

5. Rootstocks

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Severe overgrowth of Verna on Fraser rootstock

INTRODUCTION

All commercial lemon varieties in Australia are budded onto selected rootstocks. The decision about which rootstock to use has important long-term effects on the potential life and profitability of plantings. Some scion rootstock combinations are incompatible. With lemons the most well known is the incompatibility of Eureka lemon on *Poncirus trifoliata*, Troyer and Carrizo citranges and Swingle citrumelo. No single rootstock is suitable for all sites or for all varieties. As a result, take great care in selecting the best rootstock for the soil, growing conditions and the markets being targeted.

The ideal rootstock is likely to vary with the soil type, depth and previous land use. The variety and clone of lemons to be grown is sometimes also an important factor. Rootstock can effect both time of harvest and fruit quality, and both of these factors can have a big effect on dollar returns. Rootstock can have a large effect on many aspects of production including yield, fruit quality, tree size, tolerance to salts and diseases, and scion compatibility. The general tolerance and fruit quality effects of various citrus rootstocks (although not specifically detailed for lemons) is detailed in Tables 1, 2 and 3.

General rootstock information sheets are contained at the end of this section.

Table 1: The relative tolerance of citrus rootstocks to nematodes and diseases

Rootstock	Phytophthora tolerance	Tristeza tolerance	Exocortis tolerance	Citrus nematode
<i>P. trifoliata</i>	1	1	5	1
Swingle citrumelo	2	1	2	1
Troyer citrange	2	1	4	3
Carrizo citrange	2	1	4	3
Benton citrange	2	1	4?	3?
Cleopatra mandarin	3	1	1	4
Rough lemon	4	2	1	4
Sweet orange	5	2	1	4

Key: 1 = best of rootstocks listed; 5 = worst of rootstocks listed; ? = uncertain.

Table 2: The relative tolerance of citrus rootstocks to salinity and soil types

Rootstock	Salinity	Calcium (Alkalinity)	Soils		
			Sandy	Loam	Poorly drained
<i>P. trifoliata</i>	5	5	2	2	1
Carrizo citrange	3	4	2	2	2
Troyer citrange	3	4	2	2	2
Benton citrange	4	4	2	2	2
Swingle citrumelo	2	4	2	2	1
Rough lemon	4	3	1	3	5
Sweet orange	3	2	2	1	4
Cleopatra mandarin	1	1	3	2	3

Key: 1 = best of rootstocks listed; 5 = worst of rootstocks listed

Table 3: General effects of citrus rootstocks on fruit quality

Quality Characteristic	Troyer/Carrizo citranges	Rough lemon	Sweet orange	Cleopatra mandarin	Swingle citrumelo	<i>P. trifoliata</i>
Fruit Size	medium	Large	medium	small-med	med-large	med-large
Rind Thickness	thin	Thick	medium	thin	thin	thin
Rind Texture	smooth	Coarse	medium	medium	smooth	smooth
Fruit Maturity	mid	Early	mid	mid	mid-late	mid-late
Total Soluble Solids (TSS)	high	Low	medium	medium	high	high
Acid Content	medium-high	Low	medium	medium	medium	high
Juice Content	high	Low-med	medium	med-high	high	high

Rootstocks and their main characteristics

Benton citrange. Benton citrange was released to industry in 1985 and commercial plantings using this rootstock have gradually increased since the early 1990's. It has performed well in replant soils and is the only citrange selection which can be used under Eureka lemon without inducing severe incompatibility. The research at Renmark showed that it is also very successful in virgin soils.

Citrus volkameriana. *C. volkameriana* is being used as an alternative rootstock for lemons and has similar characteristics to Rough lemon. Trees are large and vigorous with lower yields than Rough lemon and with generally poor fruit quality characteristics. It has some resistance to *Phytophthora* root rot being slightly better than Rough lemon.

Cleopatra mandarin. Cleopatra tends to produce most of its roots near the soil surface and could be considered for shallow soil situations (on mounded rows), especially if the subsoil is high in free lime (calcium carbonate).

