Citrus Rootstock Technical Guide – Mature Tree Assessments

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Introduction

Original citrus plantings in the Riverland were either on own roots, or used pure bred rootstocks such as Sweet orange, Cleopatra mandarin and Rough lemon, which provided some advantages in terms of yield and/or fruit quality. However, as existing orchards began to be replanted, it was recognised that these rootstocks were unable to cope with the disease and nematode load in soils which had previously contained plantings, especially citrus.

Hybrid rootstocks were the answer to this problem, and breeding programs have been undertaken across the globe, attempting to combine the most advantageous characteristics of a range of Citrus species, and other, related genera such as Poncirus.

A range of these new generation rootstocks have been imported into Australia, or bred here, and SARDI has evaluated a number of them under local conditions and with locally selected varieties. During the period 1989 to 2002, a range of citrus rootstock trials were established in the Riverland, principally at Loxton Research Centre. Initial evaluation of these trials was conducted for up to 10 years from planting, although most often measurements were not continued past five or six years of age due to funding limitations.

The now mostly mature trees in these trials were revisited over two harvests (2015 and 2016), and performance evaluated and compared with data collected during the 1980's to early 2000's.

Materials and methods

The longevity, tree and cropping performance and fruit quality of trees in four historic rootstock trials were assessed across the 2015 and 2016 harvests. Three of the trial sites were located on Loxton Research Centre, with the fourth being located on a private property between Loxton and Berri. In all, 21 rootstock genotypes were assessed.

Three of the trial sites had previously been assessed by Peter Gallasch and had associated datasets available for longitudinal comparisons of tree size, yield and various fruit quality parameters.

In season data were analysed by two-way ANOVA using SigmaPlot Version 13 (Systat Software Inc. GmbH, Erkrath, Germany). Longitudinal analysis was performed using the R software (R Core Development Team, version 3.1.3, 2015), and analysis of variance (ANOVA) was used to statistically test for differences between rootstocks and time periods within sites. Pairwise-t-tests were then employed when there were significant main effects and interactions.

Results from the four local trials were compared with published information from around the world, and performance summarised in Table 1. Performance summaries were compiled for selected rootstocks.

Table 1 Identification of potential issues with scion/rootstock combinations represented in the revisited trials

Rootstock	Navelina Orange	Hockney Navel Orange	Summer Gold Navel Orange	Washington Navel Orange	Afourer Mandarin	Murcott Tangor	Imperial Mandarin
Rough Lemon				7			
Rangpur Lime				5,6			
Philippine Red Lime		6	5,6				
Santa Barbara Red Lime			6				
Cleopatra Mandarin							
Emperor Mandarin							
Sunki Mandarin	5,6	5,6	5,6				
Sweet Orange				6			
Taiwanica							
Volkameriana				5,6	7		4
Trifoliata							
Swingle Citrumelo					**2,4,5,6**	**2,4,5,6**	2
F80-5 Citrumelo	**1,2**	5,6					
F80-7 Citrumelo	**1,2,7**						
Nelspruit 639					2		3
Benton Citrange				5,6			
Carrizo Citrange							3
Troyer Citrange						2	3
Troyer 341							
C-32 Citrange							
C-35 Citrange	**1,2**	5,6	5,6		2,5	2,4	3

1 – Incompatible combination, significant tree death
2 – Bud union exhibits creasing
3 – Overgrowth by the rootstock, potential for girdling
4 – Poor tree health
5 – Tree size reduced
6 – Yield depressed
7 – Poor internal fruit quality

Performing well
Some concerns
Not recommended

Results of citrus rootstock investigations

The matrix presented in Table 1 summarizes where issues were identified in specific scion/rootstock combinations found in the trials. In the table, cells coloured green indicate that no significant problems were identified. Yellow cells identify combinations which demonstrate some issues, generally of a moderate nature. Red cells identify combinations which are not recommended due to major issues resulting in tree death or very poor tree growth, health and yield. White cells are scion/rootstock combinations not present in the trials.

The numbers in the yellow and red cells code for the type of issue identified, and are explained by the key at the base of the table.

Performance summaries for selected rootstocks

Of the rootstocks summarised in Table 1, a selection are summarised in more detail below. These include the standard rootstocks used within the Australian citrus industry, based on the list of rootstocks routinely available from AusCitrus (Auscitrus, 2016), as well as selected additional rootstocks which are of particular interest.

