Assessing the horticultural performance of new citrus rootstocks via short-term orchard trials

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NSW Department of Primary Industries

Project Number: CT07002

CT07002

The research contained in this report was funded by Horticulture Australia Ltd with the financial support of the citrus industry.

ISBN 0 7341 3306 5

Published and distributed by:
Horticulture Australia Ltd
Level 7
179 Elizabeth Street
Sydney NSW 2000
Telephone: (02) 8295 2300
Fax: (02) 8295 2399

Horticulture Australia

Horticulture Australia Limited

FINAL REPORT

CT07002
(Jan 2014)

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Khurshid *et al.*

NSW Department of Primary Industries
Dareton

Horticulture Australia

NSW DEPARTMENT OF
PRIMARY INDUSTRIES

CSIRO

Project CT07002: Assessing the horticultural performance of new citrus rootstocks via short-term orchard trials

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This report describes the results from a series of trials conducted at Dareton NSW, Australia). This project investigated the performance of Chinese rootstocks on a range of scions selected from previous evaluation work funded by the Australian Centre for International Agricultural Research (ACIAR).

Funding and acknowledgements: This project has been funded by HAL using citrus industry levy and matched funds from the Federal government.

Jan 2014

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Media Summary

The national citrus rootstock improvement program of Australia is a multi-stage process involving glasshouse screening for seed characteristics, seedling uniformity, graft compatibility, disease resistance and salt tolerance, followed by orchard evaluation with a range of scion varieties. Orchard evaluations are conducted in two phases comprising short-term trials (up to 10 years) to identify candidates for entry into longer-term semi-commercial based plantings in collaboration with industry under a range of soil, climatic and management conditions. This report describes the results from the short-term assessments of horticultural performance in a range of trials conducted at Dareton, NSW. Superior rootstocks emerging from these trials will be entered into longer-term industry-based commercial evaluation plantings across Australia.

The research conducted at NSW DPI, Dareton focussed on short-term trials to evaluate the horticultural performance of a large number of experimental rootstocks with the aim of identifying candidates for entry into longer-term, industry-based commercial trials. There were a tital of five stages (modules) A, 1, 2, 3 and 4 of trials established at Dareton (Table 2.4, page 16). The data from the experimental trials from stage A and stage 1 has been been completed and reported in previously HAL funded project CT03025 in 2007.

This report presents the data from stage 2 (planted in 2001) and stage 3 (planted in 2003) experimental trials conducted on scion varieties Navelina, Lane Late navel, Imperial mandarin and Eureka lemon to evaluate the performance of the various rootstocks. The rootstocks evaluated in these trials at Dareton were sourced from the Peoples Republic of China and CSIRO's breeding program. The introductions of rootstocks from China were via seed and occurred in two projects supported by funds from ACIAR during the period 1992-to-2002. All the rootstocks included in this component had been screened by NSW DPI and CSIRO for disease resistance and salt tolerance under glasshouse conditions before prior to 1999.

Data presented in this report from these trials at Dareton concern rootstock effects on the performance of trees with regard to tree establishment, growth, chloride uptake, disease resistance, fruit yield and quality. Data concerning tree growth, fruit yield and quality are reported only for the second and third stages established, while data for chloride uptake are reported for trees in three stages.

Rootstock effects on tree growth, fruit yield and quality were assessed over a period of five years in the stage 1 that had been established in 2001 (four trials with Navelina, Lane Late navel, Imperial mandarin and Eureka lemon). Root excavation was also carried out in trees from stages 1 and 2 to investigate root distribution and structure. Based on cumulative fruit yield, size and internal quality, as well as tree size, a number of rootstocks were selected from stage 1 according to their effects on different scion varieties with potential for entry into further longer-term (semi-commercial) trials.

Selected rootstocks as an outcome of this research work:

Navelina
***P. trifoliata*: Jiangjin large leaf, Small leaf, Ghana and Xianyong**

Lane Late
***P. trifoliata*:** Guanyun, Xianyong and Ghana

Imperial mandarin
C reticulata: Mantou hong and ***P. trifoliata:*** Ghana

Eureka Lemon
P. trifoliata: Wangchang large leaf, No. 22 and Wanyan

Technical Summary

The national citrus rootstock improvement program of Australia is a multi-stage process involving the establishment of source trees, ensuring uniformity of rootstock seeds and seedlings, glasshouse screening for disease and salt tolerance, short-term preliminary field trials to evaluate horticultural performance; and longer-term evaluation in semi-commercial plantings under a range of soil, climatic and management conditions. This report describes results from preliminary field trials conducted to investigate rootstock effects on the horticultural performance of a range of scion varieties. The trials were conducted in major regions for citrus production in the Murray Valley. The results from the trials will be used to identify rootstocks for entry into longer-term, commercially orientated and industry-based trials in the major regions for citrus production. The new industry based trials will also include the current commercial verities.

The rootstocks evaluated in experiments conducted at Dareton were sourced as seed in 1992-to-2002 from the Peoples Republic of China and CSIRO's rootstock breeding program as a part of the ACIAR funded project. All the rootstocks included in the current HAL supported project have been screened by NSW DPI and CSIRO for disease resistance and salt tolerance under glasshouse conditions.

Tree growth, fruit yield, and internal fruit quality data collected for five years are reported for trials established in 2001 (Stage 2) and 2003 (Stage 3) for Navelina, Lane Late navel, Imperial mandarin and Eureka lemon) at NSW DPI, Dareton. Root excavation was also carried out in Stages 1 and 2 to investigate root distribution and structure. Chloride concentrations in leaves of scions are also reported to support earlier glasshouse experiments and investigate further the chloride exclusion capacities of the rootstocks.

Fruit yield and quality data were collected was based on cumulative yield, fruit size, internal fruit quality and tree size, a number of promising rootstocks were identified with potential for entry into longer-term follow-up industry-based plantings. Generally, trees grafted to *P. trifoliata* rootstocks produced better yields and yield efficiencies for sweet oranges in Stage 2. No recommendations were made from the rootstock trials conducted in Stage 3. Despite the good salt exclusion ability, the rootstocks bred by CSIRO breeding program failed to produce yield and fruit quality which would have been of commercial significance to the Australian citrus industry.

Selected rootstocks as an outcome of this research work are from Stage 2:

Navelina
P. trifoliata**:** Jiangjin large leaf, Small leaf, Ghana and Xianyong

Lane Late
P. trifoliata**:** Guanyun, Xianyong and Ghana

Imperial mandarin
C reticulata: Mantou hong and ***P. trifoliata:*** Ghana

Eureka Lemon
P. trifoliata: Wangchang large leaf, No. 22 and Wanyan

The selected rootstocks had higher yield and internal fruit quality. Out of the above rootstocks Ghana appears to be as one of the selected rootstock for Navelina, Lane Late and Imperial mandarin and therefor has the potential to be trailed with new commercial scions in the forthcoming new project (CT14004 – application submitted to HAL).

Chapter 1: General Introduction

1.1 History of the Rootstock evaluation scheme

Rootstocks have a major impact on the horticultural performance of citrus scion varieties and consequently influence the health and productivity of a citrus industry (Broadbent, 1993). The effect of citrus rootstocks on tree vigour and size, fruit yield, fruit size and a range of other quality factors are well documented (Castle, 1987). Therefore, the use of improved rootstocks is an important step for achieving a more productive and competitive industry. The Australian citrus industry is focussed on developing fresh fruit and fresh juice production and expanding export market opportunities.

The priorities for rootstock improvement in Australia were determined by a National Citrus Rootstock Screening Working party formed in 1985. The major objective of this working party was to promote a nationally coordinated rootstock evaluation program and to review screening procedures to determine the most effective means of evaluating germplasm for characteristics deemed essential, desirable or of minor importance. These characteristics reflected disease pressures and growing conditions in major production areas as well as anticipated developments within the industry. The ranking of characteristics deemed necessary for Australian citrus rootstocks agreed to by the working party in the mid 1980s has since underpinned the national program for rootstock improvement.

The National Citrus Rootstock Improvement Program was initiated as a result of the deliberations of the mid 80's working party. Rootstock improvement in Australia incorporates a multi-stage process starting with screening in a greenhouse for seed and seedling characteristics (disease and salt tolerance) before short-term replicated field trials are conducted on a range of scion varieties. Promising rootstocks are then selected for long-term commercial trials under a range of soil, climatic and management conditions (Bevington, 1998).

