Choosing a Rootstock

Choosing an appropriate rootstock for a new planting is among the most important decisions a grower makes because it lasts for the life of the planting. Growers should systematically consider the factors that affect rootstock performance on the specific site before selecting a rootstock. This chapter reviews the main factors that influence rootstock performance and summarizes the characteristics of the commonly used California rootstocks.

Once the decision is made on which scion variety to use, incompatible rootstocks can be eliminated. The fruit quality of the scion can also influence rootstock selection. Rootstocks that reduce solids and acid content (e.g., the Rough Lemon group) should not be used with a scion that also has low solids and acids, but they may be acceptable for a higher-quality scion. Similarly, with most scions, rootstocks that increase fruit size are desirable, but late navel oranges tend to have such large fruit sizes that a further increase may decrease crop value.

Rootstocks can strongly influence a tree’s response to a variety of stress factors. Important soil factors include salinity, poor drainage, and calcareous soils. Climatic stresses such as the probability of freeze should be considered. In California, the major diseases and pests that influence rootstock choice are Phytophthora gummosis and root rot, citrus nematode, and citrus tristeza virus (CTV). Some other diseases, including dry root rot and Diaprepes weevil, are either rare or affect all rootstocks similarly. Holding fruit for late harvest can also be considered a stress on the tree and fruit. Rough Lemon rootstocks cause high levels of granulation in late-harvested navel oranges, including Lane Late. Choosing one of these rootstocks limits the harvest window available to the grower.

After eliminating unacceptable choices based on these considerations, the grower can choose among the remaining rootstocks. Using a standard rootstock with a long history in California is less risky than using a newer rootstock. However, newer rootstocks may turn out to have higher yield or longevity. Risk can be reduced by using knowledge about the performance of various rootstocks on the planting site. Local experience is often the best guide, so consider planting a small area with some newer rootstocks to evaluate their performance at your site. The experience of others on nearby sites with similar soils and scions can also be very helpful. For a summary of rootstock characteristics, see table 5.1.

General Notes on Rootstock Descriptions

**Origin:** Information on the origin of the rootstock.

**Nursery behavior:** Seediness of the rootstock fruit, degree of uniformity of seedlings, and ease of pushing buds of common scions under greenhouse conditions.

**Tree size:** The effect of the rootstock on tree size in locations where it is well adapted, not locations where it is stressed by soil, disease, or crowding. In general, comments apply to trees of any age. Exceptions, such as trees that typically grow rapidly when young but more slowly later, are noted. For all scions except Eureka lemon, trees on Troyer or Carrizo are considered standard size. Trees more than 20% larger than the standard (in canopy volume) are considered to be large, while those more than 20% smaller are semidwarf (“intermediate” in table 5.1). Most data on tree size are for oranges; the limited data on lemon
Table 5.1. Effects of citrus rootstocks on tree performance, disease resistance, and fruit quality

<table>
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<th>Rootstock</th>
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<td>I-Lg</td>
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<td>C35</td>
<td>I-H</td>
<td>I</td>
<td>T</td>
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<td>T</td>
<td>P</td>
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<tr>
<td>Swingle</td>
<td>I</td>
<td>I</td>
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<td>T</td>
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<tr>
<td>Trifoliate</td>
<td>I-H</td>
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<tr>
<td>Sour Orange</td>
<td>I-H</td>
<td>I-Lg</td>
<td>S</td>
<td>T</td>
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<td>G</td>
</tr>
<tr>
<td>Rough Lemon</td>
<td>I-H</td>
<td>I-Lg</td>
<td>T</td>
<td>S</td>
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<tr>
<td>Volkameriana</td>
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<td>Macrophylla</td>
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<td>I</td>
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</tr>
</tbody>
</table>

Key: G = good, H = high, I = intermediate, L = low, Lg = large, P = poor, S = susceptible, T = tolerant.

Notes:
*EL = Eureka lemon, FN = Fukumoto navel, FNN = Frost nucellar navel, LL = Lisbon lemon, O = oranges (all).
†Eureka lemon often declines by about 10 years, Lisbon lemon by 15 to 20 years.

and grapefruit trees indicates generally similar behavior. Mandarins are less well characterized.

**Yield:** Actual yield (pounds of fruit per tree) of trees planted at standard density (about 100 trees per acre for oranges) in an area where the rootstock is well adapted. Since yield changes over time, the evaluation given is approximately the cumulative yield of trees during the first 10 to 20 years. In many orchards, trees will have reached full size by this time. In any case, little data on performance of trees older than 20 years is available.

