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Citrus Rootstock Usage, Characteristics, and Selection in the Florida Indian River Region

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SUMMARY. Sour orange (*Citrus aurantium*) has been the dominant citrus rootstock in the Indian River region of Florida since the initial plantings in the 1880s. Use of this rootstock in new plantings has been rare since 1990 because of heightened concern about decline strains of citrus tristeza virus (CTV), to which this rootstock is highly susceptible. Because the proportion of trees remaining on sour orange rootstock and the rate of decline among them are important in predicting the economic consequences for the Indian River citrus industry, two surveys of rootstock usage were conducted for citrus in this growing region. In the first survey, growers were asked about rootstock usage and problems observed across all types of citrus, and responses represented 35% of acreage. In the second survey, growers were restricted to rootstock usage and grower observations on decline for grapefruit (*C. paradisi*), and responses represented 53% of acreage. Even though 44% of all current Indian River grove area has been planted since 1987, when use of sour orange for new plantings largely ceased, 48% of all citrus and 55% of all grapefruit grove area are currently on sour orange rootstock. The percentage of grapefruit trees on sour orange rootstock that showed significantly health decline in 2000 was 8% based on grower reports. The other rootstocks representing substantial commercial grove area have known problems and limitations that are likely to prevent any of them from gaining the prominence once held by sour orange. Swingle citrumelo (*C. paradisi* x *Poncirus trifoliata*) at about 25% of grove area, Cleopatra mandarin (*Citrus reticulata*) at about 8%, and Smooth Flat Seville (*Citrus* hybrid) at about 3% all represented similar acreage for grapefruit and across all cultivars, while Carrizo citrange (*C. sinensis* x *P. trifoliata*) use was reported for 4% of grapefruit and 13% overall. Evaluation and development of new rootstocks is vitally important for the Indian River area, especially for soils with significant clay and calcium content.

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Sour orange was the dominant rootstock used in the Indian River area (in the central east coast of Florida) for much of the past century because it is adapted to a wide range of soils and confers excellent fruit quality (Castle, 1987). However, trees on sour orange rootstock are highly susceptible to quick decline strains of citrus tristeza virus (CTV), which are common in Florida (Powell and Pelosi, 1993), but CTV spread previously was variable and often slow because established vectors were inefficient. With the introduction of the brown citrus aphid (BCA) (*Toxoptera citricida*) to Florida in 1995 (Pelosi et al., 1996), spread of CTV is expected to be much more rapid, because this insect can pick up and transfer the virus with greater efficiency than other aphids present on Indian River citrus (Yokomi et al., 1994). The heightened threat of CTV has resulted in selection of alternate rootstocks, but many acres of citrus on sour orange rootstock are still in production.

Worldwide overproduction of grapefruit has greatly depressed prices, and the Indian River area is the world's largest producer (Florida Agricultural Statistics Service, 2001). The proportion of trees remaining on sour orange rootstock, and the rate of decline from CTV, may be important in gauging the economic future for the Indian River citrus industry, especially for efforts to predict the duration of the current oversupply of grapefruit.

In addition, grapefruit was widely planted on swingle citrumelo rootstock in the 1980s and 1990s. Some of these plantings have become unproductive where planted on soils with significant clay content or calcareous materials (Castle and Stover, 2001). Further losses from those groves may also influence future Indian River production. Finally, while sour orange excelled as a rootstock on all Indian River citrus soil types, no other rootstock has demonstrated sustained performance as a superior choice for grapefruit scions on alkaline soils or those that contain substantial clay, making rootstock selection especially problematic. This study was conducted to provide information relevant to these issues relating to rootstock usage in the Indian River citrus growing region.

Materials and methods

GENERAL ROOTSTOCK SURVEY IN 1998. Surveys were sent to numerous area citrus growers in June 1998 to assess the overall grove area planted with different rootstocks in the Indian

River region, without regard to scion varieties. Respondents were also asked to identify any problems that they observed with the following rootstocks: sour orange, Cleopatra mandarin, Carrizo citrange, Swingle citrumelo, Smooth Flat Seville, and Sun Chu Sha mandarin (*C. reticulata*).