1.2 Background of the current project

The development and subsequent use of improved rootstocks to increase yield efficiency, fruit size, external and internal fruit quality is an important step towards developing a more productive and competitive citrus industry in Australia. *Poncirus trifoliata*, Troyer and Carrizo citranges are commonly used rootstocks in Australian for oranges and mandarins, and while these rootstocks have many desirable characteristics, they also have some negative attributes that can affect production. For example, these rootstocks are highly susceptible to the salinity of the soils and irrigation water used in the major citrus growing areas of the mid-to-lower Murray Valley, *viz*. the Sunraysia region of NW Victoria and SW New South Wales (NSW), and the Riverland of South Australia. Root zone salinity has been shown to affect citrus fruit yields and quality (Lehmann, 2003). In another example, *Poncirus trifoliata* rootstocks are often unsuitable for Australian mandarin varieties and a strong overgrowth at the graft union is observed on mature mandarin trees.

Thus, the national citrus rootstock improvement program seeks to identify and develop new rootstocks with advantages over currently used stocks where biotic and abiotic factors restrict Australian citriculture in reaching its full potential. This project was closely aligned to the national program and used a number of short-term rootstock trials established in the main citrus growing regions to identify rootstocks that improved scion performance with regard to yield, cropping efficiency, fruit quality, salt tolerance and disease resistance. The anticipated output from the project was that superior genotypes will be recommended for testing in wider, commercial trials.

The research conducted at NSW DPI, Dareton focussed on short-term trials to evaluate a large number of experimental rootstocks to identify candidates for entry into longer-term, industry-based commercial plantings. There were five modules; Module A (Stage A) - mixed rootstocks, Module 1 (Stage 1) - Mixed rootstocks, Module 2 (Stage 2) - Trifoliata rootstocks, Module 3 (Stage 3) - CSIRO hybrids and Module 4 (Stage 4) - Vietnamese rootstocks. Stage A was grafted to Valencia, Stages 2, 3 and 4 were grafted to Navelina and Lane Late sweet oranges, Imperial mandarins and Eureka lemons. The results from Stage A and Stage 2 have been reported in project CT03025 (Final report submitted 2007 to HAL). Trees for the other three stages were propagated and planted during the course of CT03025 (2001-2005). Stages 2-4, comprised four (Navelina, Lane Late, Imperial mandarin, Eureka lemon) trials each, which reflected the number of scion varieties used to evaluate the performance of the various rootstocks. This report is based on the data collected from Stage 2 and Stage 3.

1.3 Project Objectives

The main objectives of this project were:

- To assess the horticultural performance of a range of rootstock types in terms of yield, fruit quality, vegetative growth and rootstock and scion compatibility.

- To confirm data obtained in greenhouse and laboratory-based screening tests for salt tolerance and diseases resistance of a range of local selections and imported Chinese and Vietnamese rootstocks and to assess the performance of these rootstocks on different scion varieties in terms of tree establishment, growth, salt tolerance, fruit yield and quality in short-term orchard trials.

- To select promising rootstocks based on their horticultural performance in the short-term trials for entry into longer-term, commercial trials at grower's properties in the main citrus production regions.

1.4 Structure of the final report

Chapter 1: Introduction.

Chapter 2 reports on short-term performance trials conducted at NSW DPI, Dareton Primary Industries Institute, Dareton. This component of the project continued previous research by NSW DPI and CSIRO Plant Industry that was co-funded by the Australian Centre for International Agricultural Research (ACIAR), in which new rootstock germplasm was introduced to Australia from the PR China and Vietnam. Research conducted in ACIAR-supported projects included preliminary greenhouse and laboratory based screening of the rootstock germplasm prior to testing selected rootstocks in short-term field trials.

Chapter 3 reports the influence of rootstock on scion chloride concentration and also on the short-term performance trials from Module 3.

Chapter 4 reports on the conclusion and recommendations based on the current research studies. This chapter also describes strategies for wider adoption of the promising rootstocks for the citrus industry in Australia.

Chapter 5 reports technology transfer and extension activities undertaken during the course of project CT07002. This also includes a reference list.

Chapter 2: Short-term horticultural performance trials with new rootstocks

This chapter reports on short-term trials established to investigate the orchard performance of the new rootstock germplasm to identify candidates for entry into longer-term industry-based evaluation trials. This component of the project continued previous research by NSW DPI and CSIRO Plant Industry, co-funded by ACIAR, in which new citrus rootstock germplasm was introduced from the PR China and Vietnam. The ACIAR-supported projects included preliminary greenhouse and laboratory-based screening of rootstock germplasm.

2.1 Origin of the germplasm

The rootstocks used in the trials reported here were sourced from South East Asia and CSIRO's rootstock breeding program. The germplasm from South East Asia came from the Peoples' Republic of China and Vietnam, and was introduced to Australia as part of two projects supported by ACIAR from 1993 until 2002.

Due to Australian quarantine restrictions associated with the introduction of budwood from China and Vietnam, the rootstock germplasm was introduced as seeds. Citrus seeds can be mono- or polyembryonic. In polyembryonic seeds, the embryos are derived either from nucellar tissues or zygotes. Barring somatic mutation, nucellar embryos develop into seedlings that are genetically identical to the source or mother tree and thus offer an option for the safe movement of germplasm from countries where pests and diseases prevent the introduction of budwood. Citrus diseases and pests are rarely transmitted via seed tissues and a surface treatment with a fungicide and bactericide adequately reduces the biosecurity risk.

At the start of the first ACIAR project, seedling trees of each introduction were established in an arboretum as seed source trees for future research and commercial use. Seedlings propagated from introduced seeds were assessed for uniformity and characterised using isoenzyme polymorphisms, particularly with regard to trueness-to-type. Characterisation was important for transferring the results of Australian tests back to China and Vietnam and to allow accurate propagation of additional seed source trees for industry use should any of the introductions have commercial potential. The potential propagation of off-types from introduced seed is of concern to the Australian industry (Sykes and Lewis, 1995).

During the ACIAR funded projects the rootstock introductions were screened under greenhouse conditions for *Phytophthora* root and collar rot resistance/tolerance, Citrus Tristeza Virus (CTV) resistance (Sarooshi and Barkley, 1996 and Sarooshi *et al*. 1999), salt exclusion and early indications of graft incompatibility using a ring-grafting technique. The initial screening was conducted at CSIRO at Merbein and NSW DPI's Elizabeth MacArthur Agricultural Institute (EMAI). This chapter reports on the testing of the rootstock introductions in short term field trials at Dareton.

2.1.1 Germplasm from China

There were several introductions of germplasm from the PR China during the course of the projects supported by ACIAR. However only rootstocks introduced as seeds during 1993 and 1994, and for which Australian source trees were established, were propagated for inclusion in the horticultural performance trials at Dareton. These selections were made from a large population of families that had been progressively screened at NSW DPI's EMAI (Broadbent, 1993) and CSIRO (Sykes, 2011) for the following characteristics:

- polyembryony and uniform nucellar seedling production,
- tolerance to *Phytophthora* root and collar root,
- resistance to CTV,
- sodium and chloride exclusion capacity.

Details of this germplasm for mixed rootstocks are summarised in Table 2.1(a).

Table 2.1(a): Rootstock introductions from PR China assessed in short-term performance trials at NSW DPI, Dareton.

Year introduced	CSIRO code no.	Common name	Species name
1993	CO107	Nianju	*Citrus reticulata*
	CO108	Jinju	*Citrus reticulata*
	CO109	Shantou suanju	*Citrus reticulata*
	CO110	Jiangjing suanju	*Citrus reticulata*
	CO111	Jugan	*Citrus reticulata*
	CO112	Zhoupi Jiangjin	*Citrus reticulata*
	CO113	Gulin Jinqianju	*Citrus reticulata*
	CO114	Hongpi suanju	*Citrus reticulata*
	CO115	Anjiang hongju	*Citrus erythrosa*
	CO116	Zhuhongju	*Citrus erythrosa*
	CO117	Hongju	*Citrus reticulata*
	CO118	Cao shixiangju	*Citrus erythrosa*
	CO129	Nanju	*Citrus erythrosa*
	CR140	Zhenchen	*Citrus junos*
	CR141	Jiangbei Xiangchen	*Citrus junos*
	CR142	Xiechen (FALSE)[a]	*Citrus junos* (hybrid?)
			(hybrid *Citrus aurantium*)
	CR143	Goutou chen	
	CR144	Daidai	*Citrus aurantium*
	CR145	Ichang papeda 2586	*Citrus ichangensis*
	CR146	Ichang papeda No. 4	*Citrus ichangensis*
	CR147	Ichang papeda 2-3	*Citrus ichangensis*
	CR148	Lunan	*Poncirus trifoliata*
	CR149	Houpi	*Poncirus trifoliata*
	CR150	Donghai	*Poncirus trifoliata*
	CR151	Zhoupi	*Poncirus trifoliata*
	CR152	Tanghe No. 6	*Poncirus trifoliata*
	CR153	Zao Yang	*Poncirus trifoliata*

[a]The seedlings that emerged following the germination of the introduction labelled Xiechen had trifoliate leaves and therefore were not *C. junos.* This accession has been called False Xiechen.

