

# Selecting citrus rootstocks

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## Introduction

Rootstock selection is one of the most important factors to consider when planning a citrus development. Rootstocks affect yield, fruit size and quality. They also vary in their adaptability to different soil types, tolerance of adverse soil conditions, soil pests and diseases and their suitability for use on replant sites.

The most appropriate rootstock will depend on:

- site characteristics
- the intended planting system
- the likelihood of specific pest, disease or salinity problems
- the variety to be grown
- planned market outlets
- marketing strategies for the fruit.

For a long-lived orchard, the rootstock needs to tolerate the soil conditions in which it is to grow (Table 1). For example, a rootstock that is susceptible to phytophthora should not be planted in heavy clay soil or an orchard with poor drainage.

The scion or varietal selection must also be compatible with the rootstock. Excessive rootstock suckering, bud union creasing, rootstock overgrowth and tree death are symptoms of incompatibility. However, these can usually overcome by using a sweet orange interstock.

Comprehensive soil surveys and profile descriptions of the proposed orchard sites should be obtained before planting.

## Common commercial rootstocks: characteristics and limitations

In Australia, different rootstock varieties are used in the major production areas because of different soil types and growing conditions.

The main pest and disease considerations are citrus nematodes, phytophthora root and collar rots and citrus tristeza virus (CTV). All rootstocks used in Australia should be CTV tolerant.

Rootstocks for replant situations should also be tolerant of phytophthora and citrus nematode.

The main rootstocks currently used in Australia are *Poncirus trifoliata*, *Troyer* citrange, *Carrizo* citrange, Swingle citrumelo, Cleopatra mandarin, rough lemon, sweet orange and Benton citrange. Trifoliolate rootstocks are predominantly used in the Riverina while South Australia and Murray Valley use *Troyer* and *Carizzo* citrange. In Queensland mandarin plantings, *Troyer* citrange is predominantly used (Milner 2018).

*Poncirus trifoliata*, *Carrizo* and *Troyer* citrange remain the most popular rootstocks for oranges, accounting for approximately 70% of Auscitrus seed sales (Auscitrus Annual Report 2018, 2019). Flying dragon remains a popular rootstock for the retail nursery trade (Auscitrus Annual Report 2018, 2019).

Six new Chinese citrus rootstocks have been released by NSW DPI for the Australian industry. The rootstocks will provide greater options for growers so they can match rootstocks to their scion and site.

For lemons, Benton citrange and Cox hybrid are the most widely planted rootstocks (Milner 2018; Auscitrus Annual Report 2018, 2019).

General characteristics and major limitations of the main rootstocks are summarised in Table 1. Effects on fruit quality and relative ranking for nematode, phytophthora, CTV, salt and lime tolerance are shown in Table 2 and Table 3, further highlighting rootstock differences.

Ranking of rootstocks for specific attributes is based on data from research trials conducted under uniform conditions. Actual horticultural performance under commercial conditions will depend on management inputs.

Table 1. The advantages and disadvantages of the major citrus rootstocks used in Australia.