Cox mandarin hybrid (3798). Cox is a Scarlet mandarin x *P. trifoliata* hybrid bred by NSW Agriculture and released commercially in 1995. It is resistant to *Phytophthora* root and collar rots and has shown promise in screening trials as a rootstock for Eureka lemon with no signs of the bud union incompatibility. Cox has relatively seedy fruit and produces uniform, moderately vigorous seedlings in the nursery. This variety is now being used commercially.

Fraser Seville hybrid (4017) is a Smooth Seville x *P. trifoliata* hybrid bred by NSW Agriculture and released commercially in 1995. It is resistant to *Phytophthora* root and collar rot. It was recently assessed as a rootstock for Fino, Verna and Eureka at two Australian sites and shows little promise as a commercial rootstock for lemons.

Nelspruit hybrid 639 is a Cleopatra mandarin x *P. trifoliata* hybrid bred in South Africa. It has performed well as a rootstock for Eureka lemon at the Gosford trial site producing fruit with a higher percentage of juice and citric acid than that grown on Rough lemon rootstock. Nelspruit hybrid has shown moderate susceptibility to *Phytophthora* and hence its use would be better confined to virgin, well-drained sites.

Poncirus trifoliata. It is incompatible with Eureka lemon. This is not a preferred rootstock for South Australian growing conditions because of its low

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tolerance to soils high in lime and to saline irrigation water. If used, for example in clay soils near Renmark for the growing of Lisbon lemons, it would produce high quality fruit.

Rough lemon. Rough lemon is a very good rootstock for producing large healthy trees, however, it tends to produce fruit rough in texture and lower in juice. These negative effects could be at least partly countered by adjusting nutrition programs but rough lemon also tends to produce larger fruit with thicker skins. Trees are more prone to damage from root diseases, nematodes and water logging. Mature fruit can be stored, “on tree” for less time, compared with other rootstocks.

Rough lemon is best suited to virgin soils and should not be used in replant soils. In replant soils Benton citrange, Cox mandarin hybrid or Troyer citrange (incompatible with Eureka lemon) should be considered.

Sweet orange. This is an excellent rootstock for soils that have not previously been cropped with citrus. If soils have adequate depth and are free draining, sweet orange enhances yield and fruit quality, and “on tree” storage of fruit. Because of its susceptibility to root rots and nematodes, it is not recommended for replant situations.

Swingle citrumelo. This rootstock is relatively new in Australia. It has performed very well under grapefruit, well under oranges when they are not grown on poor or highly calcareous soils but there is not much known about its performance under lemons. It is incompatible with Eureka lemon. Although Swingle produces very well in many soil types, it is reported that it performs poorly in soils high in lime. It is superior to the citranges in its tolerance to water logging and nematodes and similar in its tolerance to root rots and soils high in lime.

Troyer and Carrizo citranges. These rootstocks cannot be used with Eureka lemon due to incompatibility problems. When using Lisbon or other varieties there are small but significant differences in performance between these two rootstocks. Both are suited to replant soils where calcium (free lime) levels are not high and both have good tolerance to nematodes, *Phytophthora* and other replant diseases. They are inferior to Rough lemon and *C. volkameriana* for translocation of soil water from the roots to the leaves and fruit. Citrange rootstocks tend to produce smaller fruit.

Key References

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Ballasch, P. T., and Staniford, M. **Citrus Varieties and Rootstocks for the Riverland**. 2003.

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Lemon Variety Rootstock Compatibility Chart

Rootstock	Eureka	Fino	Lisbon	Meyer	Verna	Yen Ben
Benton citrange	✓	✓	✓	✓?	✓*	✓
Carrizo citrange	×	✓?	✓	✓?	✓	✓
Nelspruit hybrid 639	✓	✓	?	?	✓	✓**
Cox mandarin hybrid (3798)	✓	✓	?	?	✓	?
Fraser seville hybrid (4017)	✓	✓	?	?	✓*	
<i>P. trifoliata</i>	×	✓	✓	✓	✓	✓
Rough lemon	✓	✓	✓	✓	✓	✓
Sour orange	✓	✓	✓?	?	?	?
Swingle citrumelo	×		✓	×		×
Sweet orange	✓	✓	✓	✓	✓	✓
Troyer citrange	×	✓?	✓	✓?	✓	×
<i>C. volkameriana</i>	✓	✓	✓	✓	✓*	✓
Schaub Rough lemon	✓	✓*	✓?	?	✓*	?
C35 citrange	×	?	?	?	?	×

