CALIFORNIA CITRUS ROOTSTOCKS

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California Citrus Rootstocks

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"No problem in citrus culture is worthier of painstaking research than the one having to do with rootstocks. The whole gamut of citrus fruit production is affected by the relation of rootstock to scion and the adaptability of different combinations to the environment. Something is known but much remains to be found out."

—H. H. Hume (1957)

Introduction

A cultivated citrus tree normally consists of two joined parts that originated as two separate trees. The top portion, located entirely aboveground, is called the scion, cultivar, or scion cultivar. The bottom part, located almost entirely belowground, is called the rootstock. The two connect a short distance up the trunk at the bud union, where they were originally grafted together.

Citrus rootstocks grow from seeds. Most seeds are the products of sexual (*zygotic*) union, with genetic information from both male (pollen) and female (egg) parents. This means that every seed has a unique genetic component. No two rootstocks grown from these unique, sexually produced seedlings would behave in quite the same way in a given situation, and this sort of unpredictability can be undesirable in production agriculture.

Citrus, however, has an unusual genetic situation. Whereas most plants produce monoembryonic seeds (each seed has a single embryo), many citrus cultivars produce both monoembryonic and polyembryonic seeds (each seed can have multiple embryos). Frequently, two or more of these embryos survive to produce a plant when the seed is germinated. Only one embryo in a polyembryonic seed, the zygotic embryo, receives the male genetic material; the other embryos in the seed are called *nucellar embryos* because they arise from nucellar tissue. Because they do not result from sexual union, nucellar embryos are asexual and exclusively maternal in origin. Their genetic makeup is identical to that of the mother plant.

The nucellar embryos of some citrus varieties are more likely to outcompete their zygotic counterparts during germination, with the result that those varieties produce mostly nucellar seedlings. Propagators say that a citrus variety with this characteristic is *highly nucellar*, and consider this to be a desirable quality because such a variety will produce a consistently high percentage of true-to-type seedling rootstocks from each batch germination.

In other tree fruit industries, the use of seedling rootstocks would indicate a lack of a clonal (vegetative propagation) alternative and the ready availability of seed. The highly nucellar polyembryony of citrus rootstocks, however, allows propagators in the citrus industry to rely upon seedling rootstock production. If the industry had to rely upon monoembryonic seed, the results would be more variable. Even with highly nucellar rootstock varieties, nursery operators must visually "rogue" the seedbeds to eliminate the more variable zygotic seedlings that survive germination.

The top (*scion*) of the citrus tree is produced by grafting a vegetative bud into the rootstock seedling. The citrus tree scion is genetically identical to its parent tissue, and the process of budding it to a rootstock seedling is known as *clonal propagation*. The resulting combination is by convention written as *scion/rootstock*.

To select a rootstock effectively, one must understand the purpose of roots, and therefore of rootstocks. Roots serve multiple functions. They anchor the tree in the ground. They absorb and transport water to the aboveground parts of the tree, and do similar work with nutrients. They serve as synthesis or conversion sites for growth regulators. Finally, the roots store food reserves. By being present in the soil, roots also alter the rhizosphere, the soil environment in which they exist.

To be useful, a rootstock must also meet certain requirements. It must be compatible with the chosen scion, adaptable to edaphic (*soil*) and climatic environments, and capable of providing a substantial vertical and horizontal root distribution, and it must have a strong, persistent, and adequate annual growth pattern.

Beyond these functions and requirements, propagators value a rootstock for its ability to enhance any aspect of citrus production that will translate into increased production or quality in a given situation. These factors include disease and pest resistance, cold tolerance, tree vigor, effects on juvenility, harvest date, internal and external fruit quality, yield, and postharvest quality.

The degree to which a specific rootstock fulfills these functions and requirements, and enhances any factor that translates into profit, determine its value for a specific purpose. The better you understand how a rootstock achieves its effects in a given situation, the more likely it is that you will select the optimal rootstock. This publication presents the current knowledge of California citrus rootstocks as a way of helping you make that decision.

History of California Rootstocks

In closing his review of citrus rootstocks Wutscher (1979) stated, "...rootstocks have contributed perhaps more than any other factor to the success or failure of citrus industries around the world." This is no less true in California. As recently as 1897, the question of seedling versus budded trees was debated in California (Webber 1897).

At first, California growers did not use rootstocks. The California industry was later encountering the horticultural circumstances and disease pressures that forced growers in Florida and other citrus-producing areas to use rootstocks. The Florida industry began to topwork onto existing sour orange (*Citrus aurantium* L.) trees in the 1830s in order to produce palatable sweet oranges (*Citrus sinensis* [L.] Osbeck). The discovery of foot rot and gummosis in the Azores in 1842 led to the practice of budding desirable scions onto disease-tolerant rootstocks (Chapot 1965). Budding later spread to most European growers for the same reasons.

The development of suitable rootstocks for the California citrus industry has been shaped by the two objectives just mentioned: disease tolerance and specific horticultural characteristics of individual rootstocks. Sour orange rootstock was introduced in the 1890s to combat foot rot. Disease resistance later became an even greater factor in rootstock development in California with the discovery of citrus viruses in the 1930s (Fawcett 1934; Klotz, Calavan, and Weathers 1972; Wutscher 1977). Subsequently, such specific horticultural aspects of individual rootstocks as the ability to influence fruit earliness, yield, and quality, or the ability to minimize site limitations became important as the demand for citrus grew and as new production areas were developed.

Before the 1880s, California citrus groves were made up of seedling trees, most of them oranges and lemons planted in the missions and hacienda gardens of southern California. Introduction of the popular seedless Washington navel in 1872 made rootstocks necessary; the new orange did not produce enough seed to meet the demand for trees.

The first rootstock used was sweet orange (*Citrus sinensis* [L.] Osbeck), one of the two most common rootstocks in California until the 1940s (Webber 1948). The other, sour orange (*Citrus aurantium* L.), was adopted in the 1890s for its ability to tolerate phytophthora gummosis and produce high-quality fruit. Rough lemon (*Citrus jambhiri* Lush) was introduced early in the 1900s as a rootstock for grapefruit and lemons in sandy desert areas, where it produced high yields. Its lack of cold tolerance and poor fruit quality ultimately precluded any widespread use. Cleopatra mandarin (*Citrus reticulata* Blanco) was used to a limited extent during the search for tristeza-tolerant rootstocks, and its limited use continued once its value was discovered in saline soil plantings. Grapefruit (*Citrus paradisi* Macf.) rootstock's ability to provide fruit of excellent quality and size led to a brief period of use in the early twentieth century, but its susceptibility to foot rot soon led to its disuse. Sweet orange, sour orange, rough lemon, and Cleopatra mandarin remained the major California rootstocks until the late 1940s.

Events in the 1940s led to major changes in California rootstocks. The identification of the devastating tristeza virus virtually ended the use of sour orange and led to the introduction of Troyer and Carrizo citranges (sweet orange × trifoliate orange hybrids) (Batchelor and Bitters 1952; Bitters et al. 1954). Troyer combined many desirable characteristics, and rapidly became the leading rootstock in California. Approximately 65 percent of the rootstocks produced between 1950 and 1970 were Troyer. During the same period, plantings in the San Joaquin Valley increased as those in Los Angeles, Orange, and Riverside counties decreased. With these changes came renewed interest in a cold-tolerant rootstock. Trifoliate orange (*Poncirus trifoliata* [L.] Raf.) is now commonly used in colder areas of the San Joaquin Valley where soil pH permits. *Citrus macrophylla* (Alemow) was introduced as a lemon rootstock for southern California coastal Eureka lemons. Today, these four rootstocks, and to a lesser degree the earlier four, dominate California citrus rootstock production.

Recent citrus rootstock research has resulted in two new rootstock releases: C–32 and C–35. Both are citranges, hybrids of 'Ruby' orange (*Citrus sinensis* [L.] Osbeck) and trifoliate orange (*Poncirus trifoliata* [L.] Raf.). They appear to be tolerant of citrus nematode and tristeza. C–35 is generally more tolerant of phytophthora than C–32 or Troyer. In addition to these releases, several other rootstocks are being tested or used by growers, despite limited experience in California. Among them are Yuma Ponderosa lemon, Swingle, Rangpur, Volkameriana, and Schaub rough lemon. All are still considered experimental in California, although several have been used extensively outside the state. This publication includes information on all of these, except Schaub rough lemon, for growers who wish to attempt limited plantings.

Development of California Citrus Rootstocks

Currently, there are no pressures on the California citrus rootstock industry equal to that exerted by tristeza in the 1940s. However, continuing disease and pest problems, continued northern geographical shifts in the industry, compatibility problems (particularly with lemons), and the introduction of new scion cultivars emphasize the limitations of current rootstocks. Also, growers are always interested in developing rootstocks that facilitate production, minimize site limitations, diversify the industry, and enhance cultivar quality.

Tristeza, *Phytophthora parasitica* and *Phytophthora citrophthora*, and citrus nematode continue to be major problems among widely used rootstocks. Only trifoliate orange and Swingle tolerate all four well. You can generally avoid exocortis, cachexia, and psorosis by using virus-free budwood, and *Armillaria melia* is not universally present.