Details of this germplasm for trifoliata type rootstocks are summarised in Table 2.1(b).

Table 2.1(b): Rootstock introductions from PR China assessed in short-term performance trials at NSW DPI, Dareton.

Year introduced	CSIRO code no.	Common name	Species name
1994	CR158	Wanyan	*Poncirus trifoliata*
	CR159	Jiangjin large leaf	*Poncirus trifoliata*
	CR160	No. 24	*Poncirus trifoliata*
	CR161	Ghana	*Poncirus trifoliata*
	CR163	Xianyong no. 8	*Poncirus trifoliata*
	CR165	Guanyun no. 1	*Poncirus trifoliata*
	CR166	Small leaf	*Poncirus trifoliata*
	CR168	No. 22	*Poncirus trifoliata*
	CR170	Xiaogan	*Poncirus trifoliata*
	CR171	Donghu no. 1	*Poncirus trifoliata*
	CR175	No. 5	*Poncirus trifoliata*
	CR176	Bopi	*Poncirus trifoliata*
	CR177	78-85	*Poncirus trifoliata*
	CR179	84-75	*Poncirus trifoliata*
	CR180	84-79 (Seln. Of Zao Yang)	*Poncirus trifoliata*
	CR181	Wangchang large leaf	*Poncirus trifoliata*
	CR183	85-24	*Poncirus trifoliata*
	CR185	84-77	*Poncirus trifoliata*
	CR194	Mantou hong (mandarin) [b]	*Citrus reticulata*

[b] Seeds from Mantou hong were introduced as part of a consignment generated via controlled cross-pollinations in China using pollen from *P. trifoliata*. Nucellar seedlings were easily distinguished from zygotics based on the dominant trifoliate leaf characteristic.

2.1.2 Germplasm from Vietnam

Germplasm was introduced from Vietnam on several occasions and included scion and rootstock accessions for not only evaluation but also as a genetic resource to be maintained in the arboreta. An example of the latter was a consignment of seeds collected from wild pummelo trees growing near the Vietnam-Laos border in the central region west of Hue.

These selections were made from a large population of families generated at CSIRO during 1980-82 that had been progressively screened at NSW DPI's EMAI and CSIRO for the following characteristics:

- polyembryony and uniform nucellar seedling production,
- tolerance to *Phytophthora* root and collar root,
- resistance to CTV,
- sodium and chloride exclusion capacity.

Only rootstock genotypes that showed potential in the greenhouse and laboratory trials conducted during the ACIAR projects were included in the subsequent field trials at Dareton. Details of these rootstocks are given in Table 2.2.

Table 2.2: Rootstock introductions from Vietnam assessed in a short-term performance trial at NSW DPI, Dareton.

CSIRO code no.	Common name	Species name
CO163	Mat orange	*Citrus sinensis*
CO168	Hong Kim orange	*Citrus sinensis*
CO209	Chanh orange	*Citrus sinensis*
CO210	Hong Nhieu orange	*Citrus sinensis*
CO170	Tieu Son mandarin	*Citrus reticulata*
CO172	Ta mandarin	*Citrus reticulata*
CO206	Hong Nhieu mandarin	*Citrus reticulata*
CG44	Tau (? Bong Tim) lime	*Citrus aurantifolia*

Rootstocks for the trials were propagated as cuttings and grafted to scion varieties Imperial mandarin, Eureka lemon, Navelina and Lane late sweet oranges.
In addition to the new rootstocks under evaluation, Symons sweet orange, *Poncirus trifoliata* (Australian selection 22) and Carrizo citrange were included as standards. These standard stocks were propagated as nucellar seedlings and grafted with the scion varieties listed above.

2.1.3 CSIRO hybrids

Hybrid selections from CSIRO's citrus rootstock breeding program were included in the short term horticultural performance trials at Dareton. These selections were made from a large population of families generated at CSIRO during 1980-82 that had been progressively screened at CSIRO and NSW DPI's EMAI for the following characteristics:

- sodium and chloride exclusion capacity,
- polyembryony and uniform nucellar seedling production,
- tolerance to *Phytophthora* root and collar root,
- resistance to CTV.

Details of the selections from CSIRO's rootstock breeding program which were propagated as nucellar seedlings for inclusion in the trials at Dareton are given in Table 2.3.

Table 2.3: Rootstock hybrids bred by CSIRO represented in the trials established in module number 3 at Dareton. The hybrids were selected based on their performance in screening trials that assessed their ability to exclude chloride and sodium as well as tolerate *Phytophthora* root rot and CTV infection.

CSIRO code no.	Parents of selection
80.05.05	Cleopatra mandarin x Carrizo citrange
80.06.05	Symons sweet orange x Trifoliata
81.02.400	Clementine mandarin x Rangpur lime
82.01.16	Rangpur lime x Trifoliata
82.02.02	Clementine mandarin x Rangpur lime
82.02.05	Clementine mandarin x Rangpur lime
82.05.05	Ellendale tangor x Cleopatra mandarin
82.08.68	Clementine mandarin x Chinotto orange
82.09.148	Ellendale tangor x Chinotto orange
82.09.57	Ellendale tangor x Chinotto orange
82.10.07	Chinotto orange x Smooth Seville
82.04.22	Clementine mandarin x Cleopatra mandarin
82.08.45	Clementine mandarin x Chinotto orange
82.13.01	Chinotto orange x Trifoliata
82.13.03	Chinotto orange x Trifoliata

Rootstocks tested in module 3 were propagated as nucellar seedlings and grafted to scion varieties Imperial mandarin, Eureka lemon, Navelina and Lane late sweet oranges.

In addition to the new rootstocks under evaluation, Symons sweet orange, *Poncirus trifoliata* (Australian selection 22) and Carrizo citrange were included as standards. These standard stocks were propagated as nucellar seedlings and grafted with the scion varieties listed above.

2.2 Tree propagation

As described earlier (Bevington at al., 2005), nine trials, which involved rootstocks introduced from China, were established before project CT03025 commenced. There were one trial from Valencia (module A), 4 trials on Navelina, Lane Late navel, Imperial mandarin and Eureka Lemon from module 1 (stage 1) and 4 trials on Navelina, Lane Late navel, Imperial mandarin and Eureka Lemon from module 2 (stage 2), The other 4 trials in modules 3 (stage 3) on on Navelina, Lane Late navel, Imperial mandarin and Eureka Lemon and 4 trials in module 4 (stage 4) on Navelina, Lane Late navel, Imperial mandarin and Eureka Lemon were established during project CT03025 (Khurshid *et al*., 2007). The final report for project CT03025 was submitted in 2007.

The trees in the trial established in module A at Dareton in 1997 were propagated at NSW DPI EMAI by grafting Valencia orange to Chinese seedling rootstocks grown from seed introduced in 1993 (Broadbent, 1993). Thus, the first trial was established with rootstock seedlings that had not been characterised and nominated as source trees for these stocks in Australia. The trees tested in the subsequent 16 trials were all propagated from characterised source trees. The rootstocks for the trials in modules 1, 2 and 4 were propagated as rooted cuttings taken from the seedlings that had been designated as source trees for the introductions from China and Vietnam.

The CSIRO rootstocks trialed in module 3 were propagated as uniform nucellar seedlings. Similarly, the rootstocks used as standards in the trials were propagated as uniform nucellar seedlings.

Sources of cuttings
Before cuttings were taken, source trees were maintained in a healthy condition and well watered, but not over fertilised with nitrogen. Semi-hardwood cuttings were taken during early summer from first growth-flush shoots of the season that had hardened off. Cuttings were collected during the morning, which from experience at Merbein was the best time of day to ensure maximum strike or rooting rates.

Cutting preparation
Cuttings were collected using sharp secateurs enabling a clean cut without crushing or tearing the shoot tissues. For the purpose of establishing uniform trees for the trials, single-node cuttings were prepared with only one internode length of stem with one bud and leaf. Such small cuttings can be a little slower to reach a size suitable for budding but ensured that the starting material was as uniform as possible. The proximal region of each cutting was cut square. The base of each cutting was dipped into a solution of 3000 ppm of indole butyric acid (IBA) in 50% water/ethyl alcohol (v/v) before being placed in the rooting medium.