✓* Some overgrowth of the bud union observed (at the three Australian trial sites) - longterm compatibility unknown at this stage.
 ✓ Compatible
 × Incompatible
 ✓** Overgrowth in New Zealand trials
 ✓? Longterm compatibility in Australia unknown
 ? Compatibility unknown under Australian conditions



Photo by April Winchel
Severe rootstock suckering can be a sign of incompatibility



Photo by April Winchel
An example of incompatibility - overgrowth of the scion

Rootstock Characteristics Table

Stock	Characteristics	Requirements	Major risk factors
Benton citrange	Resistant to <i>Phytophthora</i> root and collar rots. Compatible with Eureka lemon. With Eureka produces trees of intermediate size and good cropping efficiency. Exocortis-free budwood.	Not suitable for calcareous soils.	Tolerance to nematodes unknown.
Cleopatra mandarin	Moderately susceptible to <i>Phytophthora</i> root and collar rots. Tristeza and exocortis tolerant. Susceptible to citrus nematode. Intermediate depth of rooting; intensive fibrous root development. Slow growing in nursery, mature trees large. Early production poor, satisfactory in mature trees. Good fruit quality but small fruit size with some cultivars.	Performs well on both heavy and light soils; best suited to loams. Lime and salinity tolerant.	Tendency to small fruit size. Good drainage and precautions against root rot essential. Slow to come into bearing.
<i>P. trifoliata</i>	Highly resistant to <i>Phytophthora</i> , tristeza and citrus nematode. Cold hardy. Intolerant of exocortis. Shallow depth of rooting but develops high fibrous root density. Tree size small to medium. Generally highly fruitful. Fruit quality very good.	Exocortis and tatter leaf free budwood. Will grow on wide range of soils, but prefers loams. Intolerant of highly acid and lime soils. Poor drought tolerance.	Incompatible with Eureka lemon and acidless oranges. Compatibility with some minor varieties unknown. Despite accumulating high levels of chloride in leaf tissue does not exhibit obvious toxicity symptoms until leaves drop. Prone to sudden death.
Rough lemon (citronelle)	Susceptible to <i>Phytophthora</i> root and collar rots, citrus nematode. Tristeza and exocortis tolerant. Mycorrhizal dependent. Extensive lateral and vertical root development. Highly drought tolerant. Produces large trees. Yields are high, of good fruit size, but poor quality. Promotes early maturity.	Best on deep virgin sandy soils.	Does not tolerate poorly drained soils. Tendency to accumulate excessive chloride leading to leaf drop. Unsuitable for some mandarins eg. Satsuma and Ellendale tangor.
Sweet orange	Very susceptible to <i>Phytophthora</i> root and collar rots; susceptible to citrus nematode. Tristeza and exocortis tolerant. Mycorrhizal dependent. Intermediate depth of rooting. On well-drained soils in inland areas produces large trees. High yielding with good fruit quality.	Best on deep sandy soils. Sensitive to dry conditions but tolerates calcareous soils.	Does not tolerate excessive soil moisture.
Swingle citrumelo	<i>Phytophthora</i> and drought tolerant; nematode resistant; tristeza tolerant. More salt tolerant than other <i>P. trifoliata</i> hybrids. Good fruit quality.	Not suited to clay or highly calcareous soils	Has tolerance to water logging. Incompatible with Eureka lemon and some orange and mandarin cultivars. Overgrows orange varieties. Fruit more prone to creasing than Rough lemon.
Troyer and Carrizo citrange	Resistant to <i>Phytophthora</i> , cold hardy. Tristeza tolerant; infection by exocortis results in reduced tree size, but no butt scaling. Mycorrhizal dependent. Intermediate depth of rooting; main lateral and fibrous root development may be poor in young trees. Medium to large trees, usually very productive with good fruit quality	Exocortis-free budwood. Adapted to wide range of soil types, except highly calcareous soils.	Incompatible with Eureka lemon. Very prone to micronutrient deficiencies, especially on calcareous soils. Compatibility with some minor varieties unknown. Prone to sudden death.