GRAPEFRUIT ROOTSTOCK SURVEY IN 2000. Surveys were again sent to numerous area citrus growers in December 2000 to assess the overall area of grapefruit planted with different rootstocks in the Indian River region. Respondents were also asked to identify the percentage of grove area on sour orange and swingle that experienced substantial decline in the preceding 12 months, and what proportion of decline appeared to result from CTV based on grower observation of field symptoms. These questions were asked to increase accuracy of economic projections about grapefruit production over the next 10 years.

Results and discussion

ROOTSTOCK USAGE FOR ALL INDIAN RIVER CITRUS FROM THE 1998 SURVEY. Out of about 182,000 acres (73,600 ha) of Indian River citrus (Florida Agricultural Statistics Service, 2001), 64,200 acres (26,000 ha) of production were represented by the 31 survey respondents, accounting for 35% of Indian River citrus. Sour orange was the dominant rootstock with 48% of the reported grove area (Table 1). Swingle, which has accounted for nearly 50% of the citrus trees propagated in Florida in the last ten years (Castle and Jerkins, 2001), accounted for 22% of reported area. Carrizo was the third most numerous rootstock reported. Cleopatra mandarin has been used on a low percentage of plantings for many years, while Smooth Flat Seville has largely been used as a replacement for sour orange in fine-textured soils in recent years (Castle et al., 1993a).

ROOTSTOCK USAGE FOR INDIAN RIVER GRAPEFRUIT FROM THE 2000 SURVEY. Out of about 83,000 acres (33,600 ha) of Indian River grapefruit (Florida Agricultural Statistics Service, 2001), 44,000 acres (17,800 ha) of production were reported by the 34 survey respondents, accounting for 53% of grapefruit grove area. Sour orange was again the dominant rootstock with 55% of the reported grove area (Table 2). Swingle accounted for 27% of reported grove area, followed by Cleopatra, Carrizo, and Smooth Flat Seville.

Comments on individual rootstocks

SOUR ORANGE. According to 2001 Citrus Budwood Registration Bureau records, sour orange use for new tree propagations in Florida ranged from 19% to 52% in every year from 1953 to the 1986–87 season, representing a total of 22 million (31%) of the 65 million trees produced. In 1987–88 only 6% of trees were propagated on sour orange, and after that time, the proportion has declined to a negligible level. Overall, since 1987–88 only 1.4 million trees (2.4%) have been propagated on sour orange out of a total of 58 million reported. This tremendous decline occurred almost exclusively because of concern about sour orange susceptibility to CTV.

It would be very risky to plant any new groves on sour orange at this time. When sour orange is included in newly planted rootstock trials, many trees develop CTV symptoms so quickly that trees remain stunted and never achieve commercial levels of production (unpublished data). In several research programs, scientists are working to confer CTV resistance that may permit safe use of sour orange as a rootstock (Deng et al., 1997; Fang and Roose, 1999; Mestre et al., 1997). However, many years of trials will be necessary before such trees can be used with confidence, and there may be consumer reluctance to purchase fruit from groves where CTV resistance is achieved using genetic transformation.

Planting on 43% of current Indian River grapefruit and 45% of all citrus grove area have occurred since 1987 (Florida Agricultural Statistics Service, 2001), when new plantings on sour orange essentially ceased. Therefore, the fact that about 50% of Indian River citrus is still on sour orange reflects the nearly complete domination of sour orange in the region before 1987. In addition to concerns about soil adaptation and general horticultural quality, some growers expressed doubt that other rootstocks provided several fruit quality advantages associated with sour orange. Grapefruit in the Indian River area may be harvested anytime from September until as late as June from the same trees, if fruit meets state-designated quality standards (Wardowski et al., 1995) and market demands. Sour orange rootstock is considered unsurpassed for maintaining fruit quality on the tree, and also is widely believed to provide superior postharvest handling qualities.

