility with 'Valencia' sweet orange.

Graft compatibility with Flame. This information is whether the rootstock has a compatibility with 'Flame' grapefruit.

Graft compatibility with Tango. This information is whether the rootstock has a compatibility with 'Tango' mandarin.

Graft compatibility with Bearss lemon. This information is whether the rootstock has a compatibility with 'Bearss' lemon.

Graft compatibility with Eureka lemon. This information is whether the rootstock has a compatibility with 'Eureka' lemon.

Additional Comments

Incompatibility. There are just a few situations where a scion/rootstock combination, like Murcott budded to Carrizo citrange or Swingle citrumelo, declines from an apparent incompatibility that manifests itself at the bud union. Other problematic combinations were described by Garnsey et al.

WARNING! Mandarins are perhaps the most sensitive scions to incompatibility, especially with trifoliate orange-hybrid rootstocks. Nursery managers and growers should be alert to the fact that new releases of mandarin scion types have generally not been tested for compatibility with a broad range of rootstocks.

Key to Symbols

Key to Symbols: **TTT** – true-to-type, **G** – Good, **P** – Poor, **H** – High, **I** – Intermediate, **L** – Low, **Lg** – Large, **R** – Resistant, **S** – Susceptible, **Sm** – Small, **T** – Tolerant, Blank space – Rating unknown or undetermined, **[ ]** – Any symbol in brackets indicates a probable or expected rating, **+/-** Relative ranking, **UFR** – University of Florida Rootstock, and **US** – USDA. Rootstock Grayscale Group 1 – Commercial; Group 2 – Minor Commercial; Group 3 – Recently or Not Yet Released.

Table 1.

Rootstocks	Year of first avail.	Horticultural traits							Tolerances							Pests and diseases						
		Seed germination*	Seedling uniformity	Tree size	Spacing	Yield per tree	Yield per acre	Juice quality	Fruit size	Salinity	High pH	Clay soil	Wet soil	Drought	Freeze	HLB incidence	Blight	Phytophthora	P. palmivora weevil complex	Burrowing nematode	Citrus nematode	Tristeza
C-35 citrange	1994	80%–90%	80%–90%	I	8–10	I	I-H	H/I	I	[P-I]	P	[P]	[I]					T+	[S]	[S]	R	T
Carrizo citrange	1932	90%	90%	Lg	8–12	H	I-H	I-H/I	I-Lg	P	P	P	I	G	G	I-H	I	I	[S]	[S]	S	T
Cleopatra mandarin	1932	>90%	99%	Lg	8–15	L-I	I	H/H	Sm	G	I	G	P	I-G	G	L	S-T	S	[S]	S	S	T
Kuharske citrange	1932	80%–90%	80%–90%	Lg	8–12	[H]	I-H	I/I	I/Lg	[P-I]	[P]			[G]	[G]			I	[S]	[R]	S	[T]
Sour orange	Long established	>90%	91%	I-Lg	8–12	I-H	I-H	H+/H	I	G	G	G	G+	I	G	L	T+	T	T	S	S	S
Swingle citrumelo	1974	>90%	95%	I	8–12	I	I	I/I	I	P	P	P	[G]	P-I	G	I	T	T+	S	[S]	R	T
US-802	2007	>90%	98%	LG	12–14	H	I	L-I/I	Lg		[I]	[G]	[I]		G	L	T	T	T			T
US-812	2001	>90%	96%	I	10–12	H	H	H/H	I		G	[I]	[I]		[G]	I	T+	T	[S]			T+
US-897	2007	>90%	98%	Sm	8–10	L	H	H/H	Sm-I		[I]	[G]	[I]		I	I	I	T	T			T
US-942	2010	>90%	96%	Sm-I	8–10	H	H	H/H	I		[G]	[G]	[G]	[G]	[G]	L	T+	T	T			T+
Volkamer lemon	1970	>90%	98%	Lg	12–15	H	I-H	L/L	Lg	I	T	I	I-G	G	P		S	T	[S]	S	S	T
x-639	1994	80%–90%	80%–90%	Lg	8–12	I	I-H	H/H	I	G	[I]	[G]	[G]		[I-G]	L		T	[S]	[S]		T
Benton citrange	1986	>90%	98%	Lg	8–12	H		H/I	I-Lg	P-I	P	[P]	[I]	G	G			T	[S]			T