**Yield efficiency:** Yield per unit of canopy volume, a ratio used to predict the productivity of a planting in which tree density is optimized for tree size. Rootstocks producing smaller trees should be planted at a higher density to achieve this. Tree cost is not considered, so this is not an economic efficiency measure. A vigorous rootstock planted at the same density will require extensive pruning or tree removal earlier than a less vigorous rootstock. The grower must determine the optimal planting density for a particular scion-rootstock combination. A rough guideline for tree spacing is that spacing for a rootstock classed as intermediate should be about 75% of that for a rootstock classed as large. For example, on sites where trees on Carrizo produce a large tree and a standard spacing is 20 feet, trees on C35 should be planted at a spacing of 15 feet.

**Internal fruit quality:** Solids, acid, juice content, and rag are considered. High quality for oranges would combine the following: a solids to acid ratio of at least 10:1 or a California standard value of 99, high levels of solids and acids (richer flavor), at least moderately high juice content, and low rag.

**External fruit quality:** High external quality would be a smooth, firm rind that is thin or of moderate thickness, with intense rind color. If rootstocks are known to affect color break, this is noted here.
Fruit size: The average size of fruit in locations where the rootstock is well adapted. This is primarily based on packline sizing of navel and Valencia oranges from trials at Lindcove Research and Extension Center. When these results do not agree with others reported in the literature, a comment is made.

Tristeza tolerance: A summary of the performance of CTV-infected orange varieties on the rootstock. Only tolerance to common California CTV isolates is considered. Trees with good tolerance do not show quick decline, are no more than slightly stunted, and have fruit of normal size.

Phytophthora tolerance: Tolerance to both gummosis and root rot are covered, and both *Phytophthora parasitica* and *P. citrophthora* are included. Gummosis is almost never observed on a rootstock rated as resistant. For root rot, the main character is tolerance—that is, the ability of the tree to grow normally in locations where root rot is common for susceptible rootstocks. The standard of susceptibility is sweet orange.

Citrus nematode resistance: Level of resistance to citrus nematode races found in California. There are at least four distinct races of citrus nematode in California. All can infect Sweet Orange, three can attack Troyer and Carrizo, and one can attack some Trifoliate Orange selections. Responses to each race are discussed separately when available. The distribution of these races in California has not recently been characterized. The rating given is based primarily on seedling tests in a greenhouse, but available evidence indicates that it correlates well with performance of trees in the field. Rootstocks with excellent resistance should be little damaged by citrus nematodes in the field.

Soil adaption: For many rootstocks, their adaptation to various soils is rather anecdotal in that few trials have compared rootstocks on different soil types. Salinity tolerance is fairly well known for many rootstocks, as is the extent of their iron chlorosis on calcareous soils. It is difficult to translate a soil analysis into guidelines that accurately predict performance of all rootstocks. Major soil problems in California are poor drainage (poor aeration), salinity (generally chlorides), and calcareous soils that lead to iron deficiency, typically called iron chlorosis. The best guide to rootstock responses to these stresses is performance of a standard rootstock (Carrizo or Troyer) on this soil. If these rootstocks perform well, most rootstocks will be suitable. If there are problems with Carrizo, more careful investigation will be needed.

Freeze tolerance: Rootstocks affect freeze tolerance of both trees and fruit. For trees, tolerance is primarily due to the degree of dormancy induced by cool temperatures before the freeze occurs. This is different than the common situation in Florida and Texas, where fall and winter temperatures are warmer than in California and trees do not become as dormant. Therefore, freeze tolerance ratings from Florida and Texas do not always apply to trees grown in California. The ratings given are primarily based on observation of trees in rootstock trials that were subject to natural freezes. Rootstocks can also confer some degree of freeze tolerance to fruit, probably through their effects on soluble solids content. Fruit with high soluble solids are somewhat more freeze tolerant than those with low soluble solids content.

Incompatibility: Compatibility with various scion cultivars, summarized from all available evidence; ratings assume that no pathogens such as exocortis viroid are present. The major practical concern is delayed incompatibility, which becomes evident when trees decline after 10 to 15 years. This is usually characterized by a bud union with a severe shoulder in which the scion is much smaller than the rootstock (see fig. 5.1). Ratings are based on available evidence from California and elsewhere, but many rootstock-scion combinations may not have been tested. In general, varieties in the major fruit types (oranges, lemons, grapefruit, and mandarins) behave similarly, but exceptions to this may occur: for example, the differences in compatibility of Eureka and Lisbon lemons with Trifoliate Orange hybrid rootstocks.

Overall: A judgment on the overall value of the rootstock and specific environments in which it performs well or should not be grown.