Medium for propagating cuttings
Cuttings were struck in a mixture of perlite and sand (2:1 v/v), which experience has shown to provide conditions favourable to root growth (dark, humid and aerated, pH 5.5-6.5), but not conducive to fungal growth.

Containers
The container used for striking cuttings was a 400 x 300 x 200 mm plastic box filled to a depth of around 150 mm. The bottom of the container was an open mesh allowing for free drainage.

Conditions for striking cuttings
Boxes of cuttings were maintained in a propagation greenhouse where they were placed on heated benches that provided bottom heat of 20-25°C. Air temperature was ambient or cooled via evaporative air conditioners. The cuttings were watered from above via an automatic misting system designed to keep the leaves constantly damp.

Care, maintenance and budding of rootlings
Cuttings were inspected after 3 months. Those that had formed roots (rootlings) were potted into a standard potting mix and transferred to a temperature-controlled greenhouse where they were maintained until they reached an appropriate size for budding. During this period the rootlings were fertilised regularly with a standard proprietary, all-purpose liquid fertiliser and pests were controlled using appropriate pesticide sprays.

When rootlings had grown to approximately pencil thickness and 20cm above the level of the potting mix, they were budded with one of four scion varieties; Eureka lemon, Imperial mandarin, Navelina and Lane late navel. The budded rootlings were maintained in the greenhouse until the scion variety had grown approximately 30 cm before they were re-located to a shade house under ambient conditions for hardening off prior to planting at NSW DPI Dareton.

2.3 Experimental design and trial conditions

There were 17 trials established at the Agricultural Research and Advisory Station, New South Wales, Department of Primary Industries at Dareton (34 10'S., 142 04'E) for the purposes of conducting preliminary horticultural evaluation of new rootstock germplasm. The trials were planted as five modules. Table 2.4 summarises the details of the different modules and trials.

Table 2.4: Summarised details of the short-term horticultural performance trials established at NSW DPI, Dareton using recently introduced or locally bred rootstocks.

Module (Stage)[1]	Year planted	Rootstock type	Experiment no[2]	Scion variety	Data reported herein[3]
A	1997	Seedling	1	Valencia orange	Tree growth, fruit yield and quality, and root structure and development.
1	1999	Clonal	2 3 4 5	Navelina orange Lane late navel Imperial mandarin Eureka lemon	Tree growth, fruit yield and quality, and root structure and development.
2	2001	Clonal	6 7 8 9	Navelina orange Lane late navel Imperial mandarin Eureka lemon	Tree growth, fruit yield and quality, and root structure and development.
3	2003	Nucellar seedlings	10 11 12 13	Navelina orange Lane late navel Imperial mandarin Eureka lemon	Tree growth, fruit yield and quality, Leaf chloride concentrations.
4	2005	Clonal	14 15 16 17	Navelina orange Lane late navel Imperial mandarin Eureka lemon	Leaf chloride concentrations.

[1] The various rootstocks were evaluated in modules planted at different times. Module A was planted with seedlings grown from rootstock seeds introduced from PR China received in 1993 before the different accessions were tested for uniformity and other characteristics and source trees were selected. The same rootstocks were used in module 1 except the plant material was propagated as rootlings from single-node cuttings taken from a single source tree that had been characterised. The rootstocks investigated in the trials that were planted as modules 2 and 4 were also propagated as rootlings grown from single-node cuttings taken from a single characterised source tree of each genotype. The rootstocks investigated in modules 2 and 4 were introduced from the PR of China and Vietnam, respectively. The rootstocks investigated in module 3 were propagated as nucellar seedlings grown from polyembryonic seeds harvested from rootstock hybrids bred and selected for salt exclusion and disease resistance at CSIRO Merbein.

[2] A number of experiments were conducted within each module according to the number of scion varieties used to evaluate rootstock performance. In module A only one scion was used whereas four scions were employed in the other 4 modules.

[3] As a series of modular plantings, not all experiments were at a suitable stage for data collection during the course of project CT07002. This is reflected in the data presented in this report.

In addition to the experimental rootstocks being assessed, Troyer citrange and Swingle citrumelo rootstocks were included as standards in module A, and Symons sweet orange, Australian *Poncirus trifoliata* strain 22 and Carrizo citrange rootstocks as standards in modules 1-4. These standard rootstocks were propagated as nucellar seedlings and grafted with the varieties listed appropriate for each module.

The first module (one trial) was planted 1997 and is referred to here as module A. The other modules (four trials each) were planted in 1999, 2001, 2003 and 2005 and are referred to as modules 1, 2, 3 and 4, respectively.

The 5 experiments from module A and module 1 have been completed and reported in HAL final report CT03025 (Khurshid *et al.*, 2007). This final report (CT07002) is comprised of data from module 2 and 3.

Climatic data for Dareton gives maximum temperature ranges of 30-32 ^{o}C during December-to-February and 16-17 ^{o}C during June-to-August and an average annual rainfall of 220 mm. The average total accumulated annual heat units are 1880. A general soil analysis of the site revealed deep loam sands from 0-80 cm over loamy sand/clay sand from 80 cm to 140 cm. The root zone was approximately 80-100 cm deep and the electric conductivity ranged between 0-0.40 ds/m. The pH of the soil solution ranged from 8-9.

Rootstocks were propagated either as single node cuttings taken from characterised source trees or as seedlings. Rootstocks were evaluated by investigating their effect on the performance of a number of scion varieties, namely Valencia orange (module A, one trial only), Navelina, Lane Late navel, Imperial mandarin and Eureka lemon (modules 1-4). Depending on the trial, *Poncirus trifoliata* strain 22 (an Australian strain), Troyer citrange, Carrizo citrange, Swingle citrumelo and Symons sweet orange rootstocks were included as standards for comparison.

The trials in each module were established using a randomised block design with one treatment (rootstock genotype) in each block. The trials in modules 2-4 were laid out as five blocks. Separate replicated trials based on scion variety were established for modules 2-4.

Trees were planted at a density of 1250 trees/hectare (2 m within each row, 4 m between rows). The trials were irrigated via a single drip line for a total of 336 hours during October-to-March and for 106 hours from April until September. Fertiliser was applied via the drip system and standard cultural practices were followed during the course of each trial. Light pruning was carried out during the investigation to manage tree canopy and to allow for accurate estimations of tree growth, canopy volumes and fruit yields.

2.4 Rootstock effects on tree growth, fruit yield and quality

2.4.1 Data collection and procedures

This section reports 8 years (2005-2012) of data (Table 2.4) collected at, Dareton Primary Industries Institute from 4 trials in module 2 that investigated rootstock effects on fruit yield and quality. Other factors such tree vigour, graft union compatibility and tolerance to disease are also considered in these trials. The effects of rootstocks on leaf chloride concentrations are reported in a subsequent section.

At the stage of preparing this document, insufficient data were available to report on rootstock performance in the trials in module 4 (Vietnamese rootstocks). A subsequent project (CT14004) will complete the evaluation of the rootstocks for module 4.

Data for tree growth, fruit yield and quality was collected for the Navelina, Lane Late navel, Imperial mandarin and Eureka lemon trees planted in 2001 were collected up until 2012. The details of the data collection are given below.

Tree health/disease assessment

Tree health was observed during spring and signs consistent with disease, physiological disorders or incompatibility were noted.

Tree vigour measurements

Tree height (m) and canopy width (m) were measured every year which allowed canopy volume to be calculated. Trunk circumference (cm) was recorded annually at the same marked position on the tree 10 cm above the graft union.

General procedure for the excavation of rootstocks and assessment of root system

Assessment of root distribution, rooting depth and spread was only carried out in module 1 and module 2 trials which were not part of the previously completed project CT03025. Selected trees were excavated and their root systems were examined in detail (Castle, 1980).

The tree canopies were removed by cutting through the trunk 0.5 m above the soil surface (Figure 2.1 a). A 1.5 m deep trench was dug all the way around the stump in a square arrangement (Fig 2.2a) with a back hoe. The spread of roots across the rows was measured and the depth of fibrous and structural roots also recorded. (Figure 2.1 b & c).

a	b	c

Figure 2.1: Root excavation process (a) digging around the tree (b) measuring the root depth (c) measuring the root spread along the rows.

After these data were recorded the tree was gently loosened and uplifted (Figure 2.2 a). Care was taken to keep the roots intact through to the final stages of lifting process.