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Flying Dragon TF	1978	80%–90%	80%–90%	Sm	5–7	L-I	H	H/H	Sm-I	P	P	G	I	P	G		P	T	[I]	S	R	T
Goutou	1994	80%–90%	80%–90%	I	8–10	[L-I]	[I]	L-I/L	Lg		[I]	G	[G]					S	[S]	[S]		T+
Kinkoji	1986	80%–90%	86%	I	8–10	[I]	I	L-I/L	I		[I]	[G]	[G]					T	[S]	[S]		T
Rough lemon	Long established	80%–90%	80%–90%	Lg	10–15	H	I-H	L/L	Lg	I	G	I	I	G	P		S	S	S	S	S	T
Rusk citrange	1960	80%–90% **	80%–90%	Sm-I	6–8	I	I-H	H+/I	I	P	P		P	[P]	P-I		[I]	T	[S]	S		T
Shekwasha mandarin	1986	80%–90%	80%–90%	I-Lg	8–15	L-I	I	I/H	Sm	[I]	G+	[G]	P	I-G	G			S	[S]	S	S	T
Smooth Flat Seville	1988	10%–49%	41%	I	8–12	L-I	I	L-I/I	I-Lg	[I]	G	[G]	I	[G]	[I]		[T]	S	[S]	[S]		[T]
Sun Chu Sha mandarin	1988	80%–90%	80%–90%	Lg	8–12	L-I	I	H/H	Sm	[I]	I+	G	P	[I-G]	[G]			S	[S]	S	S	T
Sweet orange	Long established	80%–90%	80%–90%	Lg	10–12	I	I	I/I	I-Lg	I	I	I	P	P	I		T+	S+	[S]	S	S	T
Trifoliate orange	Long established	80%–90%	80%–90%	Sm	6–8	L-I	H	H/H	Sm-I	P-	P-	G	G	P	I-G		[S]	T+	[S]	S	R	T+
US-852	1999	50%–79%	40%–60%	I	8–10	H	H	H/H	I		[I]	[I]			G	I	T	T	[S]			T
1584	2004	80%–90% **	80%–90%	I	8–12	H		I-H/I	I	[I]		G	T					I	[S]		T	T

Rootstocks	Year of first avail.	Horticultural traits							Tolerances							Pests and diseases						
		Seed germination*	Seedling uniformity	Tree size	Spacing	Yield per tree	Yield per acre	Juice quality	Fruit size	Salinity	High pH	Clay soil	Wet soil	Drought	Freeze	HLB incidence	Blight	Phytophthora	P. palmivora weevil complex	Burrowing nematode	Citrus nematode	Tristeza
C-22 Bitters	2009	80%–90%	80%–90%	Sm-I	6–8	[I]	[I]	H/I	I		G+					[I]		I			S	I
C-54 Carpenter	2009	80%–90%	80%–90%	I	8	[H]	[H]	H/I	I		I					[L]		I			G	I
C-57 Furr	2009	80%–90%	80%–90%	I	8	[H]	[H]	H/I	I		I					[L]		G			G	I
C-146	2009	80%–90%	80%–90%	I	8	[H]	[H]	H/I	I							[L]		[G]			[G]	[I]
US-896	2015	>90%	97%	Sm-I	8–10	H	H	H/H	I-Lg						I	I	T	T	[S]			T
US-1279	2014	>90%	<5%	Sm-I	8–10	H	H	I/H	I-Lg							L		T	[I]			T
US-1281	2014	>90%	<5%	Sm-I	8–10	H	H	H/H	I-Lg							L		T	[I]			T
US-1282	2014	>90%	<5%	Sm-I	8–10	H	H	H/H	I-Lg							L		T	[I]			T
US-1283	2014	>90%	96%	Sm-I	8–10	H	H	H/H	I-Lg							L		T	[I]			T
US-1284	2014	>90%	95%	I	10–12	H	H	I/I	I-Lg							L		T	[I]			T
US-1516	2015	80%–90%	73%	I-Lg	10–14	H	H	L-I/I	I-Lg							L		T	[I]			T
UFR-1	2015	80%–90%	80%–90%	I	8–10	H	H	I/H	I	[G]	G	G			I	L	[I]	T	T			[T]
UFR-2	2015	80%–90%	80%–90%	I	8–10	I/H	I/H	I/I	I	[G]					I	L	[I]	T	[I]			[T]
UFR-3	2015	80%–90%	10%–49% ***	I	8–10	H	H	I/I	I	[I]	[I]				I	L	[I]	T	[I]			[T]

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UFR-4	2015	80%–90%	80%–90%	I	10	H	H	I/H	I	G	G	G			I	L	[I]	T	T			[T]
UFR-5	2015	80%–90%	80%–90%	I	8–10	H	H	H/I	I-Lg	[I]	G				I	L-I		T	T			[T]
UFR-6	2015	80%–90%	80%–90%	Sm	6–8	H	H	H	Sm-I	[I]					G	I	[I]	T				T
UFR-15	2015	80%–90%	10%–49% ***	Lg	12	[I]	[I-H]	I/I	Lg	[G]	[G]	[G]				I	[G]	T				
UFR-16	2015	80%–90%	10%–49% ***	I/Lg	10–12	[I]	[I-H]	I/I	I	[G]	[G]	[G]				I	[G]	T	[T]			
UFR-17	2015	80%–90%	80%–90%	Sm-I	8–10	[H]	H	I/I	I	[I]	[G]		[G]		G	L	[G]	T	[I]			
US Super Sour 1	2018	>90%	<5%	Sm-I	8–12	[H]	I/I	I-H/ I-H	I-Lg							L		T				[T]
US Super Sour 2	2018			Sm-I	8–12	H	H	I/I	I							L		T				[T]
US Super Sour 3	2018			Sm-I	8–12	H	H	I/I	I							L		T				[T]

* Seed germination in the first year under appropriate storage conditions. ** Produces few seeds. *** Seedlings are highly variable.

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