As land and water in inland valleys and coastal areas of southern California become too expensive for citrus farming, production is shifting north into the San Joaquin Valley. Since 1965, the increases in central California orange acreage (navel and Valencia) have mirrored the acreage decreases in southern California. Lemon production in southern-coastal California has shifted from a 1965 high of 94.4 percent of the state's acreage to 60 percent in 1980. Over one-third of the state's lemon acreage is now in central California and the desert. Similarly, grapefruit acreage has shifted inland from southern California coastal areas to the Central Valley and desert valleys. In combination, these acreage shifts highlight the growing need for cold-hardy, salt- and drought-tolerant rootstocks.

Currently, oranges account for the largest amount of citrus acreage in California. Navels and Valencias constitute 70 percent of the total production, while grapefruit, lemons, limes, tangelos, tangerines, tangors, and mandarins make up the remaining 30 percent. Though these latter crops account for almost one-third of California's citrus acreage, optimal rootstocks have not been developed for them. Rootstock-scion incompatibility causes problems with some of these cultivars. Eureka lemons develop bud-union disorders on many of the currently available rootstocks. Satsumas do poorly on Troyer. Rootstock trials are only now being established for the various red grapefruits, new white grapefruits ('Oroblanco' and 'Melogold'), and the increasingly popular satsumas and clementines.

As horticulture becomes more sophisticated, interest is increasing in developing rootstocks for purposes beyond compatibility, disease resistance, and climate and soil tolerance. Rootstocks that possess these basic qualities and also enhance yield, quality, size, earliness, postharvest quality, tree size, or any other factor that translates into more efficient production and higher return are of interest.

Rootstock Selection

This guide organizes the best available information on rootstocks in a useable form to help you make the best rootstock selection. Step by step you will define your goal, evaluate your orchard site, and systematically select your rootstock.

STEP I: CULTIVAR SELECTION AND SITE EVALUATION

The farmer's objective in planting a new grove is to produce profit. Profit depends upon market demand and the grower's ability to meet it. Generally, unless a site has severe limitations, scion selection will precede rootstock selection.

Scion selection is primarily an economic decision; you select a specific cultivar in anticipation of market demand. Rootstock selection serves two purposes. First, the rootstock should minimize the effects of site limitations (soil-borne and insect-vectored diseases or pests, excessive cold or heat, poor-quality soil, or poor-quality or insufficient water). Second, the rootstock should enhance cultivar yield and quality. Sometimes the right rootstock can also help the grower achieve a specific annual harvest time or orchard lifetime. Any of the above parameters can be altered by management practices, but the rootstock-scion combination defines the limits.

To make your cultivar selection, you will need an accurate market analysis, and to select your rootstock, you will need an accurate site assessment. Market assessment information is available through UC Cooperative Extension county offices, grower and marketing associations, and the Crop and Livestock Reporting Service. The process of site evaluation is covered well in Volume III of *The Citrus Industry*, Chapter 2, pages 48–61 (Platt 1973).

STEP II: BUILDING ON EXPERIENCE

Each rootstock has a history that includes evidence of how it has performed under a variety of circumstances, some of which is available in written form. The best sources for this information are your fellow growers and your local county Farm Advisor.

However, the available information may not cover your specific set of conditions, and experimental literature is not always complete. Therefore, after assessing the cumulative experience and available literature on a rootstock, you will probably select the best rootstock by eliminating all unsuitable rootstocks in a prioritized, systematic manner.

The charts on pages 15 through 18 are designed to assist you in this process. Use them in the sequence presented. Briefly, Charts I, II, and III eliminate rootstocks on the basis of the primary limiting factors: incompatibility, pests, and diseases. Chart IV considers site-specific factors, such as the presence of boron, chlorides, or calcium, site drainage, soil type, and site temperature. Is the orchard site low and cold? Is it sandy, alkaline, or poorly drained? Finally, Chart V helps you categorize the remaining options by rootstock root characteristics, vigor, effects on tree size, yield, drought tolerance, and internal and external fruit quality. At this point, your future aims enter into the decision: Is yield more important than quality? Is early harvest a factor?

STEP III: ROOTSTOCK-SCION INCOMPATIBILITIES

One possible basis for determining rootstock-scion incompatibilities was developed by Webber (1948). He suggested that compatibility was indicated by a straight, smooth bud union (fig. 1), and that progressively greater size differences between the rootstock and scion indicated decreasing degrees of compatibility.

The physiological implications of bud union deformities are unknown. In terms of tree life or productivity, a less-than-smooth bud union may be meaningless. Rootstocks with trifoliate orange parentage regularly overgrow their scions (fig. 2) with no apparent problem. Lemon scions overhang certain rootstocks (fig. 3). However, some bud union deformities appear to cause scion or rootstock decline. The decline of satsumas on Troyer rootstocks appears to arise when rootstock overgrowth compresses and girdles the conducting elements of the scion. This appears to be somewhat different than the bud union crease incompatibility manifested by Frost Navel on trifoliate.

Conversely, trees with normal-looking bud unions also decline because of rootstock-scion combinations. Eureka lemon clones will seem to grow normally for several years on trifoliate parentage rootstocks before they decline from incompatibility. Some researchers suggest that this particular incompatibility is viral in origin, but no causal agent has been identified. Nucellar clones and reciprocally grafted trees of the same combination have similarly declined. Also, sweet orange and grapefruit interstocks have eliminated Eureka decline, indicating that the incompatibility is localized to the Eureka/trifoliate bud union.

Most true incompatibilities have manifested themselves as bud union disorders, such as bud union crease, a fold formed at the bud union that, with increasing growth, appears to disorganize the conducting elements and slowly girdle the tree. The most susceptible combinations are Frost nucellar navel on trifoliate, lemon on Cleopatra mandarin, Eureka lemon on Troyer and other citranges and trifoliates, Satsuma mandarin on Troyer, and certain scion lines on sour orange. 'Murcott' and 'Nova' trees on Carrizo can develop bud union crease within 8 years.

The true incompatibilities noted above are rare and should not be confused with diseases. Most rootstock-scion combinations are eliminated because of their effects on productivity, tree performance and size, and fruit quality. The rootstocks listed here are compatible with navel,

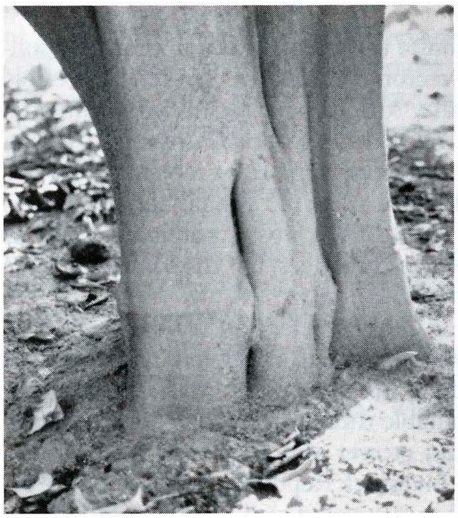

Fig. 1. Compatible rootstock scion bud union.

Fig. 2. Rootstock overgrowth at bud union.

Fig. 3. Bud union scion overgrowth.

Valencia, grapefruit, lemon, and mandarin scions. The rootstock-scion combinations are listed in Chart I. Combinations that appear to be compatible but have had limited use are noted as such. Chart II covers lemon incompatibilities.

STEP IV: DISEASE, VIRUS, AND NEMATODE TOLERANCE

The next step should be to eliminate rootstocks on the basis of their susceptibility to diseases or pests present in the scion or soil. Chart III lists rootstocks susceptible to various fungal and viral pathogens and nematodes. In California, the Citrus Clonal Protection Program (CCPP) greatly reduces the possibility of scion viral infections such as tristeza, psorosis, and the viroid exocortis. Tristeza tolerance is essential for rootstocks in infected areas because aphids transmit tristeza. Although the San Joaquin Valley is currently free of tristeza, the devastating nature of the disease makes the use of tolerant rootstocks wise. Exocortis and psorosis are unlikely to be major problems if you use disease-free budwood, since they are not transmitted by insects. Exocortis-susceptible rootstocks should not be used for replanting trees in a previously infected area. Proper preplant assessment and preparation of the soil should reduce the likelihood of harm from soilborne pests and diseases. In areas subject to nematodes or *Phytophthora* or where the soil is poorly drained, use a tolerant rootstock. You can usually minimize *Phytophthora* gummosis with fungicide applications and careful irrigation management.

STEP V: SITE LIMITATIONS

Limiting factors associated with a specific site can include high levels of chloride, boron, or lime, drainage and soil texture problems, and cold weather. Ideally, you should amend problem soils before planting; if this is impossible, select an acceptable rootstock. Chart IV organizes the rootstock responses to each of these conditions. For commercial success, the remaining rootstocks in your selection process should have at least an acceptable rating for your specific site conditions.

STEP VI: HORTICULTURAL CHARACTERISTICS

After eliminating rootstocks that are scion-incompatible, susceptible to diseases and pests, and poorly adapted to your site, match the remaining rootstocks with your specific goals. This entails considering the rootstock's horticultural characteristics, tree size and vigor, root growth as it relates to drought tolerance, cold hardiness and nutrient uptake ability, internal and external fruit quality, harvest date, and yield.