The stump and roots were placed on a metal grid and the soil removed with running water (Figure 2.2 b & c). The number of structural roots was counted and root diameters recorded. The fibrous roots were separated from the structural roots which were separated from the trunk. The stump consisted of the solid wood between the graft union and structural roots. The three components (Figure 2.3) were dried separately at 60^0 C for 24, 48 and 168 hours respectively. After the moisture had been removed the dry weights were recorded for each component.

a	b	c

Figure 2.2: (a), tree being lifted; (b), trees loaded for the washing process; (c), root system after initial processing.

a	b

Figure 2.3: (a), Roots are divided into 3 main components – fibrous roots, structural roots and stumps; (b), Components were dried to determine the dry weights.

Rootstock/scion compatibility measurements

Two types of measurements were recorded to assess rootstock compatibility with the scion varieties employed in the trials.

<u>Trunk circumference (cm) at the graft unions:</u> Trunk circumference 6 cm above and below the graft union was measured to determine the extent of any overgrowth between rootstock and scion each year (Anderson and Benatena, 1992).

<u>Visual ranking:</u> A smooth graft union indicates similar growth rates for the stock and scion allowing a thorough fusion of tissues at the graft union. Different growth rates can lead to the scion overgrowing the stock or vice-versa. The ratio between rootstock to scion growth near the graft union provides a measure of the degree of “benching” where either the stock or scion overgrows the other. ‘Benching’ can be an early predictor of stock/scion incompatibility which can be an issue in older trees. In addition to measuring trunk circumferences above and below the graft union, benching was also scored visually using a scale of 1-5 (Figure 2.4) similar to the method described by Webber (1948). The same person conducted the visual rating of the graft unions in all trials to reduce subjectivity in the results.

1	2	3	4	5

Figure 2.4: A visual ranking used to score graft union overgrowths: (1), smooth union; (2), rootstock slightly larger than scion; (3), scion slightly larger than rootstock; (4), rootstock significantly larger than scion; (5), scion significantly larger than rootstock.

Fruit yield and fruit size distribution

Total fruit weight per tree, number of fruit per tree and fruit size distribution were recorded for each tree by passing all fruits harvested across a commercial grader (Colour Vision Systems Pty. Ltd.). Fruit was sorted into five size classes based on diameter (mm): <65 mm (>138 fruit/carton), 65-67 mm (138-125 fruit/carton), 69-72 mm (113-100 fruit/carton), 75-77 mm (88fruit/carton) and >77 mm (<80 fruit/carton). Yield efficiencies (kg/cm^2) were calculated by dividing the total yield (in kg) in each year by the trunk cross sectional area.

Biennial Bearing Index (BBI)

The BBI was estimated using the deviation in fruit number in successive years (*I*) as given by Hoblyn *et al.* (1936):

$$\mathbf{BBI} = 1/n\text{-}1 * [(|a_2 - a_1| / a_2 + a_1) + (|a_3 - a_2| / a_3 + a_2) + \ldots + (|a_n - a_{(n-1)}| / a_n + a_{(n-1)})]$$

n = number of years, $a_1, a_2, \ldots, a_n, a_{n-1}$ = fruit number in corresponding years.

A BBI of 1 indicated a very strong tendency towards biennial bearing and BBI close to zero indicated that season-to-season yield variability was random.

Internal fruit quality

Fruit quality measurements were carried out at the onset of the commercial maturity period for each scion variety during each growing season. Ten fruit per tree were randomly selected from the packing line at harvest and taken to the laboratory to assess internal fruit quality. Percent total soluble solids (TSS) of the juice were obtained using a digital refractometer and % citric acid (TA) was estimated by titrating 10 ml of juice against standard 0.1 mol/L NaOH solutions. Juice sugar:acid ratios (TSS:TA) were calculated from these data as described by El-Zeftawi *et al.* (1982). Fruit length, diameter and rind thickness were recorded for Eureka lemons using digital callipers.

2.4.2 Statistical analyses

***Module 2: Experiments 1, 2, 3, 4:* (Navelina, Lane Late navel, Imperial mandarin, Eureka Lemon)**

Analysis of variance (ANOVA) was carried out using the statistical software package Genstat (2013). Where F-tests demonstrated significant ($P<0.05$) rootstock effects, means were separated using least significant differences (LSD) calculated at $p=0.05$. Data was also statistically analysed for Module 3.

Note that the Donghu rootstock treatment was excluded from the data analyses in experiments 1, 2 and 3 due to the poor performance of the trees at the early stages of the trial. At the later stages of the project nearly all Donghu trees died or did not grow beyond a tree height of 1 m.

2.5 Results and Discussions

Tree health assessment: Most rootstock/scion combinations exhibited good tree health. Donghu rootstocks performed poorly on all scions.

In Imperial mandarin a total of three trees died in No. 24 and No. 5. There was a further tree death of one tree each in No. 22, Small leaf, Tri22 and Xianyong trees. In Lane Late four trees died in No. 5 and three trees died in No. 24. There was a further tree death of one tree each in 84-79, 85-24, No. 22, Small leaf, and Tri22; while two trees died in Xianyong. In Navelina three trees died in Mantou hong, two in 78-85 and one in No. 5. No trees died on Eureka lemon (Table 2.5).

In Eureka Lemons no trees died. Eureka lemon trees are less likely to die compared to trees grafted on Navelina, Lane Late and Imperial mandarin.

Table 2.5: The number of un-healthy or dead trees out of 5 trees in Imperial mandarin, Lane Late navel and Navelina during the course of experiment for Module 2 (Trifoliata rootstocks).

Rootstocks	Imperial Mandarin	Lane Late	Navelina	Eureka lemon
78-85	0	0	2	0
84-75	0	0	0	0
84-79	0	1	0	0
84-77	0	0	0	0
85-24	0	1	0	0
Bopi	0	0	0	0
Ghana	0	0	0	0
Guanyun	0	0	0	0
Jiangjin large leaf	0	0	0	0
Mantou hong[x]	0	0	3	0
No. 22	1	1	0	0
No. 24	3	3	0	0
No. 5	3	4	1	0
Small Leaf	1	1	0	0
Tri22	1	1	0	0
Wangchang large leaf	0	0	0	0
Wanyan	0	0	0	0
Xianyong	1	2	0	0
Xiaogan	0	0	0	0

[*]Mandarin type

Rootstock excavation and root inspection

Root excavation was carried out on un-healthy or diseased trees to assess the health and structure of the root system. The citrus root system is comprised of a relatively shallow, well-branched framework of woody laterals bearing fine fibrous roots (Bevington and Castle 1982 and Castle, 1987). Root excavation is a difficult and labour intensive task and therefore root development is not often assessed as part of rootstock evaluation (Castle and Krezdorn, 1979).

The following rootstocks were excavated due to poor health and stunted growth from 2005-2012.

Module 1: In module 1 (mixed rootstocks), trees grafted to Ichangensis and Daidai rootstocks were excavated. Navelina, Lane Late, Imperial mandarin and Eureka lemon trees grafted to Ichangensis and Daidai (sour orange) rootstocks exhibited poor growth; trees were stunted, had a poor root system and incompatibility at the graft union. Therefore, these two rootstocks have been excluded from further rootstock evaluation. The poor root system and graft incompatibility can be seen in Figures 2.5-2.8.

Module 2: In module 2 (P. Trifoliata rootstocks), tree grafted to Donghu were excavated for Navelina, Lane Late and Imperial mandarin (Fig. 2.9-2.11).

	
Ichangensis	Daidai

Figure 2.5: Navelina navel trees grafted to Ichangensis and Daidai from Module 1 are shown. Trees were planted in 1999. Trees have a poor root system and incompatibility at the graft union.

Ichangensis	Daidai

Figure 2.6: Lane Late trees grafted to Ichangensis and Daidai from Module 1 are shown. Trees were planted in 1999. Trees have a poor root system and incompatibility at the graft union.

Ichangensis	Daidai

Figure 2.7: Imperial mandarin trees grafted to Ichangensis and Daidai from Module 1 are shown. Trees were planted in 1999. Trees have a poor root system and incompatibility at the graft union.

Module 2: In module 2 (*Poncirus trifoliata* rootstocks), trees grafted to Donghu were excavated.