	Characteristics	Requirements	Major risk factors
<b>Benton citrange</b>	<ul style="list-style-type: none"> <li>Resistant to phytophthora root and collar rots</li> <li>Compatible with Eureka lemon, producing trees of intermediate size with good cropping efficiency</li> </ul>	<ul style="list-style-type: none"> <li>Exocortis-free budwood</li> <li>Not suitable for calcareous soils</li> </ul>	<ul style="list-style-type: none"> <li>Limited experience, still being evaluated</li> <li>Tolerance to nematodes unknown</li> </ul>
<b>C35 (Figure 1)</b>	<ul style="list-style-type: none"> <li>Resistant to phytophthora root and collar rots</li> <li>Citrus nematode and tristeza tolerant</li> </ul>	<ul style="list-style-type: none"> <li>Certified disease-free budwood or trees might be smaller in size</li> </ul>	<ul style="list-style-type: none"> <li>Incompatible with Eureka lemon, Navelina and most likely with varieties sourced as bud sport mutations from Navelina (e.g. FJ Navel and M7).</li> </ul>
<b>Carrizo and Troyer citranges (Figure 2)</b>	<ul style="list-style-type: none"> <li>Resistant to phytophthora</li> <li>Tristeza tolerant; infection by exocortis results in reduced tree size, but no butt scaling</li> <li>Mycorrhizal dependent</li> <li>Cold hardy</li> <li>Intermediate rooting depth; main lateral and fibrous root development can be poor in young trees</li> <li>Medium to large trees, usually very productive with good fruit quality.</li> </ul>	<ul style="list-style-type: none"> <li>Exocortis-free budwood</li> <li>Adapted to a wide range of soil types, except highly calcareous soils</li> </ul>	<ul style="list-style-type: none"> <li>Incompatible with Imperial mandarin and Eureka lemon</li> <li>Very prone to micronutrient deficiencies, especially on calcareous soils</li> <li>Compatibility with some minor varieties unknown</li> <li>Prone to 'sudden death'</li> <li>Not suited to clay loam soil, tree decline occurs after 10 years</li> </ul>
<b>Citrus macrophylla (Figure 3)</b>	<ul style="list-style-type: none"> <li>Large fruit size</li> <li>Lower Brix and acidity when grown under standard practice</li> <li>If specialised water stress practices are used, internal quality can be improved</li> </ul>	<ul style="list-style-type: none"> <li>Routine de-suckering while trees are young is suggested to reduce feeding by aphids and infection with citrus tristeza virus</li> </ul>	<ul style="list-style-type: none"> <li>Susceptible to nematodes and tristeza, which can lead to tree decline</li> </ul>
<b>Cleopatra mandarin (Figure 4)</b>	<ul style="list-style-type: none"> <li>Moderately susceptible to phytophthora root and collar rots</li> <li>Tristeza and exocortis tolerant</li> <li>Susceptible to citrus and burrowing nematodes</li> <li>Intermediate rooting depth; intensive fibrous root development</li> <li>Slow growing in the nursery</li> <li>Mature trees large</li> <li>Early production poor, satisfactory in mature trees</li> <li>Good fruit quality but small fruit size with some cultivars</li> </ul>	<ul style="list-style-type: none"> <li>Suited to virgin sites</li> <li>Only performs well on lighter soils</li> <li>Lime and salt tolerant</li> </ul>	<ul style="list-style-type: none"> <li>Tends to produce smaller fruit size</li> <li>Good drainage and precautions against root rot are essential</li> <li>Slow to come into bearing</li> </ul>

	Characteristics	Requirements	Major risk factors
<b><i>Poncirus trifoliata</i></b> (Figure 5)	<ul style="list-style-type: none"> <li>• Highly resistant to phytophthora, CTV and citrus nematode</li> <li>• Intolerant of exocortis</li> <li>• Cold hardy</li> <li>• Shallow rooting depth but develops high fibrous root density</li> <li>• Requires more frequent irrigation than deeper-rooted rootstocks</li> <li>• Tree size small to medium</li> <li>• Generally, highly fruitful</li> <li>• Fruit quality very good</li> <li>• Suited to clay loam soil</li> </ul>	<ul style="list-style-type: none"> <li>• Exocortis and tatter leaf-free budwood</li> <li>• Will grow on a wide range of soils but prefers loams; is intolerant of highly acid and lime soils</li> <li>• Poor drought tolerance</li> </ul>	<ul style="list-style-type: none"> <li>• Incompatible with Eureka lemon, Imperial mandarin, Daisy mandarin and acid-less oranges</li> <li>• Compatibility with some minor varieties unknown</li> <li>• Despite accumulating high levels of chloride in leaf tissue, does not exhibit obvious toxicity symptoms</li> <li>• Prone to 'sudden death'</li> </ul>
<b>Rough lemon</b> (Citronelle)	<ul style="list-style-type: none"> <li>• Susceptible to phytophthora root and collar rots, citrus nematode</li> <li>• Tristeza and exocortis tolerant</li> <li>• Mycorrhizal dependent</li> <li>• Extensive lateral and vertical root development</li> <li>• Highly drought tolerant</li> <li>• Produces large trees</li> <li>• Yields are high, good fruit size, but poor quality</li> <li>• Promotes early maturity</li> </ul>	<ul style="list-style-type: none"> <li>• Best on deep virgin sandy soils</li> </ul>	<ul style="list-style-type: none"> <li>• Does not tolerate poorly drained soils</li> <li>• Tends to accumulate excessive chloride leading to leaf drop</li> <li>• Unsuitable for some mandarins e.g. Satsuma and Ellendale tangor</li> </ul>
<b>Sweet orange</b> (Figure 6)	<ul style="list-style-type: none"> <li>• Very susceptible to phytophthora root and collar rots; susceptible to citrus nematode</li> <li>• Tristeza and exocortis tolerant</li> <li>• Mycorrhizal dependent</li> <li>• Intermediate rooting depth</li> <li>• Produces large trees on well-drained soils in inland areas</li> <li>• High yielding with good fruit quality</li> </ul>	<ul style="list-style-type: none"> <li>• Best on deep sandy soils</li> <li>• Sensitive to dry conditions but tolerates calcareous soils</li> </ul>	<ul style="list-style-type: none"> <li>• Does not tolerate excessive soil moisture</li> </ul>
<b>Swingle citrumelo</b> (Figure 7)	<ul style="list-style-type: none"> <li>• Phytophthora and tristeza tolerant</li> <li>• Nematode resistant</li> <li>• More salt tolerant than other <i>P. trifoliata</i> hybrids</li> <li>• Good fruit quality</li> </ul>	<ul style="list-style-type: none"> <li>• Not suited to clay or highly calcareous soils</li> </ul>	<ul style="list-style-type: none"> <li>• Sensitive to overwatering</li> <li>• Incompatible with Eureka lemon and some orange and mandarin cultivars</li> <li>• Overgrows orange varieties</li> <li>• Fruit more prone to creasing</li> </ul>
<b><i>Citrus volkameriana</i></b>	<ul style="list-style-type: none"> <li>• Susceptible to phytophthora root and collar rots</li> </ul>	<ul style="list-style-type: none"> <li>• Suitable for virgin sites only</li> </ul>	<ul style="list-style-type: none"> <li>• Less Brix and acid to downgrade fruit quality</li> </ul>