Related rootstocks often have similar horticultural characteristics, so our initial discussion follows the groups shown in Chart V. The specific or relative characteristics of individual rootstocks are given under subheadings. The following discussions are meant to complement rather than summarize the information given thus far.

LEMON TYPES

The lemon types include Macrophylla, rough lemon, Volkameriana, and Yuma ponderosa lemon. All four rootstocks produce large, vigorous, precocious trees. Though trees grown on these rootstocks may not always grow larger than trees grown on less vigorous stocks, they do grow more quickly. They yield earlier, though their yields peak before those of less vigorous rootstocks. Their rapidly growing, deep, extensive, foraging roots grow into many laterals, but seldom into a marked taproot. This type of root system is drought tolerant. Vigor late in the growing season makes these rootstocks susceptible to cold injury, so they are unsuitable for cold locations.

Lemon-type rootstocks are best suited to warm, humid areas with deep sandy soils. In such areas they produce high levels of total soluble solids (TSS) per unit of land and are productive and long-lived.

Fruit yields of lemon-type rootstocks are high, particularly early in their bearing years. The fruit are large with coarse, thick peels and high shoulders, and are late to develop color and prone to early granulation.

Macrophylla (*C. macrophylla* Wester, aka Alemow), fig. 4

A distinguishing factor of the Macrophylla rootstock is its relative inability to take up boron. Though susceptible itself to tristeza, Macrophylla has been popular as a rootstock for coastal Eureka lemon because of that scion's resistance to the disease. However, rootstock sieve tube neorosis makes this combination short-lived.

Rough lemon (*C. jambhiri* Lush.), fig. 5

The rough lemon rootstock is vigorous and suckers badly. This latter quality is one way to identify it. Rough lemon is more sensitive to cold than Volkameriana, but its vigor enables it to recover quickly from frost damage. Its vigorous root growth enables it to establish itself quickly between root flushes, making it an ideal replant if phytophthora and nematodes are controlled or absent.

Rough lemon consistently produces fruit of low external and internal quality (juice percentage, TSS, and acid). It does, however, produce better quality fruit than Macrophylla.

The rootstock's vigor combines with its typically heavy crops to make rough lemon a poor candidate for late harvests. It is also a poor rootstock for extended harvests, since fruit will store poorly on the tree.

Rough lemon takes up magnesium efficiently, and is superior to trifoliate orange and Cleopatra in its ability to take up nitrogen. However, it takes up phosphorus poorly compared to Cleopatra mandarin.

Rough lemon is a particularly good rootstock for kumquat scions. It produces a desirable, thick-skinned fruit with a low incidence of splitting. It is a particularly poor rootstock for mandarins, as it produces a low-quality fruit.

Volkameriana (*C. volkameriana* Ten and Pasq.), fig. 6

In its cold tolerance, Volkameriana is superior to rough lemon or Macrophylla. The rootstock produces better-quality fruit than rough lemon or Macrophylla. Recently Limoneira 8A Lisbon lemons have survived for 3 years on Volkameriana without contracting dry root rot.

Yuma ponderosa, fig. 7

Still an experimental rootstock, Yuma ponderosa suckers badly. It has produced high yields of poor-quality fruit when grafted to Olinda Valencia, Minneola tangelo, and parent Washington navel scions. It is, however, a promising rootstock for Lisbon and Eureka lemons. With this scion it has produced better yields than Macrophylla, C–32, C–35, Troyer, Carrizo citrange, or Swingle.

MANDARIN TYPES AND HYBRIDS

There are two rootstocks in the mandarin type and hybrid category: Cleopatra mandarin and Rangpur, the experimental mandarin hybrid. Generally, they are dissimilar; Rangpur performs more like a lemon type and Cleopatra mandarin is typical of mandarins. However, both have deep, extensive root systems in sandy soils.

Cleopatra mandarin (*C. reshni* Hort. ex. Tan.), fig. 8

Trees on Cleopatra rootstock can become large but are slow to bear and subject to poor yields at first. Compared to the other rootstock in this category and to most other rootstocks, Cleopatra thrives better and produces more on heavy clay soils. However, it tolerates chlorides better on sandy loam soils than on heavier soils. The rootstock causes boron, calcium, and to a lesser degree, magnesium, to accumulate in the scion leaves. Scion leaves have low levels of potassium and, relative to rough lemon, low levels of nitrogen.

Trees on Cleopatra mandarin produce small fruit with excellent internal quality, but their yields of Valencia (particularly nucellar clones) and navel oranges have been poor. Trees on Cleopatra mandarin have a productive life of average duration.

Rangpur (*C. limonia* Osbeck), fig. 9

Rangpur is vigorous and highly productive when young. Its greater seasonal vigor causes Rangpur to induce dormancy in a scion less readily than the cold-tolerant Cleopatra mandarin. Like lemon rootstocks, Rangpur grows and produces well on deep, sandy soils in warm, humid climates. However, it has also grown well where rough lemon was short-lived. Fruit from trees with Rangpur rootstocks are large and of low to medium quality, better than fruit grown on rough lemon but lower in quality than fruit grown on sour orange or the citranges.

In recent San Joaquin Valley rootstock trials, yields and quality of parent Washington navels, Olinda Valencias, and Minneola tangelos were generally lower on Rangpur than on citrange hybrid or lemon rootstocks. Only with Lisbon lemons did Rangpur produce good yields. Though still experimental, Rangpur appears to be a good rootstock for Lisbon lemons.

ORANGE TYPES

Taiwanica (*C. taiwanica* Tan and Shim, aka Nansho daidai of Japan), fig. 10

Thought to be a hybrid of sour orange, Taiwanica has repeatedly produced poor yields and variable quality in California with grapefruit and Valencia oranges. Yields with early oranges and tangelos approached those of sour orange, but fruit were of low quality.

Sour orange (*C. aurantium* L.), fig. 11

Though sour orange is itself of medium vigor, it has been used to reduce the vigor of lemon scions. Its root system runs deep with multiple taproots, though in most soils the roots are not particularly fibrous or widespread. In its ability to impart cold hardiness to a scion, sour orange is almost equal to Cleopatra mandarin, trifoliate orange, and Swingle. Based on leaf analysis, sour orange does not take up phosphorus, potassium, and boron as well as other rootstocks.

Sour orange is the world's premier fresh citrus rootstock where tristeza does not preclude its use. It is particularly noted for its ability to store fruit on the tree with minimal deterioration and drop. Yields on sour orange are generally less than on citrange rootstocks.

Sweet orange (*C. sinensis* [L.] Osbeck), fig. 12

More and more, sweet orange is becoming a historical rootstock in California. It is an exception in this group of moderately sized, moderately vigorous trees. It grows more slowly than the others, though it eventually produces a larger tree, and it commences bearing later then sour orange or Taiwanica. It is less cold tolerant than sour orange.

The roots of sweet orange stock are shallow, dense, and fibrous, with abundant laterals, and grow best on sandy loam soils. Sweet orange takes up nitrogen, copper, and phosphorus better than most other rootstocks. Trees planted with the rootstock can be quite long-lived, still capable of producing good crops after 60 years.

TRIFOLIATE ORANGE

Trifoliate orange (*P. trifoliata* [L.] Raf.), fig.13

The trifoliate orange is a deciduous relative of citrus. Within this group, cultivars are denoted as large-flowered or small-flowered. Large-flowered selections produce larger and more productive trees, but small-flowered selections produce larger fruit, are more efficient (produce more fruit per unit of canopy volume), and mature their fruit earlier than large-flowered cultivars. In high-density plantings, small-flowered varieties can yield earlier returns.

Continued p. 11

CITRUS VARIETIES

LEMON TYPES

Fig. 4. Macrophylla lemon. Diameter: 2¾ inches.

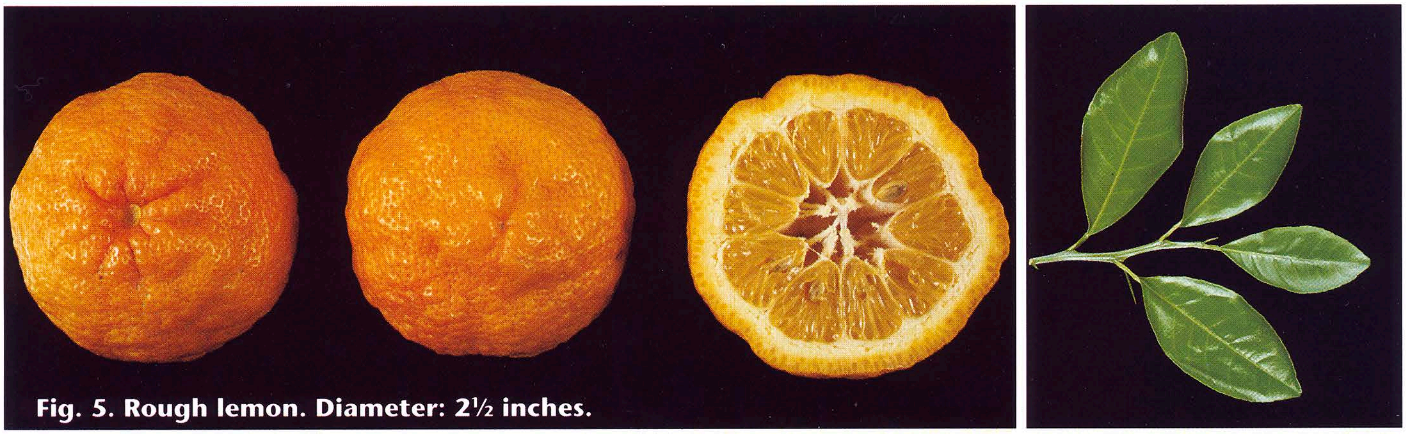

Fig. 5. Rough lemon. Diameter: 2½ inches.