Source: "Know your Rootstocks" K. Bevington, NSW Agriculture, Dareton.

Benton citrange

Origin

In 1945, a citrus rootstock breeding programme was initiated by Dr. F T Bowman of NSW Agriculture, in an attempt to obtain rootstocks compatible with Eureka lemon that were also *Phytophthora* resistant and tolerant of citrus tristeza virus. From this programme, the Benton citrange, a hybrid of Ruby Blood sweet orange and *P. trifoliata*, was selected and has performed well as a rootstock for Eureka lemon in a number of replicated trials at Somersby (Freeman *et al.*, 1986; Sarooshi and Broadbent, 1992) and at Yanco (Long *et al.*).

Seed was first released to the industry in 1984. There are some commercial plantings using this rootstock which have been established since 1990, but poor seed production in the seed source trees has been an impediment to its widespread usage.

Pest and disease

The major attributes of Benton citrange are its *Phytophthora* and tristeza tolerance and its compatibility with Eureka lemon.

Field performance

With Eureka lemon it produces trees of an intermediate size with good cropping efficiency. Being relatively compact they are more manageable than trees on the more vigorous Rough lemon.

Nursery performance

It is not a vigorous nursery stock. It is a frustrating nursery plant because seedlings are bushy and difficult to bud. In Florida some nurserymen have grown seedlings to liner size then cut them back severely to induce a single vigorous shoot from the base that then becomes the stem which is budded. Once budded the tree grows normally in the nursery.

Overseas experience

Benton citrange has been tried as a rootstock for Eureka lemon in California and was introduced as seed from Australia and included in a broad range of field trials in Florida beginning in 1986.

References

Burns, R M, Sakovich, N J, and Carpenter, J B. (1986). **Test with Eureka, Lisbons on new citrange rootstocks.** *Citrograph* 72, pp 24-25, 27.

Freeman, B., Broadbent, P. and Nicholls, P. (1986). **Evaluation of rootstocks for five lemon scions in replant ground.** *Aust. J. Exp. Agric.* 26, 751-759.

Sarooshi, R A. and Broadbent, P. (1992). **Evaluation of rootstocks for Eureka and Lisbon lemons in replant ground in New South Wales.** *Aust. J. Exp. Agric.* 32, 205-209. For application to specific circumstances, professional advice should be sought.

C-35 citrange

Origin

C-35 was bred by the University of California and released in 1987. It is a hybrid of Ruby Blood orange and *P. trifoliata*.

Tolerance to environmental and soil conditions

C35 has better tolerance to low iron stress¹ (high pH soils with high levels of available calcium) than Swingle citrumelo and trifoliolate orange. Suitable for replant sites.

Pest and disease

Tolerant to tristeza virus and less susceptible to *Phytophthora* root rot than Troyer citrange². Tolerant to the citrus nematode (*Tylenchulus semipenetrans*).

Budwood for propagation on this stock should be obtained from Auscitrus to ensure freedom from citrus exocortis viroid (CEV) and other viroids, which cause dwarfing and tree decline and from citrus tatter leaf virus to which trifoliolate orange hybrids are sensitive resulting in a yellow ring at the bud-union.

Nursery performance

Percent nucellar seedlings may be lower than for Troyer citrange.

Fruit quality

Fruit quality is excellent

Scion compatibility

C 35 is incompatible with Yen Ben lemon³, which died after 5 years in a trial at Kerikeri, New Zealand.

Overseas experience

This rootstock was bred in California, and within 10 years of its release, it is being used widely on navels especially in the San Joaquin Valley.. This is mainly because of its excellent yield efficiency i.e. for each cubic metre of canopy volume, it produces more kilograms of fruit than other rootstocks.

In the HortResearch (New Zealand) trial, C-35 has produced high yielding trees with good fruit size and internal quality. Trees on C-35 are more vigorous than those on *P. trifoliata*, but in a similar trial where satsuma mandarin is the scion variety, the vigour of C-35 has slowed down as the trees began bearing heavy crops.