### Carrizo and Troyer Citranges

**Origin:** Troyer and Carrizo rootstocks originated from a single hybrid seedling of Washington navel orange × Trifoliate Orange (parental cultivar unknown) made in 1909; the hybrid was named Troyer in 1934. The identity of seed planted at Carrizo Springs, Texas, was apparently lost, and this source was named Carrizo in 1938. While there are occasional reports of differences in performance between Troyer and Carrizo, there is no statistically convincing evidence that either is superior.
Figure 5.1 Bud unions of 25-year-old Washington navel orange on selected rootstocks at Lindcove Research and Extension Center. Photos: C. Federici.
Nursery behavior: Rootstock fruit are very seedy, and the seedlings are genetically very uniform (at least 98% nucellar). Buds push fairly well and trees grow well in the nursery.

Tree size: Tree size is standard with nearly all scions. Trees continue to grow for many years and may eventually become quite large if not controlled by pruning or crowding.

Yield: Trees on Troyer or Carrizo typically have good to excellent yields.

Yield efficiency: Moderate.

Internal fruit quality: Good to excellent with all common scions. Overall, fruit quality is good.

External fruit quality: Peel quality is generally fair to good, but creasing can be a problem with oranges. Peel thickness is medium, and texture is intermediate.

Fruit size: Fruit size is generally average in locations where trees are well adapted.

Tristeza tolerance: Good tolerance to typical California isolates.

Phytophthora tolerance: Excellent resistance to gummosis. Moderate tolerance to root rot.

Citrus nematode resistance: Resistant to some citrus nematode races, susceptible to others. The frequency and distribution of resistance-breaking races in California is not clear.

Soil adaptation: Well adapted to loam, sandy loam, and sandy soil. May perform poorly on very heavy soils with poor drainage. Poor tolerance to salinity (chlorides) and to highly calcareous soils, but among the best Trifoliate hybrids. Usually acceptable on slightly calcareous soils (e.g., pH 7.8).

Freeze tolerance: In California, trees on Carrizo or Troyer generally have relatively good freeze tolerance, because our climate induces dormancy. However, they are typically somewhat more susceptible than those on Trifoliate. Fruit also have relatively good freeze tolerance. In climates with warmer winter temperatures, such as Florida and Texas, trees often do not become dormant and are not particularly freeze tolerant.

Incompatibility: Good compatibility with all oranges, grapefruit, and Lisbon lemons. Considered incompatible with Eureka lemon, although the age at which incompatibility becomes evident varies considerably over locations and perhaps among Eureka selections. Compatibility with mandarins is complex and not well understood. Nearly all mandarins perform well for at least 10 to 15 years, but many eventually develop bud union crease and decline.

Overall: Excellent rootstocks that have been standards in California for many years. Good balance of traits and few major defects. Except for sites with calcareous soils, a very low risk choice. In specific locations, other rootstocks may perform better, but these are less broadly adapted than Carrizo or Troyer and therefore are more likely to have problems in a new location.

C35 Citrange


Nursery behavior: Seed source trees generally produce fair to good crops, fruit have 8 to 12 seed per fruit, and the seedlings are moderately uniform (about 85% nucellar). Buds push fairly well and trees grow well in the nursery.

Tree size: Somewhat reduced with nearly all scions. Typically, young trees grow well, so that size differences do not become apparent until trees have borne several crops. Relative to Carrizo, canopy volume has varied from 54% in a replant trial with Valencia to 127% with Lane Late in a replant trial of 8-year-old trees. Over 11 trials, tree size averaged about 83% as large as the trees on Carrizo. Tree size seems to depend more on the site than on the scion.

Yield: Trees on C35 typically have good to excellent yields for their size, but absolute yields are sometimes lower because of reduced tree size. Over 11 trials, the yield per tree ranged from 75% of that of Carrizo in a trial with Lane Late scion to 159% in a trial with Washington navel. The average yield over all trials was 106% of that of trees on Carrizo. Trials in which trees on C35 had higher yields than those on Carrizo or Troyer were replant trials in which the yield of Troyer or Carrizo was low or moderate.

Yield efficiency: High, mainly because trees on C35 are usually as productive as those on Carrizo or Troyer but are smaller in size.

Internal fruit quality: Good to excellent with all common scions, generally similar to the fruit quality of trees on Carrizo. Overall, fruit quality is good.

External fruit quality: Peel quality is generally fair to good. Peel thickness is medium, and texture is also intermediate. With some scions, color
break may be delayed by a few days relative to Carrizo, but this is not always observed.