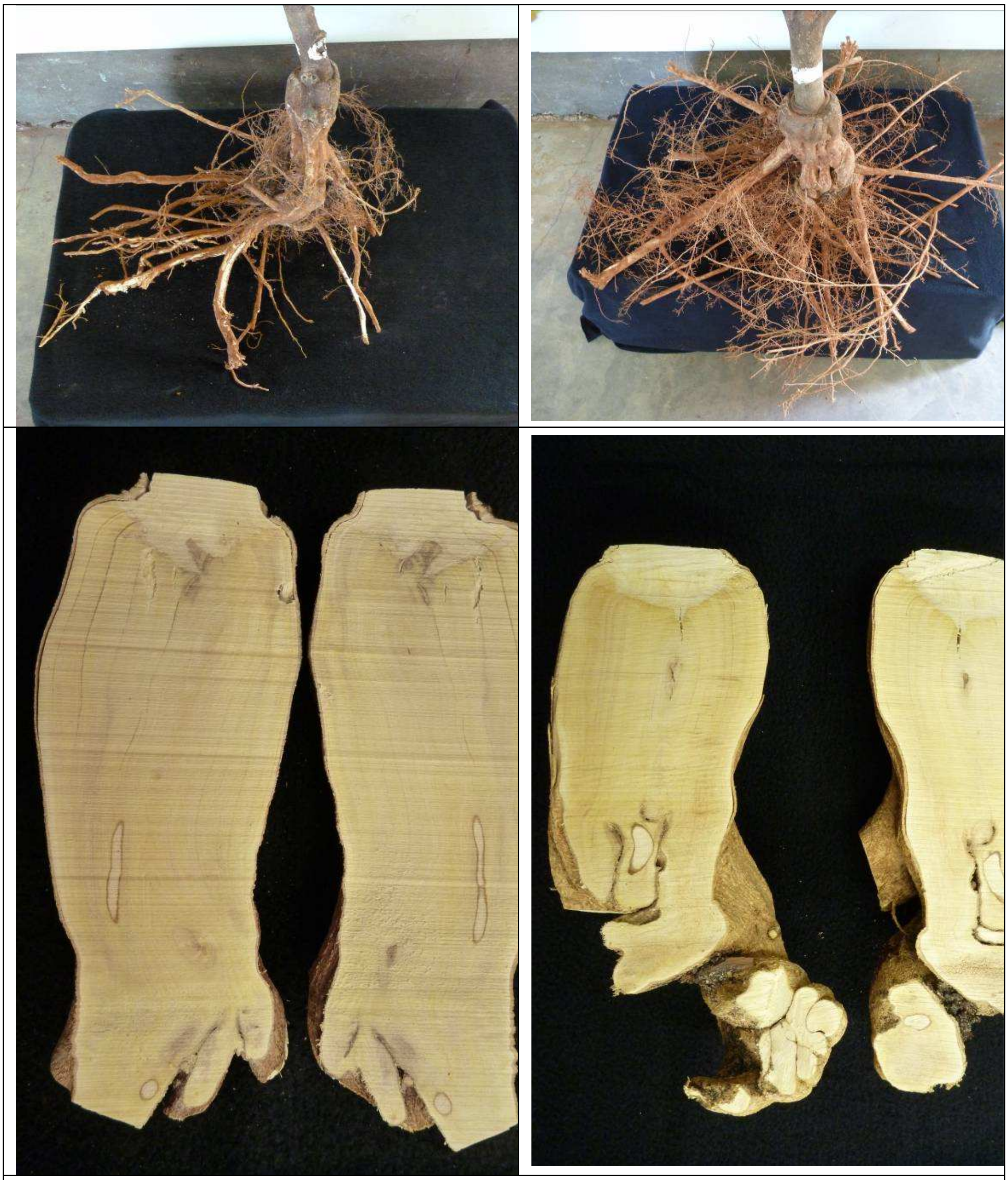

Figure 2.9: Navelina Module 2: Root system of the Donghu rootstock is shown above. Trunks were cut across the graft union to look for abnormalities, or incompatibility with the scion.

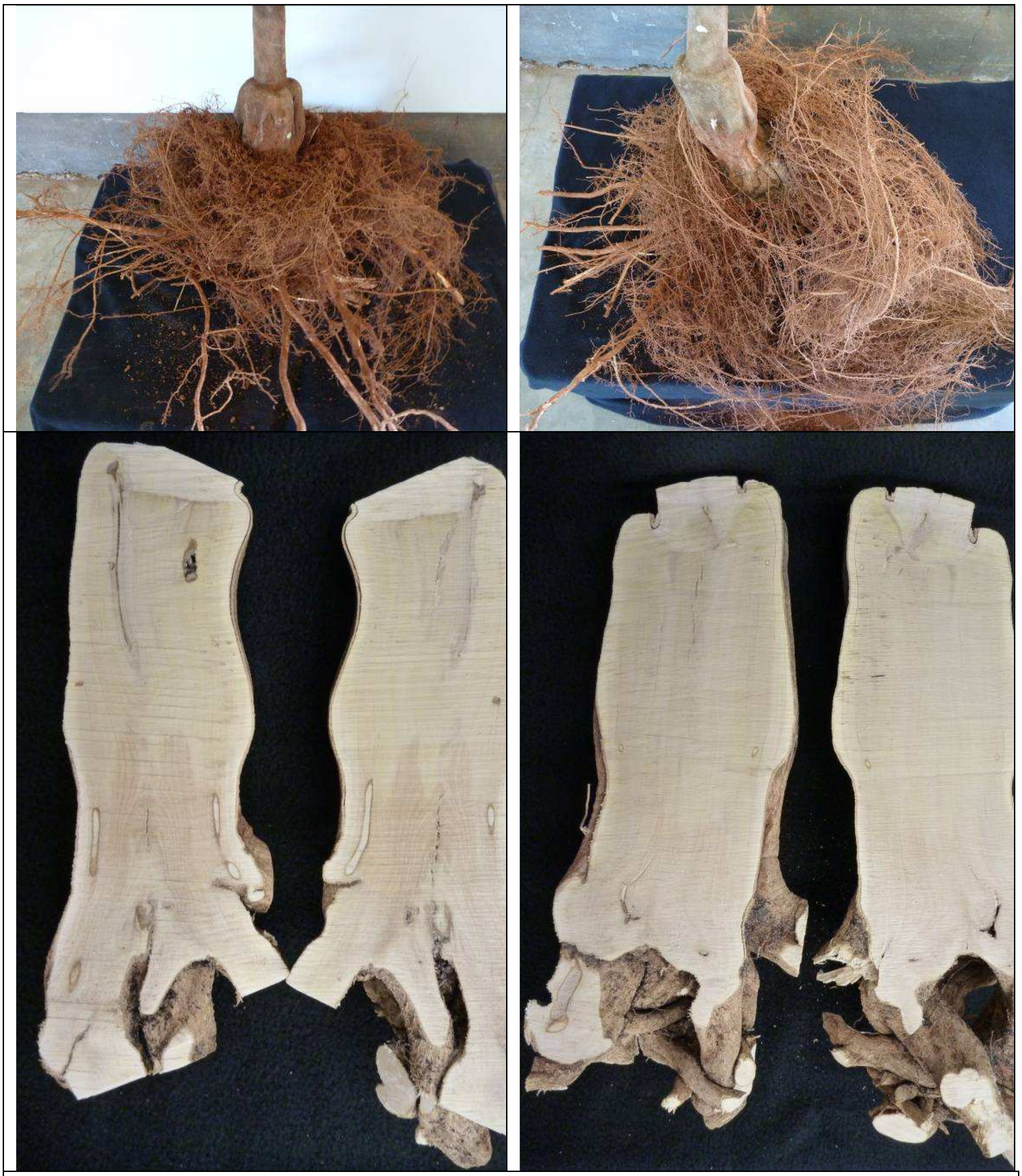

Figure 2.10: Lane Late Module 2: The root systems of the Donghu rootstock are shown above. Trunks were cut across the graft union to look for abnormalities or incompatibility with the scion.

Figure 2.11: Imperial mandarin Module 2: The root systems of the Donghu rootstock are shown above. Trunks were cut across the graft union to look for abnormalities or incompatibility with the scion. Note the distorted structural roots.

Laboratory analysis of root samples

Root samples were plated onto selective and general agar media then inspected for fungal growth (Table 2.6).

Table 2.6: Results of fungal isolations[1] from root segments of Navelina, Lane Late and Imperial mandarin trees grafted to Daidai and Ichangensis rootstocks in Module 1.

Samples from Module 1 (received 29/10/12)	**Results**
Navelina / Daidai	No pathogen detected
Navelina / Daidai	No pathogen detected
Navelina / Ichangensis	No pathogen detected
Navelina / Ichangensis	No pathogen detected
Lanes Late / Daidai	No pathogen detected
Lanes Late / Daidai	No pathogen detected
Lanes Late / Ichangensis	*Pythium irregulare* detected
Lanes Late / Ichangensis	No pathogen detected

Table 2.7: Results of fungal isolations from root segments of Navelina, Lane Late and Imperial mandarin grafted to Donghu rootstocks in Module 2.