References

1 Castle, W. S. and Manthey, J. A. 1998. **Screening citrus rootstocks for iron-deficiency tolerance.** Fruits 53: 375-381.

2 Cameron, J. W. and Soost R. K. 1986. **C35 and C32: Citrange rootstocks for citrus.** HortScience 21 (1): 157-158.

3 Currie, A., Sutton, P. Machin, T. and Anderson, P. 2002. **Yen Ben Lemon Rootstock Trial.** The Orchardist. June 2002. pp. 50-51.

Cleopatra mandarin

Origin

Cleopatra mandarin originated in India and was introduced into Florida from Jamaica in the mid 19th Century. Cleopatra mandarin has been widely distributed and trialled as a rootstock throughout the world. It is used in Florida, Spain and Australia for shallow alkaline soils.

Tolerance to environmental and soil conditions

Trees on Cleopatra mandarin are tolerant of shallow alkaline soils due to a relatively shallow root system. Cleopatra mandarin is sensitive to waterlogging and performs best in well drained soils. Cleopatra has good salinity tolerance due to its ability to exclude chloride.



Pest and disease

Cleopatra mandarin is highly sensitive to *Phytophthora* and should only be used for plantings where citrus has not been planted previously. Trees on Cleopatra mandarin are also sensitive to citrus nematodes. It is tolerant of citrus tristeza virus and exocortis.

Field performance

Cleopatra mandarin produces large trees that are characterised by low early cropping. Trees are long lived and produce consistent crops of high quality fruit between 10-30 years of age.

Nursery performance

Cleopatra mandarin is a slow growing rootstock in the nursery and is difficult to propagate. Budded trees have a tendency to remain dormant and fail to shoot. Sensitivity to *Phytophthora* and citrus nematodes requires a high level of nursery hygiene.

Fruit quality

Fruit from trees on Cleopatra mandarin are of high quality but maturity is generally later than fruit grown on Troyer and Carrizo citranges. Trees on Cleopatra tend to produce small fruit. Cleopatra mandarin is been used to extend the harvest period for Imperial mandarin in Queensland due to its late maturity.

Scion compatibility

Cleopatra mandarin is highly compatible with mandarin varieties. It is compatible with Imperial mandarin and does not show any overgrowth or cincturing at the bud union, providing an alternative to *Poncirus trifoliata* and the citranges.

Extent of plantings

Cleopatra mandarin is a minor rootstock in Australia accounting for less than 5% of total citrus plantings. It is used mainly for Imperial mandarins in Queensland and some navel oranges in shallow alkaline soils in southern Australia.

Overseas experience

Cleopatra mandarin has been an important rootstock in Spain for growing mandarins in shallow alkaline soils, but its popularity has declined in favour of Carrizo citrange. Cleopatra mandarin is the major rootstock used for mandarins in Florida. It is also a minor rootstock for oranges and grapefruit in Florida, but its popularity is declining due to poor disease tolerance in replant sites and susceptibility to citrus blight.

Poncirus trifoliata

Origin

The trifoliolate orange (*Poncirus trifoliata*) has grown in China for thousands of years and in Japan since the 8th Century. It was introduced into Australia in the latter part of the 19th Century, but because of the restricted growth of many trees propagated on this stock, it became unpopular. Trifoliolate orange became the preferred rootstock for heavy soils after research identified transmission of viroids, in particular citrus exocortis viroid, via infected budwood as the cause of the dwarfing and decline problem. Many selections of *P. trifoliata* have been made and named. The one in common use in Australia is a small leaf, small flowered selection known as the Australian selection or *P. trifoliata* 22.



A dwarfing selection known as ‘Flying Dragon’ is sometimes used as a stock for the retail trade.

Tolerance to environmental and soil conditions

Poncirus trifoliata is most suitable for lime-free soils and can withstand cold and wet conditions. However impeded drainage can result in ‘Sudden death’ of trees on this stock. Trees on *P. trifoliata* grow well on fertile clays to loams but are intolerant of highly acid or highly alkaline soils. They also react to saline conditions, and trees on *P. trifoliata* readily take up chloride through the leaves, a problem most often observed in trees watered by overhead irrigation. It is one of the preferred rootstocks for replant sites. *Poncirus trifoliata* does not develop a very deep or wide root system, but feeder roots are highly fibrous. It has poor drought tolerance.