**Fruit size:** Generally average in locations where trees are well adapted.

**Tristeza tolerance:** Good tolerance to typical California isolates.

**Phytophthora tolerance:** Excellent resistance to gummosis and very good tolerance to root rot caused by both *P. parasitica* and *P. citrophthora*.

**Citrus nematode resistance:** Resistant to all citrus nematode races found in California.

**Soil adaptation:** Well adapted to loam, sandy loam, and sandy soil. May perform poorly on very heavy soils with poor drainage, but not much data on this is available. Poor tolerance to salinity (chlorides) and to calcareous soils, where it is somewhat worse than Carrizo.

**Freeze tolerance:** In California, trees on C35 generally have relatively good freeze tolerance, because our climate induces dormancy. However, they are typically somewhat more susceptible than those on Trifoliate. Fruit also have relatively good freeze tolerance. In climates with warmer winter temperatures, such as Florida and Texas, trees may be much less freeze tolerant.

**Incompatibility:** Good compatibility with all oranges, grapefruit, and Lisbon lemons. Fuku- moto navel on C35 is subject to a decline of unknown cause that may be a type of incompatibility. Appears to be strongly incompatible with Eureka lemon, but data is limited. Compatibility with mandarins is complex and not well understood. Nearly all mandarins perform well for at least 10 to 15 years, but many eventually develop bud union crease and decline.

**Unknowns:** While trees on C35 have performed very well in most trials, performance of Valencia trees became very poor after about 10 years in one trial in San Diego County. The cause of this poor performance is not yet known, but the use of any relatively new rootstock inevitably involves some risks.

**Overall:** An excellent rootstock where it is well adapted. To take advantage of its high yield potential, trees should be planted at about 30% higher density on average than those on Carrizo. Good balance of traits and few major defects. A slightly greater risk of poor tree performance than with Carrizo, but also a good chance of higher yield in a higher-density planting that needs less tree size management than an equivalent planting on Carrizo.

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**Swingle Citrumelo (4475)**

**Origin:** A hybrid seedling of Duncan grapefruit × Trifoliate (parental cultivar unknown) made in 1907. It was named Swingle and released in 1974. Before release, it was originally sent to California as seed, identified by its temporary number CPB 4475, and some nurseries may still use this designation.

**Nursery behavior:** Rootstock fruit are seedy, and the seedlings are moderately uniform (about 90% nucellar). Buds push fairly well under optimal conditions, but these conditions are more restrictive than for Carrizo or Troyer. Trees grow well in the nursery.

**Tree size:** Tree size is generally similar to that of trees on Carrizo but can vary considerably with location, ranging from 65 to 127% over 11 trials. Over all 11 trials, the average tree size was 102% of that of trees on Carrizo.

**Yield:** Trees on Swingle typically have good to excellent yields, sometimes superior to those of trees on Carrizo. Over 11 trials, the average yield was 106% of that of trees on Carrizo. Trees on Swingle had higher yields than those on Carrizo in 8 of the 11 trials. Swingle had lower yields in two trials with Lane Late and one with Rio Red and Redblush grapefruit.

**Yield efficiency:** Moderate.

**Internal fruit quality:** Good to excellent with all common scions. Overall, fruit quality is good.

**External fruit quality:** Peel quality is generally fair to good. Peel thickness is medium, and texture is also intermediate.

**Fruit size:** Generally average in locations where trees are well adapted.

**Tristeza tolerance:** Good tolerance to typical California isolates.

**Phytophthora tolerance:** Excellent resistance to gummosis and root rot.

**Citrus nematode resistance:** Resistant to some citrus nematode races, susceptible to others. The frequency and distribution of resistance-breaking races in California is not clear.

**Soil adaptation:** Well adapted to loam, sandy loam, and sandy soil. Performs poorly on heavy soils. Poor tolerance to salinity (chlorides) and to calcareous soils.

**Freeze tolerance:** In California, trees on Swingle generally have good freeze tolerance, but they are typically somewhat more susceptible than
those on Trifoliate. Fruit also have relatively good freeze tolerance. Swingle is also considered freeze tolerant in Florida.

**Incompatibility:** Bud union typically shows more extreme shoulder development than do trees on Trifoliate, and eventual compression girdling seems likely. Declines apparently due to this incompatibility have been observed in Washington navel orange trees at Lindcove (Tulare County) that were 22 to 25 years old. Considered incompatible with Eureka lemon. Compatibility with mandarins has not been studied. Most mandarins will probably perform well for at least 10 to 15 years but will eventually develop bud union crease and decline.