Samples from Module 2 (received 15/11/12)	**Results**
Navelina / Donghu	*Pythium irregulare* detected
Navelina / Donghu	*Fusarium* sp. detected
Navelina / Donghu	No pathogen detected
Navelina / Donghu	*Pythium irregulare* detected
Lanes Late / Donghu	No pathogen detected
Lanes Late / Donghu	*Pythium irregulare* & *Fusarium* sp. detected
Lanes Late / Donghu	*Fusarium* sp. detected
Lanes Late / Donghu	No pathogen detected
Lanes Late / Donghu	No pathogen detected
Mandarin / Donghu	No pathogen detected
Mandarin / Donghu	*Fusarium* detected
Mandarin / Donghu	*Fusarium* detected
Mandarin / Donghu	No pathogen detected

[1]Root segments from each root sample submitted for testing were cut with a sterile blade, moistened then plated using aseptic technique onto 3 different selective media; Phytophthora selective agar, Pythium selective agar and ¼ potato dextrose agar (¼ PDA) (5 root pieces / plate). Plates were examined on 20/11/2012. Four plates per medium were used for Module 1 samples (Table 2.6) while 2 plates per medium were used for Module 2 samples (Table 2.7).

No Phytophthora species were isolated from the plated root samples. *Pythium irregulare* was isolated from some root pieces. This is a minor and common soilborne pathogen. *Fusarium* species are also common in soil environments. Visual inspection of the root systems did not reveal any significant health issues. Therefore the *Pythium* and *Fusarium* species isolated from a small number of root pieces are unlikely to be causing significant or economic damage to the root systems.

Root measurements

Module 1:
Root spread data indicated that the root systems of Navelina trees on Daidai and Ichangensis rootstocks extended 71 cm and 61 cm respectively within the row; and 58 and 48 cm respectively across rows (Table 2.8). The roots grew to a depth of 20 and 15 cm respectively (Figure 2.5). Trees remained stunted with the mean tree height of 1 m and trunk circumference of 9 cm for both rootstocks.
The root systems of Lane Late trees on Ichangenis rootstocks extended 58 cm within the row, 40 cm across the rows, and to a depth of 16 cm (Figure 2.6). All Lane Late trees grafted to Daidai rootstocks died during the course of this experiment.
The root systems of Imperial mandarin trees extended within the row 80 and 40 cm respectively and across the rows 66 and 28 cm respectively for Daidai and Ichangensis rootstocks (Table 2.8 and Figure 2.7). The root depth was shallower for Ichangensis (16 cm) compared to Daidai (24 cm).
Lemon trees grafted to Ichangensis rootstocks followed a similar trend to Navelina trees and all Eureka lemon trees on Daidai died during the course of experiment (Table 2.8 and Figure 2.8).

Table 2.8: Root spread within and across rows; and root depth of fibrous and structural roots of Navelina, Lane Late, Imperial mandarin and Eureka lemon trees[1] budded to Daidai and Ichangensis* rootstocks originating from China.

Cultivars	Root spread (cm) (within the row)		Root spread (cm) (across row)		Total root depth (cm)	
	Daidai	Ichang*	Daidai	Ichang	Daidai	Ichang
Navelina	76	61	58	48	20	15
Lane Late	0	58	0	40	0	16
Imperial	80	40	66	28	24	10
Eureka	0	60	0	47	0	17

[1]Trees from module 1 planted in 1999

The data suggests that canopy growth of Navelina, Lane Late, Imperial mandarin and Eureka lemon trees on Daidai and Ichangensis rootstocks were limited by the poor root systems which were not capable of meeting the water and nutrient needs of a larger tree, or were so poor that the result was tree death. Trees on Daidai and Ichangensis also failed to produce any significant positive results in terms of fruit quality and yield therefore these rootstocks should be excluded from the evaluation program.

Module 2:
Root spread data indicated that the root systems of Navelina on Donghu rootstocks extended within the row 61 cm and 50 cm across rows (Table 2.9), while the root depth was only 26 cm (Figure 2.9). The data suggested that the root system of

Donghu restricted tree growth. Trees remained stunted with the mean tree height of 1 m and trunk circumference of 12 cm.
In Lane Late on Donghu roots extended within the row 102 cm and 70 cm across rows, and to a depth of 36 cm (Table 2.9 and Figure 2.10). Trees remained stunted with the mean tree height of 1.9 m and trunk circumference of 13 cm. In Imperial mandarin, roots extended within the row 105 cm and 84 cm across rows (Table 2.9); while the root depth was 34 cm (Figure 2.11).

Lane Late and Imperial mandarin trees on Donghu rootstocks had larger root systems than Navelina. However because Donghu rootstock failed to produce significant positive results for fruit quality and yield, this rootstock was excluded from further evaluation.

Table 2.9: Root spread within and across rows; and root depth of fibrous root and structural roots in Navelina, Lane Late and Imperial mandarin trees[1] grafted onto Donghu rootstock originating from China.

Cultivars	Root spread (cm) (within the row)	Root spread (cm) (across row)	Total root depth (cm)
Navelina	61	50	26
Lane Late	102	70	36
Imperial mandarin	105	84	34

[1]Trees are from module 2 planted in 2001

Root size distribution and dry weights

Module 1:
The data recorded for the different rootstocks suggested that all Navelina, Lane Late, Imperial mandarin and Eureka lemon tress grafted to Ichangesis had a higher percentage of roots in the 0-10 mm diameter range and a smaller proportion that were 10-40 mm (Table 2.10). This aligned with root distribution and canopy growth indicating that these trees had smaller root systems and were stunted, i.e. the trees never grew beyond 1 m in tree height.

Table 2.10: Percent root size distribution in root diameter class (mm) of Navelina, Lane Late, Imperial mandarin and Eureka lemon trees[1] grafted onto Daidai and Ichangensis[*] rootstocks originated from China.

Cultivars	Root size distribution in diameter class							
	0-10 mm		10-15 mm		15-20 mm		20-40 mm	
	Daidai	Ichang[*]	Daidai	Ichang	Daidai	Ichang	Daidai	Ichang
Navelina	72	68	14	20	7	7	7	5
Lane Late	0	79	0	12	0	6	0	2
Imperial	62	72	14	13	13	13	9	2
Eureka	0	69	0	16	0	7	0	8

[1]Trees from module 1 planted in 1999

The root dry weights were similar for Navelina, Lane Late, Imperial and Eureka trees on both Daidai and Ichangenis rootstocks, with the exception of all Lane Late and Eureka trees on Daidai that did not survive. However, Navelina grafted to 60

Ichangensis had slightly larger root systems than other species used in this experiment (Table 2.11).

Table 2.11: The dry weight of the fibrous roots, structural roots and stumps and trunk circumference (cm) of Navelina, Lane Late, Imperial mandarin and Eureka lemon trees[1]. Budded trees onto Daidai and Ichangensis.

Cultivars	Total root dry weight/tree (kg)							
	Fibrous		Structural		Stumps		Trunk Circum. (cm)	
	Daidai	Ichang*	Daidai	Ichang	Daidai	Ichang	Dada	Ichang
Navelina	0.03	0.16	0.29	1.89	0.43	2.88	9.2	9.3
Lane Late	-[2]	0.01	-	0.10	-	0.12	-	7.0
Imperial	0.06	0.03	0.43	0.11	0.76	0.22	10.0	9.8
Eureka	-	0.01	-	0.06	-	0.19	-	10.3

[1]Trees from module 1 planted in 1999
[2] All Daidai trees died in Lane Late and Eureka lemon

Module 2:
The data derived from the excavation of the root systems of 5 trees on Donghu rootstocks is presented in Table 2.12. The trees propagated to Navelina had an average of 74% of roots with a root diameter of 0-10 mm. In Lane Late, Donghu rootstock has 53% of roots with diameter of 0-10 mm; while there were low percentages of roots with diameter 10 to 40 mm.

Table 2.12: Root size distribution and dry weight of fibrous roots, structural roots and stumps of Navelina, Lane Late and Imperial mandarin trees[1] grafted onto Donghu rootstock.

