

Citrus Nursery Production Guide, Chapter 4: Rootstock Selection¹

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Rootstock Uses in Florida

The large number of different rootstock varieties currently available for citrus production in Florida is unprecedented. In the early era of the history of rootstocks, sour orange was the universally most used cultivar. Because of citrus tristeza virus, other rootstocks such as rough lemon, Volkamer lemon, and Cleopatra mandarin joined the list of most used rootstocks until the mid-1970s. Then, Carrizo citrange started to dominate the market, although sour orange remained popular. Another shift occurred in 1988 when Swingle citrumelo became the most propagated rootstock for many decades. The popularity of Swingle remains high until now, and together with Kuharske (which replaced Carrizo), it is still among the most propagated rootstocks (Table 1).

Between 2005 and 2010, other trifoliate hybrid rootstocks originating from the USDA breeding program were released, namely US-812, US-802, US-897, and US-942. They quickly gained popularity and are now among the top propagated rootstocks. New varieties from the UF/IFAS program such as UFR-1, UFR-2, UFR-4, UFR-5, UFR-6, UFR-15, and UFR-17 have joined the list of rootstocks available to Florida's industry, and many more are still under evaluation. In 2014, another set of rootstocks (US-1279, US-1281, US-1282, US-1283, and US-1284) was released by the USDA (Bowman and McCollum, 2015), followed by the release of three SuperSour cultivars (SS1, SS2, and SS3)

in 2018. For the most recently released rootstocks, a limited supply of seeds is presently available, and their suitability regarding production of uniform and true-to-type seedlings is still being evaluated.

Rootstock Propagation

Rootstocks have been propagated mostly by seed, which is easy and, because of the phenomenon of nucellar polyembryony, results in genetically uniform (true-to-type) rootstocks. The number of seeds per fruit varies among rootstocks from few to more than 40 per fruit. Many of the seeds provided to nurseries come from the A. H. Whitmore Foundation Farm (Leesburg, FL) and the UF/IFAS Southwest Florida Research and Education Center (Immokalee, FL), but more and more nurseries are now planting their own seed source trees. The Bureau of Budwood Registration in Chiefland (FDACS, DPI) also has seed source trees established to provide seeds for the most popular rootstocks.

Traditionally, seed source trees are located outside and unprotected from diseases. When the bacterial disease huanglongbing (HLB, a.k.a., citrus greening) became endemic in Florida, concerns arose regarding seed transmission of the disease to newly propagated trees. Several studies have since ruled out seed transmission as a concerning factor (Albrecht and Bowman, 2009; Hartung et al., 2010). Nevertheless, HLB-affected trees may produce

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less fruit and fewer seeds. In addition, other diseases such as citrus scab and citrus canker can affect tree health and fruit production. Citrus canker is of special concern as insufficient sanitation of fruits and seeds can quickly lead to disease outbreaks in the nursery, followed by quarantine.

To eliminate diseases and other environmental stresses, rootstocks can be propagated by tissue culture or by cuttings to provide liners for budding. Tissue culture propagation has become more common in recent years because of increased replanting in combination with the higher demand for specific rootstock cultivars. Because of the higher cost and concerns about root quality, not everyone in the industry embraces tissue culture–propagated rootstocks at present. However, recent field studies have eliminated some of these concerns.

When using rootstock liners that are propagated by tissue culture or stem cuttings, it is important to realize that their root systems are different from the root systems of seedlings. In general, the relative root masses of tissue culture– and cuttings-propagated rootstock liners are smaller than the relative root masses of seed-propagated liners, especially during the early weeks of growth (Albrecht et al., 2017). It is therefore recommended to pay special attention to irrigation and nutrient requirements when using tissue culture- or cuttings-propagated rootstock liners. Optimization of management based on the specific needs of the rootstock cultivar is also advisable.

Impact of Tissue Culture

Despite the many new rootstock cultivars available to growers, Swingle was the number one rootstock in 2017–2018 and 2018–2019 with over 600,000 trees budded each year. Although this historical rootstock is still favored by the industry, the easy availability of seeds likely contributes to its persistence as one of the top propagated rootstocks in Florida. The currently most propagated rootstock is US-942 with over 900,000 propagations annually since 2019–2020. Contrary to Swingle, for which plenty of seed source trees are available, fewer seed source trees have been available for US-942. As a result, US-942 is mostly propagated by tissue culture until more seeds become available. The increasing demand for this rootstock seems justified because field trials demonstrate its consistent solid performance and higher production compared with Swingle and other rootstocks. Nevertheless, it is advised to use a diverse range of rootstocks for planting rather than a single cultivar.

With the demand for new and superior rootstocks and the adoption of higher-density production practices in

the HLB era, tissue culture propagation of rootstocks will continue to be relevant. To address quality issues and concerns communicated by nurseries, the companies in Florida who propagate rootstocks via tissue culture have steadily improved the quality of their liners. Whether tissue culture or cuttings propagation of rootstocks will impact tree growth, productivity, and resistance to wind-induced damage in the short and long term is currently under investigation. Preliminary field observations show no difference in survival and performance of trees attributable to the way rootstocks are propagated (Pokhrel et al., 2021). More details on rootstock propagation can be found in chapter 6 of this guide, HS1329, *Citrus Rootstock Propagation: Traditional Techniques and Recent Advances* (<https://edis.ifas.ufl.edu/hs1329>).