Grapefruit comprised 46%, and sweet orange 49%, of all citrus grove area in the Indian River district in the1999–2000 season (Florida Agricultural Statistics Service, 2001). The rate of CTV infection has been extensively studied in sweet oranges and generally shows an exponential increase when infected percentage exceeds 10% (Gottwald et al., 1997). It appears likely that sweet orange (*Citrus sinensis*) trees planted on sour orange will decline within a few years in most Indian River groves, because quick decline strains of CTV are widespread, BCA is present, and most groves on sour orange include trees with CTV decline symptoms. However, the rate of CTV infection and decline is much harder to predict in grapefruit. Infection rate of grapefruit with CTV remained linear throughout 11 years of study in Spain, even when infection exceeded 25% (Gottwald et al., 1996). With BCA and CTV present in the Dominican Republic, the rate of CTV infection was low in grapefruit, with maximum infection remaining below 2%. This is especially interesting since initial infection was discovered 2 years before study completion and throughout this period a nearby orange block displayed a logarithmic increase in infection (Gottwald et al., 1998). There is some evidence that detection of CTV infection may be more difficult and variable in grapefruit than in sweet oranges and that infection rate may exceed detection (C.A. Powell, personal communication).

In different groves, percentage of grapefruit trees on sour orange that displayed significant decline in the year 2000 ranged from 1% to 70% in the 2000 Indian River survey, with a mean estimate of 8% (Table 2). Almost all reported decline in these trees was attributed by growers to CTV. Caution should be used in interpreting grower-reported rates of decline and attribution to a specific disease, but a high degree of variability would be expected and it is impractical to actually assess decline over such large acreage. Of all Indian River grapefruit groves planted on sour orange, 62% reported substantial decline in 5% or fewer trees and only 11% of groves reported decline in more than 10% of trees. This large range in response may reflect variation in initial infection with CTV quick decline strains, aphid populations, and possibly effects of stress on symptom development. Unfortunately, there are no published data on the rate of CTV symptom development after grapefruit trees on sour orange are infected. While some experts anticipate that grapefruit responds much like sweet orange, with severe symptoms expressed one to two years after infection (T.R. Gottwald, personal communication), other virologists suspect that grapefruit harbor infection for many years until symptoms are triggered by additional stress (C.A. Powell, personal communication). Anecdotal reports suggest that the severe 2001 spring drought may further accelerate tree loss from CTV.

If symptoms develop at the same rate as infection, but lag by several years, then the 8% decline reported by Indian River growers is slightly greater than the average annual infection rate observed in Spanish grapefruit without BCA present, but is within the range of annual increases which were observed (Gottwald et al., 1996). Environmental effects on flush development, aphid populations, CTV titer and interaction among these factors can all influence the annual infection rate (Gottwald et al., 1997) resulting in fluctuations within the fundamental infection rate relationship. Alternatively, the reported decline rates may reflect more rapid infection for Indian River grapefruit resulting in part from introduction of BCA.

Better management decisions could be made with improved understanding of CTV spread and resultant decline in grapefruit. If grapefruit decline from CTV does follow a linear pattern with annual losses of 8%, then most grove area of grapefruit on sour orange would be lost in 10 to 15 years, but overall supply might be largely unaffected. If decline from CTV does become exponential, as in sweet orange, accelerated loss of grapefruit groves may substantially influence profitability and overall grapefruit supply from the surviving groves.