**Overall:** Excellent rootstock where it is well adapted. Disease resistance makes it a good choice for replant situations. Somewhat narrower soil adaptation than Carrizo. Incompatibility with Washington navel at 20 to 25 years predicts short tree life, but it is not yet known whether these declines occur with all scions and locations.

**Rough Lemon**

**Origin:** Apparently a hybrid that occurred naturally in India, where there are several very distinct forms. Several selections have been made, including the Florida selections Estes and Milam, with burrowing nematode resistance, and a California selection, Schaub, with better Phytophthora root rot tolerance. Several other selections are available, but no remarkable differences in tree performance on these have been documented. Rough Lemon is similar to but distinct from Volkameriana (see below), which is also from India.

**Nursery behavior:** Rootstock fruit are seedy, and the seedlings are genetically very uniform (about 98% nucellar). Buds push well, and trees grow well in the nursery.

**Tree size:** Generally similar to that of trees on Carrizo but can vary considerably with location, ranging from 54 to 129% over 11 trials. Over all 11 trials, the average tree size was 96% of that of trees on Carrizo. Overall, trees are more vigorous than those on Carrizo, but tree size is more frequently reduced by Phytophthora root rot, citrus nematode, and freeze damage.

**Yield:** Trees on Rough Lemon typically have good to excellent yields, sometimes superior to those of trees on Carrizo. Over 11 trials, the average yield was 96% of that of trees on Carrizo. Trees on Rough Lemon had higher yields than those on Carrizo in 5 of the 11 trials. Rough Lemon had much lower yields than Carrizo in all three trials with Lane Late navel scion.

**Yield efficiency:** Moderate.

**Internal fruit quality:** Poor to fair with all common scions. In comparison with fruit from trees on Carrizo, fruit from trees on Rough Lemon have 1 to 2% lower soluble solids, lower acid, and a lower juice percentage. The fruit are more susceptible to freeze damage, and late-harvested oranges granulate earlier. Lemon quality is good.

**External fruit quality:** Peel quality is generally fair to good. The peel is often thicker than that of fruit from trees on Carrizo, and the texture is sometimes rougher.

**Fruit size:** Generally average in locations where trees are well adapted.

**Tristeza tolerance:** Good tolerance to typical California isolates.

**Phytophthora tolerance:** Poor tolerance to gummosis and root rot. Schaub is slightly better than other Rough Lemon selections in most greenhouse tests, but field performance has not been much different.

**Citrus nematode resistance:** Susceptible to all citrus nematode races.

**Soil adaptation:** Well adapted to sandy and sandy loam soils. Often performs poorly on heavy soils. Fair tolerance to salinity (chlorides) and good tolerance to calcareous soils.

**Freeze tolerance:** In California, trees on Rough Lemon generally have poor freeze tolerance. Fruit also have poor freeze tolerance.

**Incompatibility:** No common incompatibilities but often produces many suckers. Removal of these creates wounds that can lead to gummosis infection.

**Overall:** Fair rootstock where it is well adapted, particularly on sandy soils. Should not be used for late-harvested oranges or in cold locations. Poor choice for scions with naturally low solids and acid content.

**Volkameriana**

**Origin:** Apparently a hybrid that occurs naturally in India. Also known as Volk and Volkamer Lemon, it is similar to Rough Lemon in many characteristics.
**Nursery behavior:** Rootstock fruit are seedy, and the seedlings are fairly uniform (about 80% nucellar). Buds push very well, and trees grow well in the nursery. Testing in California began only in about 1989, so less data is available than for some other rootstocks.

**Tree size:** Young trees are usually very vigorous, and trees can be large. In a lemon rootstock trial near Santa Paula, Volk with Lisbon scions produced the largest trees in the trial, but Eureka trees on Volk were only moderate in size (similar to Eureka lemon on Macrophylla rootstock). Yield and yield relative to tree size were moderate. With Lane Late navel scion, 11-year-old trees at two locations were much smaller than those on Carrizo. In a Valencia trial in Pauma Valley, trees on Volk were slightly smaller than those on Troyer.

**Yield:** Trees on Volk typically have average yield for their size.

**Yield efficiency:** Moderate.

**Internal fruit quality:** Fair with all common scions. In comparison with fruit from trees on Carrizo, fruit from trees on Volk have 1 to 2% lower soluble solids, lower acid, and a lower juice percentage. The fruit are more susceptible to freeze damage, and late-harvested oranges granulate earlier. Lemon quality is good.

**External fruit quality:** Peel quality is generally fair to good. The peel is often thicker than that of fruit from trees on Carrizo, and the texture is sometimes rougher.