Rough Lemon

C. jambhiri Lush.

- Washington navels at Loxton produced moderate yields of fruit with low levels of Brix and acid.
- Low sugar and acid characteristics are well documented (Castle, 1987; Castle et al., 1993; Fallahi et al., 1991; Fallahi and Rodney, 1992; Ferguson et al., 1990; Tribulato, 1979).
- Reputation for large crops (Castle, 1987; Castle et al., 1993; Fallahi et al., 1991; Fallahi and Rodney, 1992; Ferguson et al., 1990) not reflected in Loxton trials.
- Reports of graft union disorders in Moro orange Tribulato (1979), and incompatibility with Shamouti orange Ashkenazi (1988).
- Fruit generally susceptible to disorders such as albedo breakdown (Treeby et al., 1995), and development of mould and wastage (Tindale, 1950) and rind disorders (Cronje, 2013) under storage. Ritenour et al. (2004) found variable performance, with low levels of stem end rind breakdown, but high levels of decay.
- Not recommended for replant situations (Hardy, 2004; von Broembsen, 1985).

Rangpur Lime (Rangpur)

C. limonia Osbeck

- In the Loxton trials produced small trees and low yields.
- Literature suggests poor to moderate fruit quality (Ashkenazi, 1992; Castle, 1987).
- Susceptible to most diseases and pests (Ferguson et al., 1990), as well as albedo breakdown (Treeby et al., 1995).

Cleopatra Mandarin

C. reshni Hort. ex Tan.

- Performed well in all of the Loxton trials.
- Navel oranges known to perform well (Castle et al., 2000; Ferguson et al., 1990), production low in early years but increases as trees mature (Castle, 1987; Forner-Giner et al., 2003).
- Mandarin performance also known to be good (Ferguson et al., 1990), with the same issue of delayed bearing (Ashkenazi, 1992; Castle and Baldwin, 2006).
- Fruit shows low levels of albedo breakdown (Treeby et al., 1995), and low susceptibility to decay under storage (Ritenour et al., 2004), but high levels of weight loss under storage

(Alirezanezhad and Eamin, 2006; Machado et al., 2015).
- Only recommended for soils which have not previously had citrus trees (Hardy, 2004).

Sweet Orange

Citrus sinensis [L.] Osbeck

- Performed well under mandarin scions at Loxton, consistent with the literature (Castle, 1987; Castle et al., 1993; Ferguson et al., 1990), and adequately under Washington navel orange.
- Recognized as being of intermediate vigor and producing intermediate yields (Castle et al., 1993), low yield in Loxton navel orange trial may reflect the relatively close planting distance (6.5 x 3 m) and mature size of these trees, resulting in competition for space, light and nutrients. May perform better in a uniform planting all on Sweet orange.
- Has been shown to produce fruit with low susceptibility to albedo breakdown (Treeby et al., 1995), but moderate susceptibility to mould and wastage in storage (Tindale, 1950), and high susceptibility to postharvest disorders (El-Zeftawi et al., 1989).
- Not recommended for replant situations (Gallasch and Staniford, 2003; Hardy, 2004).

Volkameriana (Volkamer lemon)

C. volkameriana Ten. & Pasq.

- Not widely used in Australia, but available commercially.
- Generally considered to have similar characteristics to Rough lemon (Castle, 1987; Castle et al., 1993; Hardy, 2004; von Broembsen, 1985).
- Performed adequately under Murcott tangor at Loxton, but tree size was reduced in Washington navel trees, and tree health was poor in Imperial mandarins.
- Ferguson et al. (1990) lists incompatibility with Satsuma mandarins but provides no source for the finding, and gives a rating of “Uncertain” in respect of compatibility with navel oranges and mandarins, due to less than 10 years of observations being available at that time.
- The majority of literature reports high vigour, large tree size and high yields in trees of a range of varieties (Castle et al., 2010; Castle et al., 1993; Fallahi and Rodney, 1992; Forner-Giner et al., 2010; Georgiou, 2000, 2002; Hardy, 2004; Tribulato, 1979; Tsakelidou et al., 2002; Tuzcu et al., 1999; Waqar et al., 2007; Zekri and Al-Jaleel, 2004).
- Some examples where Volkameriana produced the smallest tree size (Stenzel et al., 2003; Tazima et al., 2013) and lowest yields (Tazima et al., 2013, 2015).
- Tribulato (1979) reports disorders of the graft union but no impact on tree health in Moro orange trees, and Ashkenazi (1988) reports incompatibility with Shamouti orange.
- Fruit quality known to be relatively poor (Castle et al., 1993; Fallahi et al., 1991; Fallahi and Rodney, 1992; Hardy, 2004; Tuzcu et al., 1999), Loxton trials found low juice content and thick rinds in Afourer fruit.
- Produces fruit with good storage performance, with low levels of decay, weight loss, juice percentage loss and decline in TSS and acid (Alirezanezhad and Eamin, 2006).