Swingle citrumelo. Swingle citrumelo began to be widely planted from the late1980s, as a CTV-resistant, productive rootstock, yielding good fruit quality (Castle et al., 1993b; Fallahi et al., 1989). It was used for only 8% of Florida citrus trees propagated from 1953–87, but has been used for 48% of trees propagated since that time (Citrus Budwood Registration Bureau, 2001). It has proven well adapted to most of the better-drained citrus soils, and is currently the most widely planted citrus rootstock in Florida. However, by the mid-1990s it was apparent that Swingle performs poorly on many soils with high pH, especially if soils are also characterized by chronic wetness and/or substantial clay content near the soil surface (Castle and Stover, 2001). Such soils are commonplace in the Indian River area. Frequently, growers report that trees on Swingle initially grow well on these sites but begin to decline after 5 to 7 years, with substantial losses in vigor and productivity. The 4.6% decline reported for trees on Swingle in the year 2000 (Table 1) suggests that most of the Swingle plantings on problem soils were identified before this survey, but some growers reported decline in 50% of their Swingle acreage. On soils where Swingle is well adapted in the Indian River area, it remains one of the best choices for new plantings.

Carrizo citrange. Carrizo citrange is a popular rootstock for production of processing oranges in Florida and is replacing Troyer citrange as the dominant rootstock in California (M.L. Roose, personal communication). Like Swingle, it is CTV resistant, is quite susceptible to citrus blight in Florida (Castle, 1987; Castle and Tucker, 1998). Trees on Carrizo are noted for early production and high yields, but generally have lower fruit soluble solids than otherwise comparable trees budded on sour orange or swingle (Castle, 1987, Castle et al., 1993b). These traits make Carrizo less popular for fresh fruit production, thus explaining its relatively minor importance as a rootstock for grapefruit in the Indian River area (3.7%). However, because processing oranges are also grown in the Indian River area, the overall use of Carrizo is higher (12.9%) across all citrus than its use for grapefruit.

Use of Carrizo as a rootstock has been as high as 52% of the annual total Florida nursery tree production (Citrus Budwood Registration Bureau, 2001), but has been declining in recent years. Nevertheless, the use of Carrizo accounts for about 24% of trees propagated since 1953.

Cleopatra mandarin. Cleopatra mandarin has been used for 4% to 22% of propagated trees annually between 1953–2000, averaging 10% for the entire period (Citrus Budwood Registration Bureau, 2001). This rootstock has a reputation for producing good yields of high quality tangerine types (*C. reticulata* and some hybrids) and tangelos (*C. paradisi* x *C. reticulata*). It is also considered an excellent rootstock for production of oranges and grapefruit marketed late in the normal maturity period for a given variety. However, orange and grapefruit trees on Cleopatra have low yields, produce small fruit, and reach mature bearing at a later age (Castle, 1987; Castle et al., 1993b). The use of Cleopatra in the Indian River for all citrus types, and grapefruit in particular, is similar to statewide levels. Cleopatra is CTV resistant, with high salinity tolerance, delayed development of citrus blight,

Table 1. Percentage[z] of grove acreage on individual rootstocks for the Indian River citrus region, reported for all types of citrus in 1998 and grapefruit only in a 2000 survey. Percentage of grapefruit trees on sour orange and swingle citrumelo reported by growers to decline significantly in 2000, as reported in a December 2000 survey.

Rootstock	Grove area reported in 1998 survey for all types of citrus (%)	Grove area reported in 2000 survey for grapefruit (%)	Grove area declining in 2000 as reported in 2000 survey for grapefruit (%)
Sour orange	48.3	54.7	7.9
Swingle citrumelo	22.0	27.3	4.6
Carrizo citrange	12.9	3.7	na
Cleopatra mandarin	7.5	8.5	na
Smooth Flat Seville	3.0	2.7	na

[z]Only rootstocks representing 1% or more of acreage are listed.

tolerance to alkaline soils, and a tendency to develop foot and root rot (*Phytophthora* spp.; Castle and Tucker, 1998). It also has the reputation of producing some of the longest-lived trees in the Indian River area.