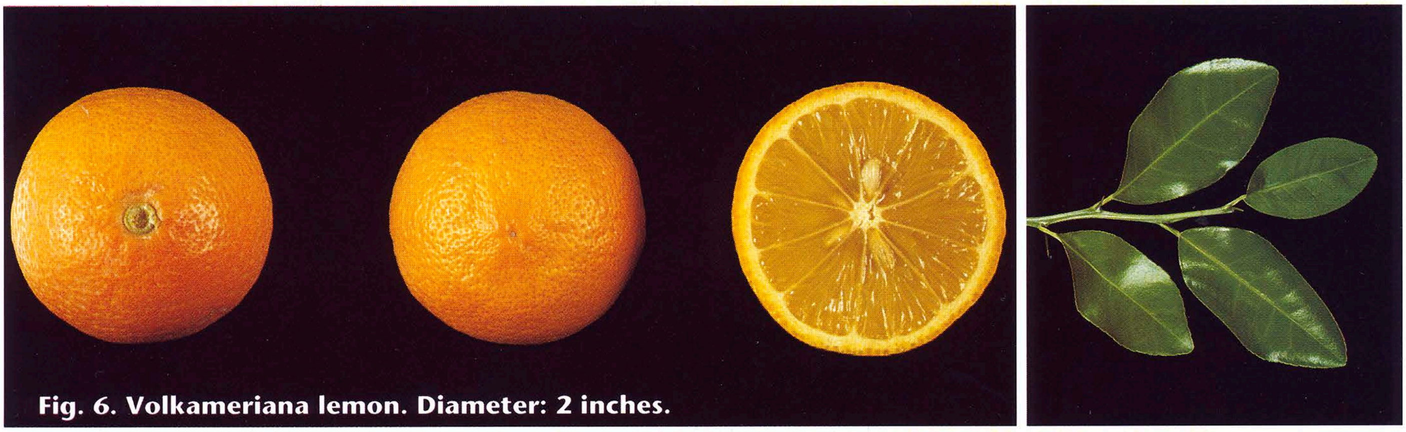

Fig. 6. Volkameriana lemon. Diameter: 2 inches.

Fig. 7. Yuma ponderosa lemon. Diameter: 4¾ inches.

MANDARIN TYPES AND HYBRIDS

Fig. 8. Cleopatra mandarin. Diameter: 1¾ inches.

ORANGE TYPES

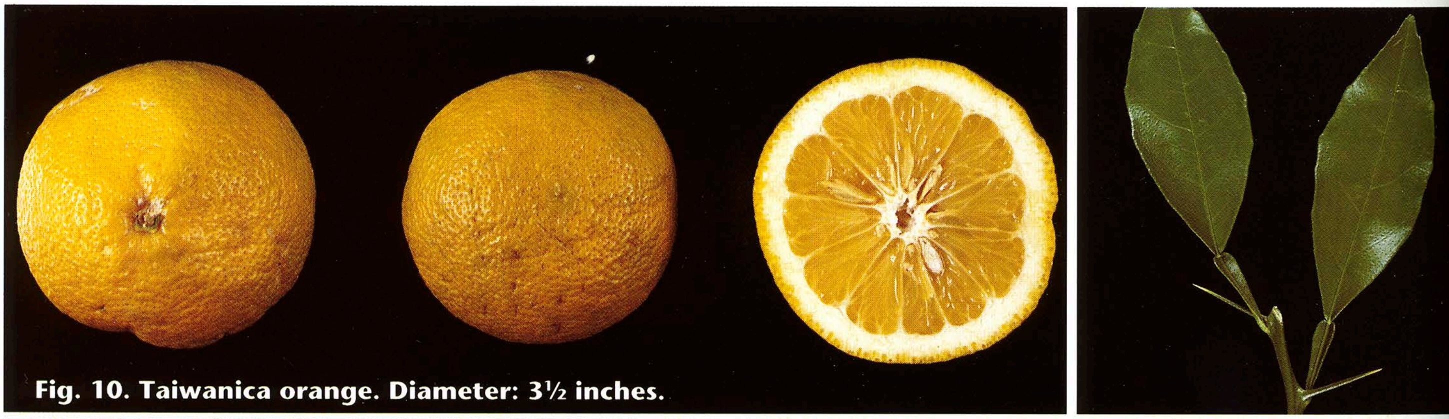

Fig. 10. Taiwanica orange. Diameter: 3½ inches.

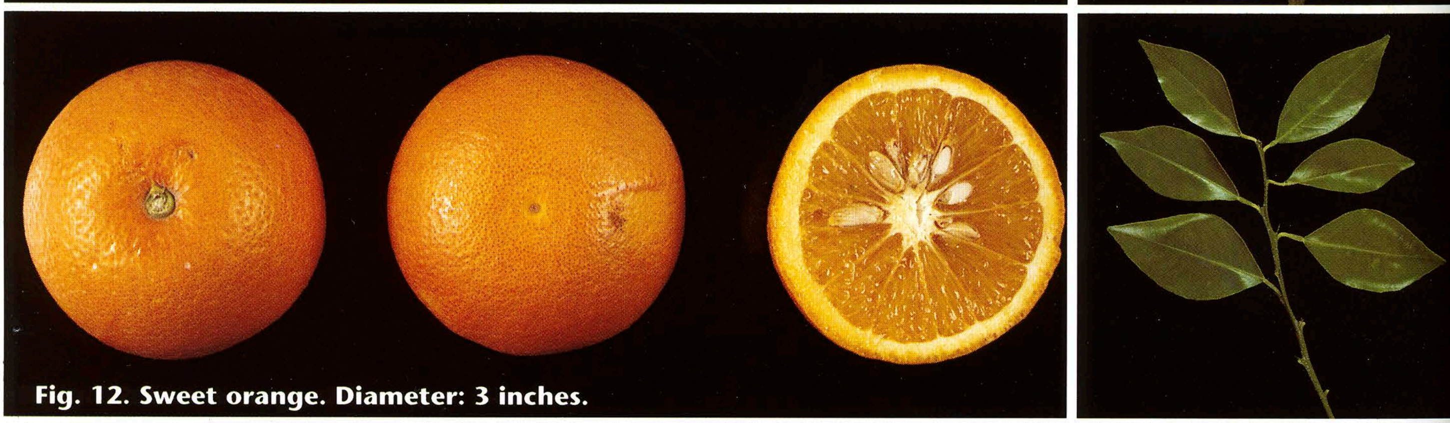

Fig. 12. Sweet orange. Diameter: 3 inches.

TRIFOLIATE ORANGE

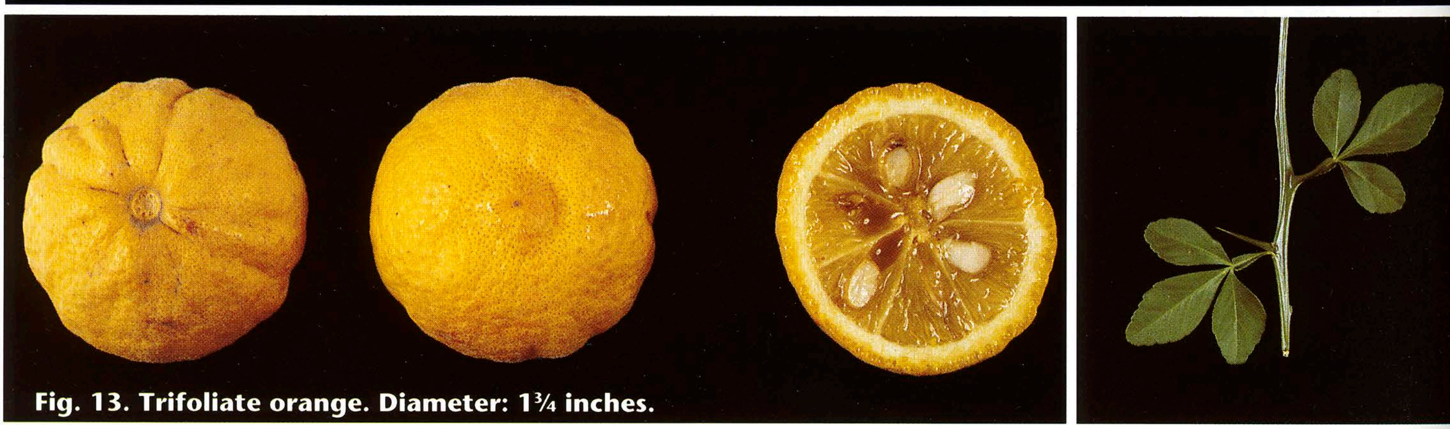

Fig. 13. Trifoliate orange. Diameter: 1¾ inches.