Pest and disease

Poncirus trifoliata is highly resistant to *Phytophthora* root and collar rots and citrus nematode. It is immune to citrus tristeza virus. Budwood for propagation on this stock should be obtained from Auscitrus to ensure freedom from citrus exocortis viroid (CEV) and other viroids, which cause dwarfing, and from citrus tatter leaf virus to which trifoliolate orange is sensitive resulting in a yellow ring at the bud-union. This rootstock is responsive to viroid dwarfing and is recommended as a stock for viroid dwarfing of oranges.

Field performance

Poncirus trifoliata is generally a good rootstock for oranges, satisfactory for grapefruit (although small fruit size is sometimes reported), most mandarins and lemons with the exception of Eureka lemon. A major drawback in the use of *P. trifoliata* is the slow initial establishment of new plantings. Cropping efficiency is good. Trees propagated on *P. trifoliata* are suitable for planting at high density. Field performance in tropical and sub-tropical regions is generally poor.

Nursery performance

P. trifoliata is the slowest growing of all commercial rootstocks. Nursery trees on *P. trifoliata* take 6-12 months longer to grow compared with Troyer and

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Carrizo citranges. It is the most difficult of the commonly used rootstocks to propagate. Early spring and late autumn propagation of *P. trifoliata* are difficult due to extended winter dormancy. Small flowered selections are less vigorous than large flowered types and are more bushy.

Fruit quality

Fruit quality is excellent, with high total soluble solids and acid content and a smooth thin peel. Fruit size is medium and maturity mid to late. Juice content is high. Trees propagated on *P. trifoliata* produce fruit with high early season acidity but show excellent late holding characteristics.

Scion compatibility

Incompatible with Eureka lemon, a yellow ring incompatibility develops at the bud union. Cincturing at the bud-union is often a problem with Imperial mandarin, which can be overcome by use of a sweet orange interstock.

Extent of plantings

P. trifoliata is the most commonly used rootstock for the heavier soils of the Riverina and Curlwaa regions in New South Wales. Sales of *P. trifoliata* seed through Auscitrus are consistently higher than for other stocks, although less than the cumulative figure for Troyer and Carrizo citranges.

Overseas experience

P. trifoliata is the predominant rootstock in China, Japan and Argentina. It is also used in the Central Valley of California in heavy soil areas.

Rough Lemon

Origin

Rough lemon originated in the Himalayan foothills in India and has been used as a rootstock for citrus in Australia for more than one hundred years. It was most widely used in Australia in the first half of the 20th Century. A wide range of Rough lemon selections exist and the most commonly used selection in Australia is the McKillop selection

Tolerance to environmental and soil conditions

Trees on Rough lemon are highly drought tolerant. Production of an extensive root system enables trees on Rough lemon to forage effectively for soil nutrients. Rough lemon also has some tolerance to alkaline soils and moderate tolerance to salinity. Rough lemon is suitable for sandy, well drained soils.

Pest and disease

Rough lemon is highly sensitive to *Phytophthora* and should only be used for plantings where citrus has not been planted previously. Trees on Rough lemon are also sensitive to citrus nematodes. Tolerant of citrus tristeza virus and exocortis. Rough lemon rootstocks are highly susceptible to lemon scab under high rainfall coastal conditions. Infected nursery trees on Rough lemon may be a source for transmission of lemon scab to existing plantings.

Field performance

Rough lemon is a highly vigorous rootstock and shows good yield performance in early years. Rough lemon produces large trees with a large well developed root system. Trees older than fifteen years often suffer from alternate bearing and declining yields. Trees on Rough lemon often decline rapidly after twenty years due to poor tree health.

Nursery performance

Rough lemon is the quickest growing of all common rootstocks. It is also the easiest rootstock to propagate and has the longest propagation season. Due to their high vigour, nursery trees on Rough lemon have a high nutritional requirement. Nursery stocks are susceptible to citrus leafminer damage.