Trifoliata (Trifoliate orange)

Poncirus trifoliata [L.] Raf.

- Not commonly used in South Australia due to its low tolerance for high pH soils and saline water (Gallasch and Staniford, 2003), but grows well in heavier soils (Hardy, 2004).

- Only present in one of the Loxton trial sites, where it gave moderate yields.
- Some literature indicates high fruit quality from trees on Trifoliata (Castle, 1987; Castle et al., 1993; Hardy, 2004), moderate quality fruit from trees at Loxton may be the result of the trial being planted in sandy soil.
- Compatible with most orange varieties, including Washington navels, but known to express incompatibility symptoms with Roble orange (Garnsey et al., 2001), and some mandarins (Ashkenazi, 1988).
- Fruit recognized as having low levels of albedo breakdown (Treeby et al., 1995), and storing well, with low incidence of mould and wastage (Tindale, 1950) and good storage life (Fruit Research Institute Sichuan Agricultural Academy China, 1982).
- However, Hifny et al. (2012) found variable results under storage, with good retention of fruit firmness and SAR, but declining TSS and acid, and Arras and Chessa (1986) found high levels of decay.

Swingle Citrumelo (Citrumelo 4475)

P. trifoliata (L.) Raf. x Duncan grapefruit (*C. paradisi* Macf.)

- Showed early promise as a replant rootstock for a wide range of varieties (Castle, 1987; Castle et al., 1988; von Broembsen, 1985).
- Over time a range of compatibility issues have come to light.
- In the Loxton trials, bud union creasing, lack of tree growth, poor tree health and depressed yields of Murcott tangors (Figure 1) are entirely consistent with the weight of published material (Ashkenazi, 1992; Barbasso et al., 2005; Castle and Baldwin, 2006; Castle and Stover, 2000; Garnsey et al., 2001).

Figure 1 Murcott tangor tree on Swingle citrumelo, compare health and size with trees in background

- Similar symptoms in Afourer mandarin at Loxton suggest this problem may affect many more mandarin types (Ashkenazi, 1988; Garnsey et al., 2001).
- Imperial mandarin at Loxton also showed signs of development of tissue abnormalities at the bud-union, but no obvious tree symptoms.
- Although the performance of Washington navel oranges at Loxton was adequate, literature indicates that symptoms consistent with incompatibility have also been observed in common orange and navel orange trees on Swingle (Ashkenazi, 1988; Castle and Stover, 2000; Garnsey et al., 2001; Schneider and Pehrson, 1985).
- However, other reports from some of the same authors show positive results in trials of oranges on Swingle (Castle et al., 2000; Castle et al., 2010), so

incompatibilities appear to be the exception rather than the rule.
- Fruit has performed well for decay under storage (Ritenour et al., 2004), but more work is needed.

Nelspruit 639 (x639)

Cleopatra mandarin (*C. reshni* Hort. ex Tan.) x *P. trifoliata* (L.) Raf.

- Published information is positive, with good tree size and cumulative yields under Washington navels at eight years of age (Castle et al., 2000), and Murcott tangors at nine years (Castle and Baldwin, 2006).
- Navel fruit size is large (Castle et al., 2000; Castle and Ferguson, 2003).
- Susceptible to citrus blight (Castle and Ferguson, 2003).
- Performed well under Murcott tangors at Loxton,
- Bud union issues under Afourer and Imperial mandarins, and use under these varieties cannot be recommended.
- In the absence of local trials under navels it is assumed that performance should be good, based on information from the USA, but further local evaluation is recommended.
- Little post-harvest storage work has been carried out, the small amount available shows that fruit performs well for levels of decay and stem end rind breakdown (Ritenour et al., 2004).

Benton Citrange

Citrus sinensis [L.] Osbeck x *Poncirus trifoliata* [L.] Raf.

- Originally bred specifically for use with Eureka lemon (Hardy, 2004), which shows incompatibility with many of the commonly used rootstocks, especially those with Trifoliata parentage.
- Has been tested with other citrus varieties, but has not performed exceptionally with any of them.
- Trial trees at Loxton performed well under Imperial and Afourer mandarin and Murcott tangor, but produced small trees and low yields under Washington navel.
- Under Washington navels in Florida, produced small trees with moderate yield (Castle et al., 2000), and under Murcotts in Florida produced inconsistent tree size and was rated as "C"-grade, being deemed not promising enough to progress to yield evaluation (Castle and Baldwin, 2006).
- Few compelling reasons to use this rootstock under Riverland conditions, except with Eureka lemon.

Carrizo and Troyer Citrange

Citrus sinensis [L.] Osbeck x *Poncirus trifoliata* [L.] Raf.