Which Rootstock to Plant

When deciding which rootstock to plant, the first thing to consider is the scion variety. Several of the newer rootstocks described elsewhere in this document have become more popular. However, it has been historically observed that for sweet orange production most rootstocks are suitable, except sour orange because of incompatibility in the presence of the citrus tristeza virus. Late-season sweet oranges have been the most widely planted in Florida, and the Valencia clone SPB-1-14-19 was the most widely propagated sweet orange, accounting for 84% of all late-season sweet oranges produced in 2021–2022. Most sweet oranges were propagated on US-942. For very vigorous scions, such as the promising HLB-tolerant Sugar Belle, rootstocks that induce a small tree size, such as Flying Dragon or US-897, are not recommended because they are vulnerable to uprooting under tropical-force winds.

Sour orange rootstocks produce excellent grapefruit trees, but because of the citrus tristeza virus–induced decline of trees grafted on sour orange, trifoliate hybrid rootstocks can be acceptable replacements. For some lemons, especially Eureka, trifoliate hybrid rootstocks are not recommended because they can lead to incompatibility issues and decline. Volkamer lemon produces trees with acceptable fruit quality. Persian (Tahiti) lime does well when budded onto rough lemon or Volkamer lemon. Persian limes have also been successfully grown onto Swingle rootstock. Key (Mexican) limes are generally budded onto rough lemon or sour orange rootstocks, but trees can also be budded onto Volkamer lemon. For the newer specialty citrus such as the Finger lime selections, vigorous rootstocks such as Volkamer and medium-vigor inducing rootstocks, such as Kuharske, Swingle, US-942, and US-812, are suitable

(Bowman et al., 2019; Dutt, unpublished). In general, rootstocks that can provide vigor to the Finger lime tree are suitable.

Another factor to consider is the disease history of the grove, especially frequency of *Phytophthora*, *Diaprepes* root weevil, and nematodes. Most of the currently used rootstocks have trifoliate orange parentage, which generally renders them more tolerant to these diseases than non-trifoliate rootstocks. UFR-4 and UFR-5 rootstocks showed good tolerance to the *Diaprepes*/*Phytophthora* complex in greenhouse tests (Grosser et al., 2003) and along with UFR-1 have also performed quite well in field locations with heavy *Diaprepes* pressure (Grosser, unpublished). UFR-4 also performs well as a rootstock for Finger limes. Unfortunately, few rootstocks have the good performance traits of sour orange when it comes to adaptability to unfavorable soil conditions, particularly high pH, and salinity. Whether the new SuperSour rootstocks show the same positive attributes as sour orange in terms of soil adaptability remains to be explored. More details on rootstock traits can be found in the rootstock selection guide (<https://flrootstockselectionguide.org>).

Tree size is another important factor to consider. Among the most vigorous trees available at present are Volkamer lemon, rough lemon, and the trifoliate hybrid rootstocks US-802 and X-639. Although the large vigor may allow trees on these rootstocks to better cope with HLB, if planted too close, regular pruning is required. If fruit quality is of concern, it is important to recognize that high-vigor-inducing rootstocks generally produce lower-quality fruit. For juice production, a lack in solids can be compensated for by higher-density planting.

Although high-vigor rootstocks can produce a large and attractive-looking canopy despite HLB, this may not always translate to production of large numbers of fruit (Kunwar et al., 2021 and 2023). In the pre-HLB era, trees were productive for several decades. Now, trees will inevitably become HLB-affected, resulting in premature loss of productivity. Therefore, planting smaller trees at higher density than in the past may be a wise choice to ensure profitability. This is best achieved by choosing small- to mid-size-inducing rootstocks.

High yield efficiency at medium size is provided by rootstocks such as US-812, US-942, UFR-2, UFR-4, and UFR-5, although UFR-2 can be slow to reach its full production potential. These rootstocks are also compatible with most scion varieties. If very high density is desired, US-897 is a good choice. Although the low vigor of this rootstock may

not manifest during the early years, older trees remain considerably smaller than trees on standard rootstocks such as Swingle while producing high-quality fruit. Another rootstock to be considered for high-density planting is C-22 (“Bitters”), though it is very susceptible to wind-induced uprooting (Kunwar et al., 2021 and 2023). Many new UF rootstock varieties have been bred specifically to induce small tree size and high yield efficiency. Among these, UFR-6 is showing promise, because it produces fruit with exceptional quality (Grosser et al., 2011). UFR-17 is also performing well at multiple locations, including flatwoods sites (Grosser, unpublished). Other UF varieties are still under evaluation in field trials across Florida, and some are performing quite well.

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Table 1. Top 15 rootstocks propagated from 2017 to 2022 in Florida. Source: 2021-2022 Citrus Budwood Annual Report, Florida Department of Agriculture and Consumer Services (<https://www.fdacs.gov/content/download/108719/file/2021-2022-citrus-budwood-annual-report.pdf>).

	2021-2022	2020-2021	2019-2020	2018-2019	2017-2018
1	US-942	US-942	US-942	Swingle	Swingle
2	Kuharske	Kuharske	Kuharske	US-942	US-942
3	X-639	X-639	X-639	Kuharske	X-639
4	Swingle	Swingle	Swingle	Sour orange	Kuharske
5	Sour Orange	Own Root	US-897	X-639	Sour orange
6	US-812	US-812	US-812	US-897	US-802
7	Volkamer	Sour Orange	Sour Orange	US-802	US-897
8	Own Root	US-897	US-802	Own Root	UFR-04
9	C-146	Volkamer	Volkamer	US-812	US-812
10	US-897	US-802	C-54	Volkamer	C-35
11	Rough Lemon	Rough Lemon	Rough Lemon	C-35	Cleopatra
12	C-35	C-35	UFR-4	UFR-4	Volkamer
13	US-802	C-54	C-35	UFR-17	UFR-3
14	C-54	Poncirus trifoliata	C-57	Poncirus trifoliata	C-22
15	Cleopatra	UFR-4	US-1777	US-1516	Carrizo