SMOOTH FLAT SEVILLE. Smooth Flat Seville (SFS) has some horticultural properties similar to those of sour orange, but is CTV tolerant, and probably is a hybrid of pummelo (*C. maxima*) and sour orange (Barrett and Rhodes, 1976). In many cases, trees budded to this rootstock have comparable tree size, yield, and fruit size to those on sour orange, but juice quality is often lower (Castle and Tucker, 1998).

Nursery tree production on SFS did not reach 1% of the state annual output until 1993, but from 1993–99 it has been used for 7.3% of state nursery production (Citrus Budwood Registration Bureau, 2001). There were a few plantings established on SFS in the Indian River area in the 1970s and 1980s (when the rootstock was called Australian Sour Orange) and they have performed well (Castle et al., 1993a). In soils where trees on Swingle are likely to decline, growers generally report satisfaction with trees grown on SFS. It is likely that use of this rootstock will continue to increase in the short term, especially for grapefruit. Unfortunately, there is a high degree of zygotic seedling production from SFS seed (Bowman, 1995; Castle et al, 1993a), making stringent identification and elimination of off-type liners desirable in the nursery. Difficulty in identifying all off-type SFS seedlings will probably make plantings on SFS somewhat more variable than plantings on other rootstocks.

SUN CHU SHA. Sun Chu Sha is a mandarin rootstock generally similar to cleopatra in virtually all characteristics (Castle and Tucker, 1998; Hutchison et al., 1992). Although represented by relatively few trees, Sun Chu Sha has been used increasingly in the last few years, and was reported to be performing satisfactorily in the Indian River area.

VOLKAMER AND ROUGH LEMON. A small number of growers reported use of lemon-type rootstocks. While overall use was less than 1% across all citrus types, several growers reported that 5% to 7% of their planted area was on lemon stocks, and one indicated that 36% of their grove area was on lemon. Across all Florida citrus nursery production from 1953–99, rough lemon and Volkamer lemon (*C. limon*) were used as rootstocks for 5.7% of the trees (Citrus Budwood Registration Bureau, 2001). Trees on these rootstocks are known for high and early yields, but lower juice quality, and high citrus blight susceptibility (Castle, 1987). The Indian River area has focused on fresh fruit and high soluble solids processing fruit, thus, these rootstocks have much lower usage than the state average. It is likely that use in the Indian River is largely restricted to processing oranges because high yields of trees on lemon rootstocks typically result in high production.

Future developments

A wide range of new citrus rootstocks is being developed by both the University of Florida (e.g., Grosser et al., 1998), and the USDA–Horticultural Research Laboratory in Ft. Pierce, Fla. (e.g., Wutscher and Bowman, 1999), and promising rootstocks from other areas are regularly brought to Florida for evaluation. Advanced selections are currently being tested against standard rootstocks in numerous trials around the state. It is likely that information from these trials will result in plantings of several new rootstocks on a commercial scale within 5 years. Broader plantings and longer experience with the best new rootstocks will inevitably identify problems and limitations for at least some of them, but it is likely that a few of the current advanced selections will prove attractive and will be used for a substantial proportion of Indian River citrus production in the next 20 years.

Creation and evaluation of new citrus rootstocks will remain active for the foreseeable future. Better rootstocks offer the possibility of improved yield, fruit quality, and time of maturation, and should also provide the most efficient solutions for current and future soil/water/nutrient issues and pest problems in the root zone. More dwarfing rootstocks with good horticultural properties are also likely to identified and utilized for harvesting advantages (Wheaton et al., 1991) and possibly better spray efficiency. The constantly increasing availability of new technologies for plant improvement will make many rootstock options available in the future. It is anticipated that growers will select rootstocks according to scion variety, localized soil characteristics, marketing plan, and their perception of opportunities and risks across a group of available rootstocks. Because we are unlikely to identify a single rootstock suitable for almost all plantings, an expert system is being developed to help growers work efficiently in this newly complex era of citrus rootstock selection.

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