- Widely considered to have arisen from the same original selection, and generally demonstrate only minor differences in performance (Castle, 1987; Castle et al., 2000; Castle et al., 1993; Hardy, 2004; von Broembsen, 1985).
- International literature reports high vigour and good early cropping (Castle, 1987; Castle et al., 2010; Castle et al., 1993; Hardy, 2004), although some variable performance (von Broembsen, 1985) and small fruit size in older trees (Gallasch and Staniford, 2003; Hardy, 2004) has been reported.
- Washington navels at Loxton performed well in early harvests, producing amongst the highest yields, but mature trees are no longer among the highest yielding in the trial.
- Symptoms of bud union creasing under Murcott tangor (Troyer only) and overgrowth of the rootstock under Imperial mandarins (both rootstocks) in the Loxton trials are indicators that these combinations may develop problems over their expected life span.

- Issues with compatibility have been reported in the literature, for Roble and Page oranges (Garnsey et al., 2001), and for mandarins and their hybrids (Ashkenazi, 1988; Castle et al., 1993), especially Murcott tangor (Castle and Stover, 2000; Garnsey et al., 2001).
- This information has arisen since Ferguson et al. (1990) published their recommendations that these citranges are compatible with oranges and mandarins in general. Subsequent experience has identified significant exceptions to the rule.
- Increased rind creasing has been reported on these rootstocks (Gallasch and Staniford, 2003; von Broembsen, 1985).
- Avoid when planting mandarin trees.
- High early yields of Washington navel oranges may not be sustained into maturity, evaluate the benefits of high yields early in orchard life against moderate long term yield projections when deciding whether to use these rootstocks under navel oranges.
- Shown to produce fruit with moderate albedo breakdown susceptibility (Treeby et al., 1995), but good performance across the board for storage problems such as rind disorders (Cronje, 2013), chilling injury (McCollum et al., 2002), decay (Arras and Chessa, 1986) and general storage quality (Akpinar and Kaska, 1993).
- However, D'hallewin et al. (1994) found that fruit from trees on Troyer performed poorly for decay and declining SAR under storage, and Ritenour et al. (2004) found variable results across various citrus varieties and storage conditions.

C-32 Citrange

Ruby Blood orange (*C. sinensis* [L.] Osbeck) x *Poncirus trifoliata* (L.) Raf.

- A limited history of evaluation, but has performed well in all trials reported to date.
- In Florida, Hamlin sweet orange trees performed equal best (Castle et al., 2010), and Washington navel orange trees were in the most productive group (Castle et al., 2000).
- Castle and Ferguson (2003) indicate that trees are “consistent in their vigor, large size, and excellent yield”.
- Significantly, there have been no reports of bud union creasing or incompatibility symptoms in the literature to date.
- At Loxton both Murcott tangor and Afourer mandarin trees were large and healthy, returned high yields of fruit, and showed no evidence of bud union creasing.

C-35 Citrange

Ruby Blood orange (*C. sinensis* [L.] Osbeck) x *Poncirus trifoliata* (L.) Raf.

- A sibling of C-32 citrange which demonstrated promising characteristics in early evaluation.
- Failed to live up to early promise at Loxton, with less than optimum performance under all scions.
- Demonstrated bud union creasing under mandarin types, leading to poor tree health and size (Afourer and Murcott), and rootstock overgrowth (Imperial).
- Although Ferguson et al. (1990) characterized it as compatible with mandarins, Castle and Baldwin (2006) found wide differences in performance of Murcott across soil types, with most trees performing poorly, and an overall rating of C given to the combination.
- Roose (2009) found decline in Valencia trees from around 10 years of age, and Garnsey et al. (2001) reported “strong” bud union symptoms and the presence

of canopy effects in incompatibility observations of 'Roble' sweet orange.

- Bud union creasing of Navelina orange trees (Figure 2) has led to widespread tree death at Loxton. Forner-Giner et al. (2003) did not report development of incompatibility symptoms in 10 year old trees in Spain, but symptoms at Loxton did not appear until around 12 years.

Figure 2 Bud-union creasing in Navelina on C-35 citrange

- Tree size reduction is a known characteristic of this rootstock (Castle et al., 2000; Castle et al., 2010; Castle and Ferguson, 2003; Forner-Giner et al., 2003; Roose, 2009), but tree size reduction is expected to be compensated for by higher yield efficiency (Castle and Ferguson, 2003; Hardy, 2004).
- In the Loxton trials, however, yield per trunk cross sectional area (TCSA) was middle of the range to low under both navel oranges and mandarins, suggesting that planting trees at higher density may still not recover yield per hectare to the same level as obtained with other rootstocks at normal spacing.

Further Reading

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