**Fruit size:** Generally average in locations where trees are well adapted.

**Tristeza tolerance:** Good tolerance to typical California isolates.

**Phytophthora tolerance:** Moderate tolerance to gummosis and root rot, somewhat better than that of Rough Lemon, but worse than Carrizo. Susceptible to *P. citrophthora*.

**Citrus nematode resistance:** Susceptible to all citrus nematode races.

**Soil adaptation:** Well adapted to sandy and sandy loam soils. Often performs poorly on heavy soils. Fair tolerance to salinity (chlorides) and good tolerance to calcareous soils.

**Freeze tolerance:** In California, trees on Volk generally have poor freeze tolerance. Fruit also have poor freeze tolerance.

**Incompatibility:** No common incompatibilities.

**Overall:** A fair rootstock where it is well adapted, particularly on sandy soils. Should not be used for late-harvested oranges or in cold locations. A poor choice for scions with naturally low solids and acid content. Overall, similar to Rough Lemon, but with slightly better Phytophthora tolerance.

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**Trifoliate Orange**

**Origin:** A citrus relative that grows in China. Many different selections have been made. Those commonly used as rootstocks in California fall into three groups: large-flowered types (Pomeroy), small-flowered types (Rubidoux and Rich 16-6), and Flying Dragon (a distinctive small-flowered type).

**Nursery behavior:** Rootstock fruit are seedy, and the seedlings are moderately uniform (about 80 to 90% nucellar). Buds are somewhat difficult to push, and trees grow more slowly in the nursery, sometimes taking a year longer than Carrizo. Flying Dragon is particularly difficult in the nursery, with a higher percentage of zygotic seedlings and slower growth than other Trifoliate types.

**Tree size:** With Rubidoux or Rich 16-6, trees are generally similar in size to trees on Carrizo but can vary considerably with location, ranging from 53 to 151% over eight trials. Over all eight trials, the average tree size was 91% of that of trees on Carrizo. Trees on Pomeroy are typically somewhat larger than those on Rubidoux or Rich 16-6, and those on Flying Dragon are strongly dwarfed, orange trees not reaching more than about 7 feet tall after 20 years.

**Yield:** Trees on Trifoliate typically have good to excellent yields, sometimes superior to those of trees on Carrizo. Over eight trials, the average yield was 91% of that of trees on Carrizo. Trees on Trifoliate had higher yields than those on Carrizo in three of the eight trials. Yields of trees on Pomeroy are typically somewhat greater than those on Rubidoux or Rich 16-6 but are proportional to tree size.

**Yield efficiency:** Moderate.

**Internal fruit quality:** Good to excellent with all common scions. Fruit typically have high solids, acids, and juice content.

**External fruit quality:** Peel quality is generally good. Peel thickness is medium and texture is smooth.

**Fruit size:** For Rubidoux and Rich 16-6, fruit size is generally average in locations where trees are...
well adapted. Trees on Pomeroy often produce larger fruit than those on Carrizo.

**Tristeza tolerance:** Good tolerance to typical California isolates.

**Phytophthora tolerance:** Excellent resistance to gummosis and root rot.

**Citrus nematode resistance:** Resistant to some citrus nematode races, susceptible to others. The frequency and distribution of resistance-breaking races in California is not clear.

**Soil adaptation:** Well adapted to loam, sandy loam, and clay soils. Can also perform well on sandy soils, but only if irrigation is managed very carefully because roots are shallow and therefore trees on Trifoliate are quite susceptible to drought. Poor tolerance to salinity (chlorides) and to calcareous soils.

**Freeze tolerance:** In California, trees on Trifoliate generally have the best freeze tolerance of any rootstock. Fruit also have relatively good freeze tolerance.

**Incompatibility:** Bud union typically shows considerable shoulder development, which sometimes leads to compression girdling. Rich 16-6 was selected to be more compatible with Frost nucellar navel orange and generally has somewhat less shoulder development than other selections. Trifoliate is incompatible with Eureka lemon. Most mandarins perform well for at least 10 to 15 years but eventually develop bud union crease and decline.

**Overall:** An excellent rootstock where it is well adapted. Disease resistance makes it a good choice for replant situations. Narrower soil adaptation than Carrizo.

### Cleopatra Mandarin

**Origin:** A high-acid mandarin type that apparently originated in India.

**Nursery behavior:** Rootstock fruit are seedy, and the seedlings are uniform (about 98% nucellar). Seedlings grow slowly at cool temperatures. Buds are sometimes difficult to force.

**Tree size:** Generally similar to that of trees on Carrizo. For trials of 22 to 25 years with navel, Valencia, and Minneola scions, the average tree size was 101% of that of trees on Carrizo.