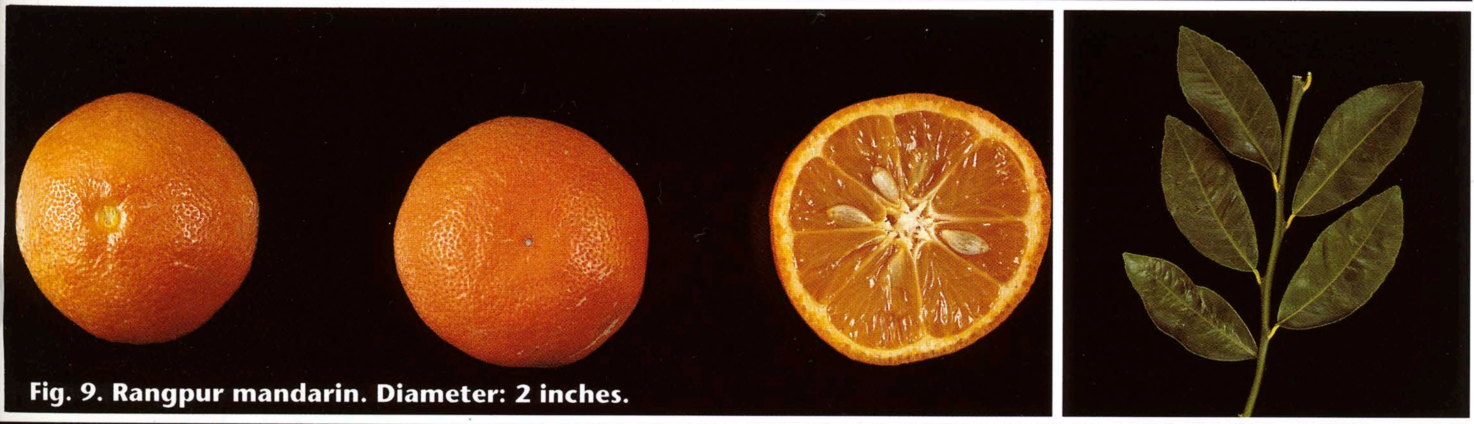

Fig. 9. Rangpur mandarin. Diameter: 2 inches.

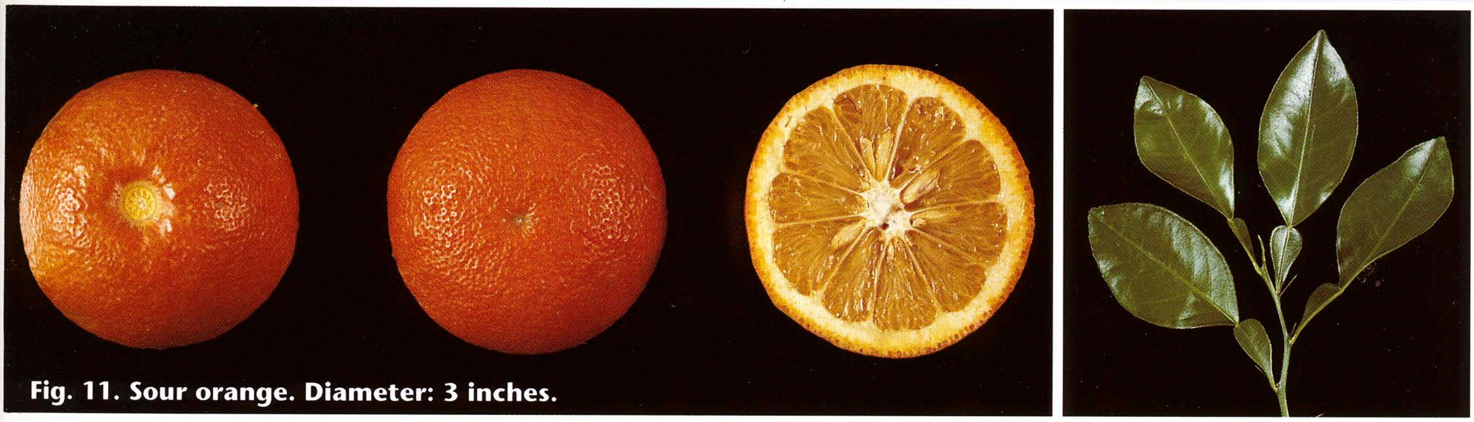

Fig. 11. Sour orange. Diameter: 3 inches.

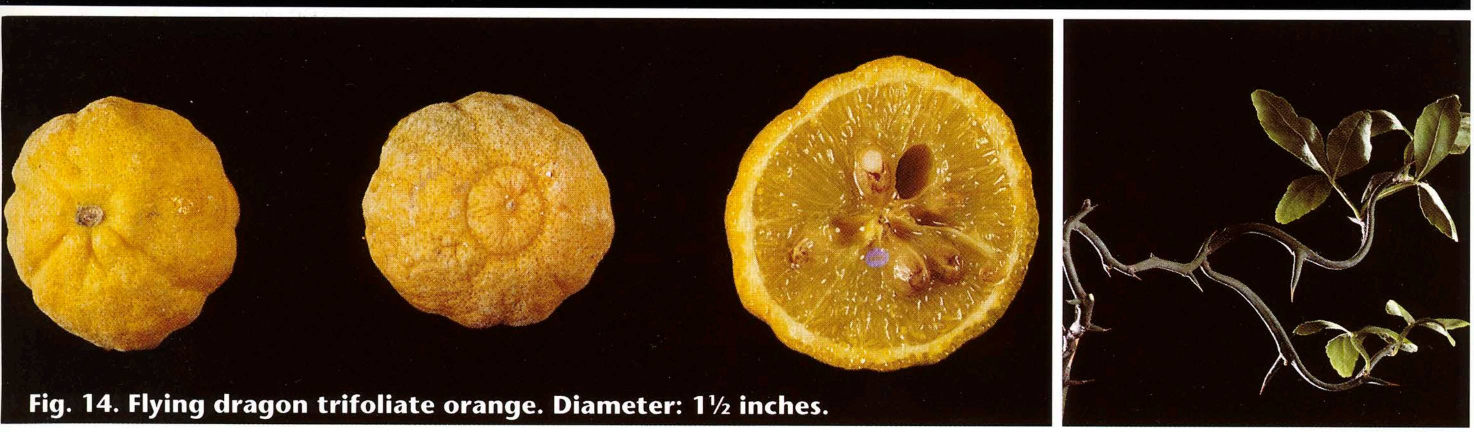

Fig. 14. Flying dragon trifoliate orange. Diameter: 1½ inches.

TRIFOLIATE HYBRIDS


Fig. 15. C–35 trifoliate hybrid. Diameter: 2 inches.

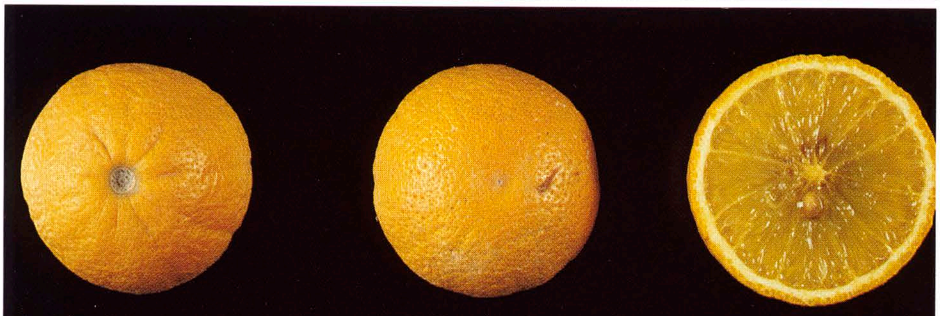


Fig. 16. C–32 trifoliate hybrid. Diameter: 2 inches.

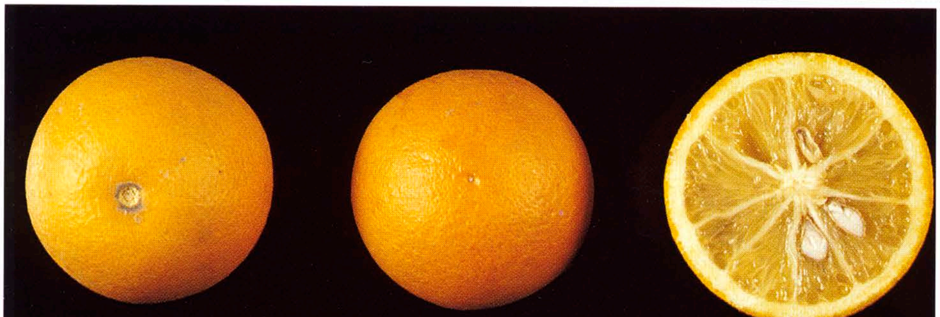
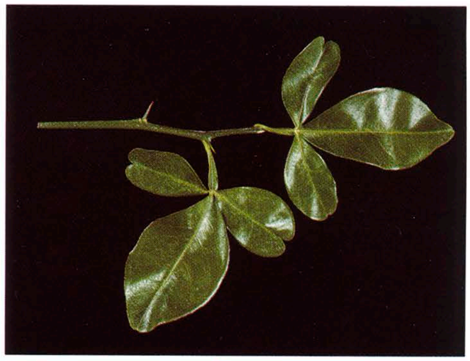

Fig. 17. Carrizo trifoliate hybrid. Diameter: 2 inches.