Table 2. The general effects of rootstocks on citrus fruit quality.

	C35	<i>Carrizo and Troyer citranges</i>	Cleopatra mandarin	<i>Citrus macrophylla</i>	<i>Poncirus trifoliata</i>	Rough lemon	Sweet orange	Swingle citrumelo	<i>Citrus volkamariana</i>
Acidity	high	medium-high	high	low	high	low	medium	medium	low
Fruit size	medium	medium	small-medium	large	medium	large	medium	medium-large	large
Juice content	high	high	medium	low	high	low-medium	medium	high	low
Maturity	mid-late	mid	mid	early	mid-late	early	mid	mid	early
Rind texture	smooth	smooth	medium	coarse	smooth	coarse	medium	smooth	coarse
Rind thickness	thin	thin	thin	thick	thin	thick	medium	thin	thick
TSS	high	high	medium	low	high	low	medium	high	low

Table 3. Relative tolerance of citrus rootstocks to citrus nematode, diseases, lime and salinity.

	Citrus nematode	Phytophthora	Tristeza	Lime	Salinity
Benton citrange	?	2	1	4	4
C35	2	2	1	4	3
<i>Carrizo citrange</i>	3	2	1	4	3
Cleopatra mandarin	4	3	1	1	1
<i>Citrus macrophylla</i>	4	3	5	2	2
<i>Poncirus trifoliata</i>	1	1	1	5	5
Rough lemon	4	4	2	3	4
Sweet orange	4	5	2	4	3
Swingle citrumelo	1	2	1	5	2
<i>Troyer citrange</i>	3	2	1	4	3
<i>Citrus volkameriana</i>	4	4	1	3	2

1 = best of rootstocks listed; 5 = worst of rootstocks listed.



The compatibility results from a long-term research trial showed that Navelina orange is not recommended with C35 citrange rootstock. Concerns were also raised about reduced tree health and yields of Hockney navel and Summer Gold navel on C35 citrange rootstock (Sanderson

and Skewes 2017). Navel oranges are generally compatible with *Troyer* and *Carrizo* citrange, Cleopatra mandarin and Trifoliolate rootstocks. The known scion compatibilities for common rootstocks under Australian conditions are shown in Table 4.

Table 4. Rootstock compatibility.