**Yield:** Trees on Cleopatra typically have relatively poor yields when young but gradually improve to levels similar to that of trees on Carrizo by age 15 to 20. Over three trials, the average yield was 96% of that of trees on Carrizo.

**Yield efficiency:** Moderate.

**Internal fruit quality:** Good, and similar to that of trees on Carrizo with common scions.

**External fruit quality:** Peel quality is generally good. The peel thickness is medium, and the texture is intermediate.

**Fruit size:** Generally small to average.

**Tristeza tolerance:** Good tolerance to typical California isolates.

**Phytophthora tolerance:** Susceptible to gummosis and root rot.

**Citrus nematode resistance:** Susceptible to citrus nematodes.

**Soil adaptation:** Well adapted to all except calcareous soils, where it is moderately tolerant. Good tolerance to salinity.

**Freeze tolerance:** In California, trees on Cleopatra generally have good freeze tolerance, but they are typically somewhat more susceptible than those on Trifoliate. Fruit also have relatively good freeze tolerance.

**Incompatibility:** Considered incompatible with Eureka and Lisbon lemons.

**Overall:** Slow growth of young trees and delay in bearing generally mean that there are better choices, but good where salinity problems are expected.

### Macrophylla

**Origin:** Apparently a hybrid that occurs naturally on Cebu Island, Philippines. Also known as Alemow, it seems closely related to limes.

**Nursery behavior:** Rootstock fruit are only moderately seedy, but the seedlings are genetically very uniform (about 98% nucellar). Buds push well, and trees grow well in the nursery.

**Tree size:** With lemon, the only scion for which it is widely used in California, trees are generally 10 to 20% smaller than trees on Carrizo.

**Yield:** Lemons on Macrophylla typically have good to excellent yields during the first 10 to 15 years, often superior to those of trees on other rootstocks. However, as trees age, they typically develop health problems and yields decrease.

**Yield efficiency:** Good.

**Internal fruit quality:** Not used with oranges because internal quality is usually poor, with lower soluble solids, lower acid, and a lower juice percentage. These are not important issues for lemon.
External fruit quality: Peel quality is generally fair to good. The peel is often thicker than that of fruit from trees on Carrizo.

Fruit size: Generally average in locations where trees are well adapted. Little data is available on this characteristic.

Tristeza tolerance: Susceptible to typical California isolates, and lemons budded on it will be stunted if the rootstock becomes infected. The reaction is due to stem pitting of the rootstock (not quick decline). Isolates that do not cause stem pitting of most cultivars will do so with Macrophylla. Therefore, rootstock seedlings are generally grown in CTV-free conditions. Budded trees typically perform well in areas with CTV, perhaps because lemon is a relatively poor host.

Phytophthora tolerance: Good tolerance to gummosis and root rot.

Citrus nematode resistance: Susceptible to all citrus nematode races.

Soil adaptation: Well adapted to sandy and sandy loam soils. Often performs poorly on heavy soils. Fair tolerance to salinity (chlorides) and to calcareous soils.

Freeze tolerance: Trees on Macrophylla have poor freeze tolerance, much worse than that of trees on any other commonly used rootstock.

Incompatibility: Trees on Macrophylla, particularly lemons, are generally short-lived (< 20 years) due to rootstock necrosis. This may not be a true incompatibility, but its effect is similar. Little is known about compatibility with other scions.

Overall: The standard rootstock for lemons in many areas due to high yields. Should not be used in cold locations. There has been some recent use of Macrophylla with mandarins in Spain and elsewhere.

Sour Orange

Origin: A natural hybrid, probably of pummelo and mandarin parentage.

Nursery behavior: Rootstock fruit are seedy, and the seedlings are fairly uniform (about 85 to 95% nucellar). Buds push well under cooler conditions, and trees grow well in the nursery.

Tree size: Tree size is generally large, but in five trials it ranged from 64 to 155% of that of trees on Carrizo. The mean tree size was 105% of that of Carrizo trees. Variation seems more attributable to location than scion, since results with similar-age Lane Late navel trees ranged from 65 to 111% of that of Carrizo.

Yield: Yields in five trials ranged from 70 to 118% of those of trees on Carrizo, with an average of 88%. Superior to Carrizo in locations where Carrizo performs poorly because soils are calcareous or poorly drained.

Yield efficiency: Generally very similar to that of trees on Carrizo.

Internal fruit quality: Sour orange produces fruit of high internal quality.

External fruit quality: Peel quality is generally good.

Fruit size: Fruit size is generally average, usually slightly smaller than fruit from trees on Carrizo.

