UF IFAS Extension UNIVERSITY of FLORIDA

HS1340

UF/IFAS PEER REVIEWED

Citrus Nursery Production Guide, Chapter 4: Rootstock Selection[1]

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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. The popularity of Swingle remains high, 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, UFR-16, 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 currently 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) has recently established a 10-acre seed source plot, but seeds will not be available until 2020 or later.

Traditionally, seed source trees are located outside and unprotected from diseases. When HLB 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

1. This document is HS1340, one of a series of the Horticultural Sciences Department, UF/IFAS Extension. Original publication date September 2019. Visit the EDIS website at https://edis.ifas.ufl.edu for the currently supported version of this publication.

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factor (Albrecht and Bowman 2009; Hartung et al. 2010). Nevertheless, HLB-affected trees may produce 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 because 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 rampant in recent years because of increased replanting in combination with the large 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.

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, at least 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 2017–18 with 683,378 trees budded. 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 second most propagated rootstock during 2017–18 was US-942 with 661,003 propagations. Contrary to Swingle, for which plenty of seed source trees are available, few seed source trees are presently available for US-942. As a result, US-942 is almost exclusively propagated by tissue culture. 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 (Albrecht, unpublished). 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 are gaining in popularity. 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 72% of all late-season sweet oranges produced in 2017–18. Most sweet oranges were propagated on Swingle. For very vigorous scions, such as the promising HLB-tolerant Sugar Belle, rootstocks inducing small tree sizes, 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 most lemons, 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, Volkamer results in large trees, while Kuharske and Swingle rootstocks produce trees of medium size (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 are also performing quite well in a field trial under 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 of 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 translate to production of large numbers of fruit. For example, recent results from large-scale field-trial evaluations of a large range of different rootstocks identified X-639 among the lowest-yield-inducing rootstocks during the early production years despite the exceptional appearance of the trees (Albrecht, unpublished).

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-4, and UFR-5. 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"), although it is not commonly used in Florida at present. 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 currently under evaluation in large-scale field trials, and early results are promising.

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Table 1. Top 12 rootstocks propagated from 2014 to 2018 in Florida. Source: 2017–2018 Citrus Budwood Annual Report, Florida Department of Agriculture and Consumer Services (https://www.freshfromflorida.com/content/download/62638/1423875/2018-annual_report_combined.pdf).

	2018	2017	2016	2015	2014
1	Swingle	Swingle	Kuharske	Kuharske	Swingle
2	US-942	US-942	X-639	X-639	Kuharske
3	Kuharske	X-639	Sour orange	Swingle	Sour orange
4	Sour orange	Kuharske	US-897	Sour orange	X-639
5	X-639	Sour orange	Swingle	Cleopatra	US-802
6	US-897	US-802	US-942	US-802	US-812
7	US-802	US-897	US-802	US-897	US-897
8	Own Root	UFR-04	US-812	US-942	Cleopatra
9	US-812	US-812	Cleopatra	US-812	Carrizo
10	Volkamer	C-35	UFR-04	C-35	Volkamer
11	C-35	Cleopatra	Volkamer	Carrizo	US-942
12	UFR-04	Volkamer	Kinkoji	Volkamer	C-35