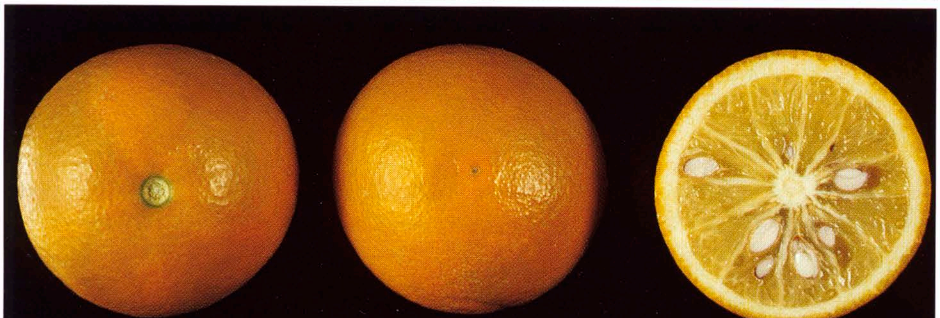


Fig. 18. Troyer trifoliate hybrid. Diameter: 2¼ inches.

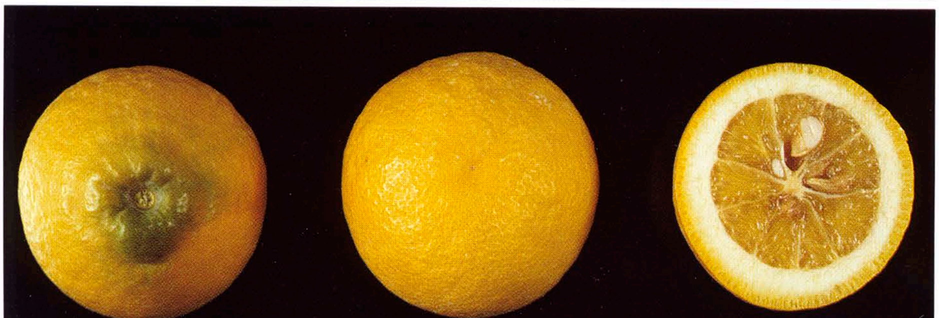


Fig. 19. Swingle trifoliate hybrid. Diameter: 2½ inches.

Trifoliate orange is the primary rootstock for citrus grown in cold areas. It is the slowest growing, least vigorous of all the rootstock groups. Trifoliate rootstocks often overgrow their scions (fig. 2).

Trifoliate root systems are shallow, with weak lateral development but abundant fibrous growth. A trifoliate seedling tree itself is cold hardy, and when used as a rootstock in a cool climate it will impart this quality to its scion. However, if trifoliate stock is used where winters can be warm with sudden freezes, the trees may sustain as much damage as trees on stocks that are less cold hardy. Saline soil or water will decrease the cold hardiness of trifoliate rootstocks.

Trifoliate rootstocks accumulate magnesium. They take up nitrogen less efficiently than rough lemon, and phosphorus more efficiently than rough lemon or sour orange. They are susceptible to zinc deficiency.

Flying Dragon trifoliate orange, fig. 14

A trifoliate selection, Flying Dragon, consistently produces dwarf trees.

TRIFOLIATE HYBRIDS

Three crosses between the genera *Poncirus* and *Citrus* have produced the five hybrids that make up the trifoliate hybrid group. The hybrids are C–32 citrange, C–35 citrange, Carrizo citrange, Troyer citrange, and Swingle citrumelo.

The first two, C–35 and C–32, are citranges, resulting from the cross of Webber-Fawcett trifoliate orange and 'Ruby' blood orange. The second two, Carrizo and Troyer, are also citranges, resulting from the cross of orange trifoliate and "Washington Navel" orange. Swingle is a citrumelo, the result of a grapefruit-trifoliate cross.

C–35 citrange (*C. sinensis* [L.] Osbeck × *P. trifoliata* [L.] Raf.), fig. 15

The C–35 rootstock is prone to zinc and manganese deficiencies. Trials thus far have produced variable yields with Navel scions: good in the San Joaquin Valley but poor after 3 years in Riverside County.

C–32 citrange (*C. sinensis* [L.] Osbeck × *P. trifoliata* [L.] Raf.), fig. 16

The C–32 rootstock, like C–35, is prone to zinc and manganese deficiencies. As a rootstock seed tree, it produces few fruit and an average of less than one seed per fruit.

Carrizo citrange (*C. sinensis* [L.] Osbeck × *P. trifoliata* [L.] Raf.), fig. 17

Unlike the experimental C–35 and C–32 citranges, Carrizo is a widely used rootstock. The Carrizo is the standard by which all Florida rootstocks are judged. In California, it is not used as much. In many cases its performance is indistinguishable from that of Troyer. It is prone to zinc and manganese deficiencies.

Troyer (*C. sinensis* [L.] Osbeck × *P. trifoliata* [L.] Raf.), fig. 18

Troyer, another widely used rootstock, is currently the most commercially successful rootstock in California, and is the standard by which all other California rootstocks are judged. In many cases, its performance is indistinguishable from that of Carrizo. It, too, is prone to zinc and manganese deficiencies.

Swingle citrumelo (*C. paradisi* Macf. × *P. trifoliata* [L.] Raf.), fig. 19

Swingle was previously tested as CPB 4475. Swingle's root system appears coarse with meager fibrous roots.

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Appendix A: Suggested Reading

BOOKS

1987

W. S. Castle. Citrus rootstocks. In: *Rootstocks for Fruit Crops*, R. C. Rom and R. F. Carlson, editors. John Wiley & Sons, New York.

1984

University of California Statewide IPM Project. *Integrated Pest Management for Citrus*. Univ. Calif. Div. Agric. Nat. Resour. Pub. 3303.

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1986

December. Vol. 72, no. 2, pp. 24–27. Test with Eureka, Lisbons, and new citrange rootstocks. R. M. Burns, H. J. Sakovich, and J. B. Carpenter.

November. Vol. 72, no. 1, pp. 8–10. Citrus tree size control with dwarfing agents. P. Broadbent et al.

September. Vol. 71, no. 12. The potential for dwarfing rootstocks for citrus. M. L. Roose.

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September. Vol. 68, no. 11, pp. 259–61. Dwarf citrus moves from theory to field. Anonymous.

1980

October. Vol. 66, no. 5, pp. 287–92. Phytophthora resistant rootstocks for Lisbon lemons in California. J. B. Carpenter, R. M. Burns, and R. F. Sedlacek.

Appendix B: Glossary

(Adapted from *Rootstocks for Florida Citrus*, 1989)

Acid (titratable acidity or TA). The total acid content of a citrus fruit, and the denominator of the TSS/TA ratio that denotes fruit ripeness. Also see *Total soluble solids*.

Biotype. An organism that has changed, whether through the sexual process or mutation, to become more or less resistant to a disease. Also, a disease agent, insect, or nematode that has developed the ability to attack a plant previously resistant to it, even though there are no visually observable changes.

Bud. A protuberance normally arising in the axil of a leaf and consisting of a greatly compressed stem with its growing point. Also see *Budding*.

Budding. A form of vegetative propagation that involves inserting a single bud with a small amount of bark and wood, or with bark only, into a cut on the rootstock seedling. The bud and rootstock are then wrapped to secure the bud firmly in place. Most citrus trees are propagated in this manner using a T-bud.

Budline. A specific source of propagation materials within a cultivar.

Bud union. The point of connection between a grafted scion and its rootstock.

Calcareous. Generally, a soil condition resulting from the presence of sufficient calcium carbonate (usually from marl, shells, or limerock) to cause the release of CO_2 when the soil is treated with cold dilute hydrochloric acid.

Clone. An asexually reproduced cultivar; a group of genetically uniform plants that have been propagated vegetatively from a single, original plant. A cultivar, such as Redblush grapefruit or Hamlin sweet orange, propagated in this manner, is referred to as having been clonally propagated and the cultivar itself is a clonal cultivar.

Cultivar. A group of cultivated plants (from cultivated variety) that can be distinguished from others by morphological, physiological, or other characteristics that are of practical significance and are retained through sexual or asexual reproduction. For example, Marsh and Redblush grapefruit are of the same species, *Citrus paradisi,* but of different cultivars. Redblush is distinguished from Marsh by its peel blush and its flesh color. These characteristics are maintained through vegetative propagation.

Fluting. The presence of ridges and furrows, rather than a smooth, uniform surface, on the trunks of some rootstocks.

Interstock. A third part of a citrus tree grafted between the scion and rootstock, usually by budding, during propagation. The interstock can make up a short piece of trunk or most of the trunk and the primary framework branches. Interstocks sometimes arise inadvertently when propagators topwork trees. A propagator may deliberately graft an interstock to impart a particular characteristic to the plant, but this is uncommon in citrus propagation.

Juvenility. The physiological state of immaturity expressed in citrus seedlings. Citrus plants in the juvenile phase do not produce flowers, usually have pronounced thorns, and are vigorous, often with a markedly upright growth form. The duration of the juvenile period varies from 1 to 2 years for Key lime, 2 to 3 years for lemon, 5 years for tangerine and mandarin, and 8 to 12 years for sweet orange and grapefruit.