	Benton citrange	C35	Carrizo Troyer citranges	Cleopatra mandarin	Poncirus trifoliata	Rough lemon	Sweet orange	Swingle citrumelo	Citrus volkamariana
Afourer	✓	!	✓	✓	Y	✓	✓	✗	✓
Eureka lemon	✓	✗	✗	?	✗	✓	✓	✗	✓
Imperial mandarin	✓	?	✗	✓	✗	✓	✓	?	✓
Late Navels	?	✓	✓	✓	✓	✓	✓	✓	✓
Lisbon lemon	✓	✓	✓	?	✓	✓	✓	✓	✓
Murcott mandarin	✓	?	✓	✓	✓	✓	✓	✗	✓
Navelina	?	✗	✓	✓	✓	✓	✓	✗	✓
Washington Navel	?	✓	✓	✓	✓	✓	✓	✓	✓

✓ = compatible, ✗ = incompatible, ? = unknown, Y = young trees show no incompatibility to date.



Figure 1. C35.



Figure 2. Carrizo citrange.





Figure 3. *Citrus macrophylla*.



Figure 5. *Poncirus trifoliata*.



Figure 4. Cleopatra mandarin.



Figure 6. Sweet orange.





Figure 7. Swingle citrumelo.

### New Chinese rootstocks

These rootstock varieties were sourced from a native citrus arboretum in China in the 1990s. They were screened in the laboratory and greenhouse to assess their resistance to phytophthora collar rot and citrus tristeza virus, bud union compatibility to common Australian scion varieties and salt tolerance. The rootstocks were planted in field trials at NSW DPI Dareton and for the past 20 years, the performance of these rootstocks with Navelina, Imperial mandarin, Lane Late navel, Eureka lemon and Valencia scions has been assessed (Khurshid et al. 2007; Khurshid 2014).

Two mandarin and four trifoliata-type rootstocks performed better than current Australian rootstocks or exhibited special characteristics. These rootstocks (Table 5) were launched in 2017 (Khurshid and Donovan 2018). Further assessment of the selected six rootstocks will be expanded to 20 grower properties in different citrus growing regions throughout Australia. Rootstock seed can be purchased from [Auscitrus](#).

Table 5. Chinese rootstock characteristics compared to Tri22.

	Anjiang hongju	Caoshi xiangju	Donghai	Ghana	Tanghe	Zao Yang
<b>Compatibility</b>	Variable	Variable	Variable	Excellent with all orange scions tested	Excellent with all orange scions tested	Excellent with all orange scions tested
<b>Disease</b>	Resistant to CTV and is moderately resistant to phytophthora	Moderately resistant to phytophthora root rot	Highly resistant to CTV, phytophthora collar and root rot	Highly resistant to CTV, phytophthora collar and root rot	Highly resistant to CTV, phytophthora collar and root rot	Highly resistant to CTV, phytophthora collar and root rot
<b>Fruit quality</b>	Internal quality acceptable for Valencia and higher for imperial mandarin	Internal quality acceptable for Valencia	Smaller fruit for Valencia and Navelina	Similar internal quality to all scions tested. Smaller fruit size for Navelina and bigger for Lane Late and Imperial Mandarin	Slightly larger fruit size for Navelina and Lane Late	Higher for Valencia and similar for Navelina
<b>Special</b>	Excludes sodium and chloride, suited to shallow and sandy soils	Excludes sodium and chloride. Deep-rooted suited for deep sandy soils		Excludes sodium and accumulates chloride	Excludes sodium	Excludes sodium and flowers later

	Anjiang hongju	Caoshi xiangju	Donghai	Ghana	Tanghe	Zao Yang
<b>Suggested scions</b>	Lane Late and Imperial mandarin	Valencia	Valencia and Navelina	Navel oranges	Valencia and Lane Late navel	Valencia and Lane Late navel
<b>Type</b>	<i>Citrus erythroa</i> (mandarin)	<i>Citrus erythroa</i> (mandarin)	<i>Poncirus trifoliata</i>	<i>Poncirus trifoliata</i>	<i>Poncirus trifoliata</i>	<i>Poncirus trifoliata</i>
<b>Vigour</b>	More than Tri22. May be suitable for medium to low density planting	More than Tri22. May be suitable for medium to low density planting	Less than Tri22. May be suitable for high density planting	Similar to Tri22	Less than Tri22. May be suitable for high density planting	Slightly higher than Tri22
<b>Yields</b>	Higher for Valencia	Higher	Higher for Valencia	Above for all scions tested	Above for all scions tested	Higher for Navelina and Valencia

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