Fruit quality

Trees on Rough lemon produce fruit with poor internal quality due to low soluble solids and acid content. Rough lemon produces the earliest fruit maturity of all common rootstocks due to the low fruit acidity. Juice content is also low and fruit from trees on Rough lemon often have a thick, coarse textured rind.

Scion compatibility

Highly compatible with lemon varieties, Rough lemon also has good compatibility with oranges, grapefruit, tangelos and most mandarin varieties. Incompatible with Ellendale mandarin. May be incompatible with Satsuma mandarins.



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Extent of plantings

The majority of citrus trees planted on Rough lemon are located in the Riverland of South Australia and are mainly orange trees greater than thirty years old. Until the late 1990s, most Eureka lemons in Australia were grown on Rough lemon rootstock. Rough lemon has declined in popularity over the last thirty years with the introduction of Troyer, Carrizo and Benton citranges and Swingle citrumelo.

Overseas experience

Rough lemon was widely used in Florida to produce high yields of fruit for processing, but its use has declined in recent years due to sensitivity to citrus blight. Rough lemon is still a popular rootstock choice for lemon growing in Arizona. It was also widely used in South Africa, but has recently been overtaken by Swingle citrumelo and *Citrus volkameriana* in popularity.

Swingle citrumelo

Origin

A hybrid of Duncan grapefruit and *Poncirus trifoliata* produced in 1907 in Florida and released by the United States Department of Agriculture in 1974. A number of introductions of Swingle citrumelo have been made into Australia, where it is a relatively new rootstock that has rapidly increased in popularity.

Tolerance to environmental and soil conditions

Swingle citrumelo is sensitive to high chloride levels in soil and irrigation water but is more salt tolerant than other trifoliolate hybrids such as Carrizo and Troyer citranges. Swingle is sensitive to high pH soils and is unsuitable for highly calcareous soils. Trees on Swingle show chlorosis problems on highly calcareous soils. Soils with a clay content greater than 25-30% may restrict root growth. Swingle is unsuitable for heavy clay soils that are over-watered. Swingle has moderate drought tolerance and is highly cold tolerant.



Pest and disease

Swingle citrumelo has some resistance to *Phytophthora* root and collar rots but is less resistant than *Poncirus trifoliata*. Tolerant of citrus nematode. Trees have good tolerance to citrus tristeza virus (CTV). Trees propagated on Swingle citrumelo are susceptible to exocortis (scalybutt). Budwood for propagation should be obtained from Auscitrus to ensure freedom from citrus exocortis viroid (CEV).

Field performance

Phytophthora and nematode tolerance of Swingle citrumelo makes it suitable for replant sites. Trees grown on Swingle are vigorous, large and produce intermediate to high yields depending on cultivar. High early yields with navel oranges have been reported in southern Australia. Under Queensland growing conditions Washington navel trees on Swingle had 50% less yield than trees on Troyer citrange. Ability to hold fruit on the tree is good. Other anecdotal evidence suggests less albedo breakdown of Navelina on Swingle citrumelo compared to Troyer and Carrizo citranges.

Nursery performance

Vigorous nursery stock that is highly nucellar. Seedlings require slightly higher rate of culling than Troyer and Carrizo citranges.

Fruit quality

The predominant experience with Swingle citrumelo in southern Australia has been with navel oranges in replant sites over the last ten years. Navel trees on Swingle have produced medium to large sized fruit with a smooth, thin rind. Washington navel fruit grown on Swingle in Queensland are of poor quality.

Swingle rootstock produces fruit with high juice and soluble solids content and mid-range acidity. Fruit matures mid-late season and rind colour development of navel oranges on Swingle is delayed. Swingle may not be a good choice for early season navel oranges due to its late maturing characteristics.

Scion compatibility

Swingle citrumelo is a superior rootstock for grapefruit producing high yields of large, excellent quality fruit with high juice content. There is some anecdotal evidence in southern Australia of a yellow ring at the bud union with some navel orange scions. Swingle has a tendency to overgrow most orange scion cultivars. Valencia yields on Swingle are moderate. Swingle is incompatible with Eureka lemon and is not recommended for Imperial mandarin due to cincturing and overgrowth at the bud union. It is incompatible with Meyer lemon. Swingle has been used as a rootstock for Murcott tangor in Queensland. Little else is known of Swingle as a rootstock for mandarins.