Leaf blade. The main, broad, flattened portion of the leaf.

Leaf petiole. The stalk with which the leaf blade is attached to the stem.

Leaf petiole wing. An outgrowth or margin resembling a leaf blade and attached to the petiole proximal to the leaf blade.

Monoembryonic seed. A seed containing only one embryo (the embryo is sexual in origin); a cultivar that produces seeds containing only one embryo (e.g., Temple, Robinson, or Clementine mandarins and all of the pummelos [*C. grandis*]).

Nematode. A small, wormlike microscopic organism that can attack roots, causing tree decline and debilitation.

Nucellar embryony. The generation of embryos solely from maternal tissue, the nucellus. In a polyembryonic seed, these asexual embryos are present in addition to the single embryo that results from the normal (sexual) fertilization process. The rapidly growing nucellar embryos of some cultivars will generally prevent development of the sexual embryo. These cultivars then produce seedlings that are virtually 100 percent nucellar. Nucellar embryony is common to many citrus cultivars.

Nucellar seedling. A seedling that has developed from a nucellar, or vegetative, embryo. Such seedlings are genetically uniform, and with rare exception free of viruses and viroids. Initially juvenile, they eventually produce adult or fruiting portions that serve as a source of budwood with which to propagate nursery trees. Most rootstock seedlings are nucellar, and so have two important advantages: they are free of viral agents, and each is genetically identical to its parent tree, so its growth characteristics are highly predictable.

Nucellar cultivar or variety. A cultivar that has been propagated, usually clonally, from a nucellar seedling of that cultivar. Such cultivars should be free of budwood-transmitted viruses and viroids, and they often exhibit greater vigor. For these reasons, they yield better than old-line cultivars.

Polyembryonic seed. A seed containing multiple embryos (one embryo is sexual, and the rest are asexual, nucellar embryos). A polyembryonic cultivar produces seed that contain more than one embryo per seed.

Replant. A plant used to replace another that has died or been removed.

Resistance. A relationship between a host and a disease agent or pest, in which the agent or pest may penetrate the host but does not reproduce. The host is unaffected by the disease.

Rootstock (stock). The portion of a grafted tree located below the bud union and consisting of the roots and lower trunk.

Scion. The portion of a grafted tree located above the bud union and consisting of the limbs and upper trunk. The scion variety determines what sort of fruit the tree will bear.

Sprout. A vigorous shoot arising from the roots, trunk, or main framework branches of a tree. The removal of sprouts is termed "sprouting."

Susceptibility. A relationship between a host and a disease agent or pest, in which the agent or pest penetrates the host and freely reproduces. The host is adversely affected, and may ultimately die.

Tolerance. A relationship between a host and a disease agent or pest, in which the agent or pest penetrates the host and reproduces only modestly. The host is slightly affected by the disease.

Total soluble solids (TSS). The measure of sugars in a citrus fruit, and the numerator of the TSS/TA ratio that determines fruit maturity. Also see *Acid.*

True-to-type. A key concept in preserving genetic identity during vegetative propagation of clones. It involves assurance that the source propagation material is correctly named and that the source has not changed in any significant way.

Variety. A synonym for *Cultivar* (the preferred term). The term *variety* is more commonly used but less precise than *cultivar*.

Vegetative propagation. Propagation without the sexual process that is involved in gametic or sexual seedling production. The plants produced by vegetative propagation are genetically the same. This includes plants produced by budding, grafting, cutting, layering, nucellar embryony, and tissue culture.

Viroid. A viruslike or naked virus particle that does not have the protein sheath of a virus. Citrus viroids include exocortis and xyloporosis.

Virus. A disease-causing particle composed of a nucleic acid nucleus surrounded by a protein sheath. Tristeza and psorosis are viruses.

Zygotic embryo (zygote). A miniaturized plant in the seed formed by the fusion of an egg cell from the female parent with gametes from the pollen tube of the male parent. The resulting seedling will have a mixture of the characteristics of both parents.

Appendix C: Nursery Characteristics of Citrus Rootstocks

Rootstock	Remarks
Lemon types	
Macrophylla (Alemow)	Seeds are polyembryonic but seedlings are variable, moderately vigorous, and bud and force easily. Those grown in greenhouses tend to lean readily, leading to excessive sprout development.
Rough lemon	Seeds are highly nucellar and germinate well. Seedlings have low vigor, but scion buds generally force easily and grow rapidly, especially in warm or hot climates. They are susceptible to scab and leaf spot (*Alternaria citri* Ellis and Pierce); seedlings tend to branch close to the ground.
Volkameriana	Similar to rough lemon except seedlings are more variable and vigorous, with straight trunk and are relatively unaffected by *Alternaria*. Little tolerance of herbicides.
Mandarin types	
Cleopatra mandarin	Seeds are highly nucellar and germinate best at temperatures above 30°C. Seedlings are vigorous in hot climates but slow-growing in cool areas, where plastic tunnels or greenhouses can improve germination. Seedlings are almost thornless, unbranched with short internodes, and cold hardy. They are easy to bud, but sometimes difficult to force.
Rangpur	Seeds are highly nucellar and germinate readily. Seedlings are vigorous, easy to handle, susceptible to *Alternaria*, bud readily, and force easily.
Orange types	
Sour orange	Seeds are 70 to 85% nucellar and germinate best at about 26°C. Seedlings are thorny, vigorous, with straight trunks and moderate branching, easy to bud and force, cold tolerant, and very susceptible to scab (*Elsinoe fawcetti* Bitancourt and Jenkins). Bud take may be low when ambient temperature is above 30°C.
Sweet orange	Seed are 70 to 90% nucellar but this varies with the cultivar. Seedlings are thorny, bushy, and vigorous, and generally easy to bud and force. Leaf diseases are rare.
Trifoliate orange	Seeds are about 90% nucellar and may require chilling for best germination. Seedlings have low to moderate vigor, are very thorny, and small-flowered cultivars are bushy, making them difficult to bud. Seedlings respond to prolonged day length, but generally go dormant outdoors in the fall. Flying Dragon seedlings must be rogued carefully because of the large number of off-types.
Trifoliate hybrids	
C-35	Produces approximately 10% zygotic seedlings. Seedlings are fairly uniform.
C–32 citrange	Produces approximately 10% zygotic seedlings. However, among nucellar seedlings leaf morphology is more variable than for Troyer and Swingle, and therefore the percentage of off-type seedlings appears higher than 10%. Thus, it is difficult to identify true-to-type seedlings.
Carrizo and Troyer citrange	Both citranges are excellent nursery plants with highly nucellar seeds, and both produce uniform, vigorous unbranched seedlings that are easy to bud and force. Tetraploids occur at rates of about 1 to 2%. Carrizo seeds can transmit psorosis. Seedlings show sensitivity to preemergence herbicides.
Swingle	Seeds are about 90% nucellar with an excellent germination percentage. Seedlings are very vigorous, uniform, upright, and easy to bud, but forcing may be erratic, with some buds not breaking. Seedlings become dormant in fall and are sensitive to preemergence herbicides.

Source: William Castle, "Citrus rootstocks," in *Rootstocks for Fruit Crops*, edited by Roy C. Rom and Robert Carlson, ©1987 by John Wiley & Sons, Inc. Modified by permission of John Wiley & Sons, Inc.

Chart I: Rootstock-Scion Combinations

(C = Compatible   I = Incompatible   U = Uncertain because observed less than 10 years   — = No information)

Rootstock	Kumquat	Navel orange	Valencia orange	Grapefruit	Mandarin[1]	Lisbon[2] lemon	Eureka[2] lemon
Lemon types							
Macrophylla	—	—	C	C	—	I[3]	I[3]
Rough lemon	—	C	C	C	C	C	I
Volkameriana[4]	—	U	C	C	U[5]	C	C
Yuma ponderosa[4]	—	U	C	—	U	C	C
Mandarin types							
Cleopatra mandarin[6]	—	C	C	C	C	I	I
Rangpur[4]	—	C	C	C	U	C	C
Orange types							
Taiwanica	—	U	C	C	U	—[7]	—[7]
Sour orange	I[8]	C	C	C	C	C	I
Sweet orange	—	C	C	C	C	C	C
Trifoliate orange	C[9]	C[10]	C	C	C[11]	C	I
Trifoliate hybrids							
C-35 citrange	—	C	C	U	C	C	—
C-32 citrange	—	C	C	U	C	C	—
Carrizo citrange	—	C	C	C	C[11]	C	I
Troyer citrange	—	C	C	C	C[11]	C	I
Swingle	—	C	C	C	U	C	I

[1]Compatibility of mandarins varies with cultivar. [2]See Chart II. [3] Rootstock necrosis often develops. [4]Information presented is based on limited observations. [5]With Satsumas this combination develops a bud union overgrowth. [6]Especially good for cultivars with larger fruit sizes; Temple, Nova, Murcott, Orlando tangelo, and grapefruit. [7]Bud unions weak, often break. [8]Slow-growing, unhealthy-looking combination. [9]Good production with this combination. [10]With some scions, particularly Frost nucellar navel, trifoliates decline after 20 years due to bud union abnormalities. Rich 16–6, an experimental trifoliate, does not display this decline. [11]Sometimes a short-lived combination.