Tristeza tolerance: Susceptible to many isolates of CTV, with orange, grapefruit, and mandarin trees showing quick decline and death within a few years after infection. Sour orange can be used with lemons in the presence of CTV.

Phytophthora tolerance: Excellent tolerance to gummosis and root rot.

Citrus nematode resistance: Susceptible to all citrus nematode races.

Soil adaptation: Well adapted to a broad range of soil types, including sand, sandy loam, loam, and clay soils. Good tolerance to salinity and to calcareous soils.

Freeze tolerance: In California, trees on Sour Orange generally have good freeze tolerance. Fruit have intermediate freeze tolerance, showing more damage than those from trees on Trifoliate or Carrizo, but less than fruit from trees on Rough Lemon.

Incompatibility: No common incompatibilities, except with kumquat and perhaps Eureka lemon, where trees decline at 12 to 15 years.

Overall: An excellent rootstock with broad soil adaptation, Phytophthora tolerance, and positive fruit quality effects. As tristeza becomes more widespread in California, all trees on Sour Orange (except lemons) are likely to be killed.

Other (Minor) Rootstocks

African Shaddock × Rubidoux Trifoliate (ASRT): A hybrid from the USDA (Indio) breeding program. It has excellent tolerance or resistance to Phytophthora and citrus nematode and typically produces large trees with excellent yields. However, recent studies indicate that trees are stunted.
by some mild Florida isolates of CTV and some common California isolates. Its susceptibility to CTV makes use of ASRT quite risky.

**Bitters Trifoliate hybrid:** A hybrid of Sunki mandarin and Swingle trifoliate from the USDA Indio breeding program released by UC Riverside in 2009. It was tested under the code C22 and may be referred to by this code by some nurseries. It is tolerant to CTV, moderately tolerant to Phytophthora, but fairly susceptible to citrus nematode. Bitters produces a semidwarf tree that often has high production for its size. It is very tolerant to calcareous soils. Fruit quality appears to be similar to that of trees on Carrizo.

**C32 Citrange:** A hybrid of Ruby orange and Webber-Fawcett trifoliate (a sister of C35 Citrange) from the UC Riverside citrus breeding program. It has good disease resistance and produces a large, vigorous tree with high yields in most locations. However, the rootstock is difficult to propagate because rootstock trees produce few fruit and the fruit have few seed. The seedlings are also somewhat variable.

**Gou Tou:** A Chinese variety that has been used some as a rootstock in Florida. It is tolerant to CTV, but susceptible to Phytophthora and citrus nematode. Gou Tou is somewhat tolerant to calcareous and wet soils. Fruit quality is relatively poor. Several different types have been imported into California under this name, but none have yet been tested as rootstocks.

**Rangpur (Rangpur Lime):** The standard rootstock in Brazil because it is tolerant to CTV and performs well without irrigation. It is very susceptible to Phytophthora and has performed poorly in several trials in California. Not recommended.

**Sun Chu Sha (Sun Chu Sha Kat):** A mandarin type that has been considered promising as a rootstock in Florida. Limited testing (three trials with lemons and Lane Late navel) in California has been disappointing. Yields have been lower than those of trees on Carrizo, but tree size is similar or larger. In Florida it is susceptible to Phytophthora and citrus nematode, tolerant to CTV, and fairly tolerant to calcareous soils. There is probably little reason to use this rootstock except on calcareous soils. Testing to evaluate performance on calcareous soils in California was initiated in 2001; it does not appear to be very tolerant in these tests.

**Sweet Orange:** Can be used as a rootstock for most varieties, but its susceptibility to Phytophthora and citrus nematode often limit the productivity and lifespan of trees. In nearly all recent trials, yield, tree size, and tree health ratings have been considerably lower than those of trees on Carrizo. These trials have all been on ground previously planted with citrus where diseases are more likely to limit productivity. Trees on Sweet Orange lack drought tolerance and are very susceptible to Phytophthora, so irrigation must be carefully managed.

**Taiwanica:** Previously, Taiwanica was considered similar to Sour Orange, but with CTV tolerance. Several trials during the last 20 years indicate that it usually performs poorly as a rootstock. Internal fruit quality is typically similar to that of Rough Lemon, and yields have been low. There is little reason to consider this rootstock.

**Trifeola.** A Minneola × Trifoliate hybrid from South Africa. There is currently little information on its performance in California, but it is included in several trials planted in 1997 and 2001.

**X639.** A Cleopatra × Trifoliate hybrid from South Africa. There is currently little information on its performance in California, but it is included in several trials.