Extent of plantings

Swingle citrumelo has rapidly increased in popularity over the last ten years in Australia and now accounts for ten percent of Auscitrus rootstock seed sales. Only Troyer citrange, Carrizo citrange and *Poncirus trifoliata* are currently more popular than Swingle citrumelo. Demand for Swingle seed is expected to increase over the next ten years.

Overseas experience

Orange trees on Swingle in Florida have declined as early as 6 years of age in soils with restrictive layers that limit vertical root development and lead to perched water tables. Experience in Spain indicates that Swingle has good tolerance to soil waterlogging. Minneola tangelo is reported to produce good fruit quality on Swingle citrumelo in Florida. Around fifty percent of all trees propagated in Florida are on Swingle citrumelo.

Troyer/Carrizo citrange

Origin

Troyer and Carrizo citranges are hybrids of Washington navel orange and *Poncirus trifoliata*. The original crosses were made in the early 1900s by the United States Department of Agriculture with the intention of producing cold tolerant scion varieties. They were later identified as being suitable for use as rootstocks. Commercial use of these rootstocks began in Australia in the 1960's. They are visually indistinguishable and under Australian conditions there is little difference in the performance of trees on either rootstock. They are general purpose rootstocks and are widely used for most commercial varieties in Australia with the exception of Eureka lemon.



Tolerance to environmental and soil conditions

Intolerant of high pH soils with high levels of available calcium and also intolerant of saline conditions. Trees on these stocks frequently show micronutrient deficiencies (zinc, iron, manganese) especially in the spring flush. Suitable for replant sites. Moderately cold tolerant. Best results with Troyer/Carrizo citrange are achieved in well drained soils. Both rootstocks are unsuitable for heavy clay soils.

Pest and disease

Troyer and Carrizo citranges are tolerant of tristeza virus and *Phytophthora* root rot but are less tolerant than *Poncirus trifoliata*. They are also tolerant to citrus nematodes, but this varies with the nematode biotype. Both stocks are responsive to viroid dwarfing. The citranges are prone to sudden death in soils with impeded drainage.

Field performance

Main lateral and fibrous root development may be poor in young trees. Mature trees are medium to large. Young trees on these stocks are vigorous and produce good crops of high quality fruits in their early years. Crop regulation should be considered an essential management requirement for mandarin cultivars grown on these rootstocks. Trees in the Murray Valley older than twenty years often show a tendency to produce smaller fruit.

Nursery performance

Troyer and Carrizo citrange are highly nucellar and produce uniform, vigorous, upright stocks that are easy to manage in the nursery. Most varieties are easy to propagate on both rootstocks with the exception of Imperial mandarin, where poor bud take is sometimes encountered. Nursery trees are faster growing than *Poncirus trifoliata* but slower than Rough lemon.

Fruit quality

Fruit quality is excellent, but there is a tendency for increased albedo breakdown in older trees. Fruit size is medium, with a thin, smooth rind. Juice and sugar content are high and acidity levels are medium to high. Fruit maturity

Rootstocks

is earlier than *Poncirus trifoliata*, Swingle citrumelo and Cleopatra mandarin but later than Rough lemon.

Scion compatibility

Fully compatible with navel and Valencia orange varieties. These rootstocks are incompatible with Eureka lemon, forming a yellow ring at the bud-union.

The decline of Imperial mandarin trees on citrange stocks, which is related to excessive rootstock overgrowth at the bud union causing a cincturing effect, may be triggered by excessive early cropping and poor management of young trees.

Extent of plantings

Combined sales of Troyer and Carrizo citrange have increased rapidly over the last ten years and now account for more than 40% of total rootstock seed sales in Australia. In Queensland, Troyer citrange is the major rootstock used for mandarins. The citranges are the most widely used general purpose rootstocks in the Murray Valley.

Overseas experience

Troyer is widely used in California, while Carrizo has been a leading rootstock in Florida. Whereas Troyer was more popular than Carrizo in Spain and South Africa, the reverse is now the case. In Israel most mandarin hybrids are propagated on Troyer citrange.