Chart II: Lemon Compatibility Status

(C = Compatible[1]   I = Incompatible[2]   U = Uncertain because observed less than 10 years   — = No information)

Rootstock	Eurekas, all	Limoneira 8A	Monroe	Prior	Strong
Lemon types					
Macrophylla (Alemow)	I (5–12)	I (16–21)	I (15)	—	I (15)
Rough lemon	I (11)	C (20)	—	—	—
Volkameriana	—	C (20)	—	—	—
Yuma ponderosa	C (20)	C (20)	C (20)	C (20)	C (20)
Mandarin types					
Rangpur	—	C (20)	—	—	—
Orange types					
Taiwanica	—	—	—	—	—
Sour orange	I (12–15)	C (20)	I (12–15)[3]	C (20)	C (20)
Sweet orange	C (20)	C (20)	C (20)	C (20)	C (20)
Trifoliate orange	I (4)	C (20)	—	—	C (20)
Trifoliate hybrids					
Troyer citrange	I (2–8)	C (20)	C (20)	C (20)	—
Swingle	—	C[4]	—		—

SOURCE: Schneider and Sakovich 1984, and additional information.
[1]"C (20)" is used to indicate freedom from necrotic tissue at the bud union of trees more than 20 years old.
[2]Following "I" the numbers indicate the age in years when delayed incompatibilities were first observed.
[3]Trees affected were on Seville bitter orange in the 1940 strain plot at Riverside, CRC project 1134 (1951–1954). However, 25-year-old Ledig and Monroe Lisbons on Bradbury sour oranges at Limoneira appeared to be free of sour orange rootstock necrosis.
[4]The oldest trees sampled were less than 20 years old.

Chart III: Disease, Virus, and Nematode Susceptibility

Rootstock	Phytophthora[1] Root rot	Phytophthora[1] Gummosis	Armillaria	Citrus nematode[2]	Controlled by budwood certification: Tristeza[3]	Exocortis	Cachexia	Woody gall
Lemon types								
Macrophylla	tolerant[4]	tolerant	susceptible	susceptible	susceptible	tolerant	susceptible	tolerant
Rough lemon	susceptible[5]	susceptible	susceptible	susceptible	tolerant	(?)[6]	tolerant	(?)
Volkameriana	susceptible	susceptible	—[7]	—	tolerant	tolerant	—	susceptible
Yuma ponderosa	tolerant	susceptible	—	susceptible	tolerant	—	—	—
Mandarin types								
Cleopatra mandarin	susceptible	susceptible	—	susceptible	tolerant	tolerant	(?)	tolerant
Rangpur	susceptible	susceptible	susceptible	susceptible	tolerant	susceptible	susceptible	—
Orange types								
Taiwanica	susceptible	tolerant	tolerant	susceptible	susceptible	tolerant	—	—
Sour orange	intermediate	tolerant	susceptible	susceptible	susceptible	tolerant	tolerant	tolerant
Sweet orange	susceptible	susceptible	—	susceptible	tolerant	tolerant	tolerant	tolerant
Trifoliate orange	tolerant	tolerant	—	tolerant	tolerant	susceptible	tolerant	—
Trifoliate hybrids								
C–35 citrange	tolerant	tolerant	—	tolerant	tolerant	—	—	—
C–32 citrange	tolerant	tolerant	—	susceptible	tolerant	—	—	—
Carrizo citrange	intermediate	tolerant	susceptible	susceptible	tolerant	tolerant[4]	tolerant	tolerant
Troyer citrange	intermediate	tolerant	susceptible	susceptible	tolerant	tolerant[4]	tolerant	tolerant
Swingle	tolerant	tolerant	—	tolerant	tolerant	tolerant	tolerant	—

[1]Root rot and gummosis are caused by both *Phytophthora citrophthora* and *P. parasitica*. Root rot is caused by *P. parasitica* in summer and *P. citrophthora* in winter. Susceptibility to the two pathogens varies among rootstocks but within a rootstock responses are similar. [2](*Tylenchulus semipenetrans*) Biotypes 1,2,3 (McCarty et al. 1979).
[3]Widespread and naturally transmitted in southern California, consequently not controlled by budwood there.
[4]Produces some dwarfing but no cracking or scaling.
[5]Variation among cultivars.
[6]Contradictory evidence.
[7]No information available.

Chart IV: Responses of Rootstocks to Soil and Climate

(good = best performance acceptable = intermediate poor or unsatisfactory = noneconomic performance — = no information)

	Soil factors							Climate
Rootstock	Chlorides[1]	Boron	Calcareous soils	Poor drainage	Sand	Loam	Clay	Cold hardiness
Lemon types								
Macrophylla	acceptable	good	acceptable	(?)[2]	good	acceptable	unsatisfactory	poor
Rough lemon	acceptable	acceptable	(?)	unsatisfactory	good	acceptable	unsatisfactory	unsatisfactory
Volkameriana	acceptable	—	—	—	good	acceptable	—	(?)
Yuma ponderosa	—	—	—	poor	—	acceptable	—	—
Mandarin types								
Cleopatra mandarin	good	(?)	good	unsatisfactory	(?)	acceptable	acceptable	good
Rangpur	good	acceptable	good	—	acceptable	acceptable	acceptable	(?)
Orange types								
Taiwanica	acceptable	acceptable	acceptable	—	acceptable	acceptable	acceptable	acceptable
Sour orange	acceptable	acceptable	acceptable	acceptable	unsatisfactory[3]	acceptable	acceptable	good
Sweet orange	(?)	acceptable	poor	unsatisfactory	acceptable	acceptable	acceptable[4]	acceptable
Trifoliate orange	poor	unsatisfactory	poor	acceptable	unsatisfactory	acceptable	good	good
Trifoliate hybrids								
C–35 citrange	—	—	—	—	—	—	—	—
C–32 citrange	—	—	—	—	—	—	—	—
Carrizo citrange	unsatisfactory	acceptable	unsatisfactory	unsatisfactory	acceptable	acceptable	acceptable	acceptable[5]
Troyer citrange	unsatisfactory	acceptable	unsatisfactory	unsatisfactory	acceptable	acceptable	acceptable	acceptable[5]
Swingle	acceptable	acceptable	unsatisfactory	—	acceptable	acceptable	unsatisfactory	good

[1] In soil or irrigation water.
[2] Conflicting evidence; extremes of performance have been observed.
[3] Poor fruit production.
[4] Sweet orange grows well on clay but overirrigation can render it susceptible to phytophthora.
[5] Troyer and Carrizo are cold hardy during cold weather but can easily be stimulated to flush by periods of warm weather.

Chart V: Effects of Rootstocks on Horticultural Traits

(High, medium, and low, or large, medium, and small = relative rankings
— = no information)

Rootstock	Tree characteristics			Fruit quality					
	Tree vigor	Tree size	Drought tolerance	Peel	TSS	Acid	Juice %	Fruit size	Yield
Lemon types									
Macrophylla	high	med	—	coarse/ thick	low	low	low	large	high[1]
Rough lemon	high	med	high	coarse/ thick	low	low	low	large	high
Volkameriana	high	med/ large	low[2]	coarse/ thick	low	low	low	large	high
Yuma ponderosa	high	large[2]	—	coarse/ thick	low	low	low	large	high
Mandarin types									
Cleopatra mandarin	med	large	med/ low	med	med	high	high	small	med[3]
Rangpur	var[4]	var[4]	high	med	low/ med	low/ med	low/ med	med	high[1]
Orange types									
Taiwanica	med	med	—	—	low	low	low	med	low
Sour orange	med	med	high	smooth, thin	high[5]	high[5]	high[5]	med[6]	med
Sweet orange	med	large	low[7]	—	high	high	high	med/ small	med/ high
Trifoliate orange	low	var[4,8] med/ small	low[7]	smooth, thin	high[5]	high[5]	high[5]	small/ med	med
Trifoliate hybrids									
C–35	low	small[9]	—	med	high	high	high	med	med
C–32	high[10]	large	—	med	high	high	high	med	high
Carrizo citrange	med[11]	med	med	med[12]	high	high	high	med	med
Troyer citrange	med	med	med	med[12]	high[13]	high	high	med	med
Swingle	low	small[9]	high	med[12]	high[14]	high[14]	high[14]	med	med[14]

[1]Particularly in early years.
[2]Evaluation based on limited or preliminary data.
[3]Slow to begin bearing.
[4]Conflicting reports; characteristic may depend on scion and location.
[5]Good rootstock for cultivars of low internal quality.
[6]Not suggested for small-fruited cultivars; sour orange accentuates this characteristic.
[7]Sweet orange and trifoliate are particularly drought sensitive on sandy soils.
[8]Varies with soil.
[9]Varies with scion.
[10]Higher vigor than Troyer.
[11]Under some conditions (Florida) displays higher vigor and bears earlier than Troyer.
[12]This rootstock exacerbates creasing with a sweet orange scion.
[13]Troyer can produce acid fruit in cool areas.
[14]In arid climates, produces better yields and higher quality of "Redblush" grapefruit and "Orlando" tangelo than most rootstocks, including sour orange.