Cultivars	Percent root size distribution in root diameter class (mm)				Dry weight/tree (kg)		
	0-10	10-15	15-20	20-40	Fibrous	Structural	Stump
Navelina	74	19	2	5	0.21	0.38	0.55
Lane Late	54	17	15	13	0.13	0.73	1.28
Imperial	33	26	20	21	0.20	0.64	1.78

[1]Trees from module 2 planted in 2001

2.6 Experiment 1 - Navelina

2.6.1 Yield and tree growth

Navelina trees grafted to *trifoliata* type rootstocks Small leaf, Jiangjin large leaf, Xianyong and Ghana produced cumulative yields of 180, 180, 168 and 167 kg/tree respectively compared to those grafted to the standard Tri22 (139 kg/tree) and to 78-85, which produced 70 kg/tree (Table 2.13). Navelina trees grafted to Tri22 (Control), No. 5, 84-77, 84-75, Wanyan, No. 24, Matou hong and 78-85 had below average yields of 137 kg/tree (Table 2.13). The yield efficiencies of the high yielding Navelina trees grafted to Guanyun, 84-77, Xianyong and Ghana were 2.2, 2.1, 2.1 and 2.0 kg/cm^2 respectively; greater than the standard Tri22 (1.8 kg/cm^2). The lowest yield efficiencies were found on trees grafted to 78-85 and 84-75 rootstocks, with each producing on average 1.2 kg/m^2. The mean trunk circumference was 31.9 cm and 28.9 cm respectively in Navelina trees grafted to Jiangjin large leaf, and Small leaf, larger than Tri 22 (23.0 cm). Trees grafted onto 78-85, 84-77 and 84-75 had 19.3, 20.7 and 20.8 cm trunk circumference respectively and were well below the Tri22 (Control) trees. Results suggest that Navelina trees grafted to test rootstocks with a larger trunk circumference are more vigorous and therefore produce greater yields. For example Jiangjin large leaf had a trunk circumference of 31.9 cm indicating significant vigour. However, tree size and cumulative yield has an association (r = 60) and the regression analysis indicates $R^2 = 39$. This means that only 39% of the linear increase in cumulative yield can be attributed to the increase in tree size and other factors also contributed to the yield increase.

The Biennial Bearing Index (BBI) was calculated to determine the annual yield variations. Navelina trees grafted to Wanyan and Xiaogan had lower BBI values (0.24 and 0.26 respectively) compared to trees grafted to Tri22 (0.33), although these results were not significantly different. Other high producing Navelina trees grafted to Small leaf and Ghana had slightly lower (but not significantly different) BBI values than Tri22. The correlation analysis of the BBI with cumulative yields and tree size indicated a poor relationship between these variables. Therefore, it was concluded that the Biennial Bearing Index does not seem to be a problem in Navelina on the basis of the data collected in this trial (Table 2.13)

Fruit size is a major consideration when fruit is sold for fresh market consumption in domestic and export markets. Heavier fruit may also have high juice content but results may vary between seasons. Navelina trees grafted onto No. 5, 78-85 and Bopi had an average weight of 252 g/fruit which was similar to Tri22 (247 g/fruit). However, these trees yielded heavier fruit compared to 84-75 (230 g), Xianyong (226 g), 85-25 (226 g), Ghana (225 g), Xiaogan (224 g) and Mantou hong (221 g) (Table 2.13).

Large fruit gains higher returns when sold for fresh consumption as prices are based on fruit size rather than weight. Therefore, the data is also presented as the percentage of large size fruit (Table 2.13). The differences were not statistically significant, although the percentage of fruit <77 mm diameter was high in Jiangjin large leaf, 78-85, and Mantou hong was above 70%, while Navelina trees grafted to Tri22, No. 22, and No. 24 produced less than 65% fruit in large size (Table 2.13).

2.6.2 Fruit quality

Statistical analyses indicated there were no significant differences between the Brix values of fruit grown on Navelina trees grafted to the different rootstocks in the field trial. However, the Brix values were 12.2 for No. 24, 12 for Xianyong (12) and 11.8 for the control Tri22. Lower Brix values of 11.4 were detected in fruit harvested from trees grafted to 78-85, Wangchang large leaf and Mantou hong.

There were significant differences in fruit TA ratios on trees grafted to different rootstocks in the field trial. 78-85 had the highest TA ratio of 13.6 compared to Tri22 (11.8), followed by Xiaogan (12.6), Guanyun (12) and Jiangjin large leaf (12) compared to the control Tri22 which had the lowest TA ratio of 10.8 (Table 2.14).

Statistically significant differences were found in the juice content of fruit harvested from trees on the trial rootstocks. Ghana, Xiaogan, 84-77 and Guanyun had 44% juice, while Tri22 had 43% juice. Rootstocks such as 78-85, Jiangjin large leaf and 84-75 had lower juice values of 41% (Table 2.14).

2.6.3 Assessment of graft union

The analysis of the visual ranking suggested that there were significant differences in the appearance of the graft unions of the different trial rootstocks, suggesting differences in compatibilities. Rootstocks No. 22, Tri22 and Xiaogan have very smooth unions. The data for rootstock:scion ratio indicates that the slight overgrowth was due to an increase in rootstock circumference rather than scion an effect of the scion. The rootstock:scion ratio for Mantou hong was 1.1 compared to 1.6 for Tri22. The rootstocks with high ratios of 1.7 were Xiaogan, Wangchang large leaf, 84-79 and No. 22; while 78-85 had a ratio of 1.9 (Table 2.15).

Table 2.13: Effect of rootstock on cumulative yield (Cum. yield), yield efficiency (YE), biennial bearing index (BBI), mean fruit weight (FW), percent fruit in the >77 mm size class (% Fruit) and trunk circumference (Trunk circ.) of Navelina orange trees during 2005-12.

Rootstocks	Cum. Yield (kg)	YE (kg/m^2)	BBI	Fruit weight (g)	% Fruit (> 77 mm)	Trunk circ. (cm)
Trifoliata22 (Tri22)	139	1.8	0.33	247	52	23.0
78-85	70	1.2	0.38	252	63	19.3
84-75	115	1.2	0.31	230	60	20.8
84-79	157	1.6	0.33	238	55	23.8
84-77	120	2.1	0.30	246	56	20.7
85-24	145	1.9	0.31	226	58	25.3
Bopi	141	1.7	0.37	251	59	26.3
Ghana	167	2.0	0.29	225	54	24.0
Guanyun	159	2.2	0.30	231	55	24.0
Jiangjin large leaf	180	1.8	0.39	236	60	31.9
Mantou hong[x]	74	1.3	0.31	221	66	22.6
No. 22	150	1.6	0.28	235	54	23.3
No. 24	106	1.4	0.28	240	52	24.7
No. 5	126	2.0	0.28	252	59	22.4
Small Leaf	180	2.0	0.32	241	61	28.9
Wangchang large leaf	153	1.9	0.29	234	57	22.0
Wanyan	111	1.9	0.24	236	58	22.1
Xianyong	168	2.1	0.33	226	56	24.2
Xiaogan	162	1.6	0.26	224	53	22.6
Probability l.s.d.	**	*	ns	***	ns	***
l.s.d (p = 0.05)	67	0.66	-	16.43	-	4.78

[x]Mandarin type

Table 2.14: The effect of rootstock on average total soluble solids (TSS), total titratable acid (TA), TSS: TA ratio and %juice in Navelina fruit for 2005-2012 growing season.

	Total solids (TSS) %	Total acid (TA) %	TSS:TA ratio	% Juice (w/w)
Trifoliata22 (Tri22)	11.8	1.0	10.8	43
78-85	11.5	0.9	13.6	42
84-75	11.9	1.0	11.2	44
84-79	11.8	1.0	11.7	41
84-77	11.9	1.0	12.0	43
85-24	11.6	1.0	11.3	43
Bopi	11.7	0.9	11.6	42
Ghana	11.9	1.0	11.7	44
Guanyun	11.8	1.0	12.0	44
Jiangjin large leaf	11.6	0.9	12.0	41
Mantou hong[x]	11.4	0.9	11.4	43
No. 22	11.9	1.0	11.6	44
No. 24	12.2	0.9	11.7	43
No. 5	11.6	1.0	11.4	43
Small Leaf	11.7	1.0	11.7	43
Wangchang large leaf	11.5	1.0	11.4	43
Wanyan	11.9	1.0	11.7	43
Xianyong	12.0	0.9	11.8	43
Xiaogan	11.8	1.0	12.6	44
Probability	ns	**	***	***
l.s.d (P = 0.05)	-	0.07	0.84	1.5

[x]Mandarin type

Table 2.15: The effect of rootstock on the appearance of the graft union on Navelina scion. Mean rootstock and scion circumferences 6 cm from the union measured in 2012 and the ratio of these measurements are also presented.

Rootstocks	Visual Ranking of graft union[1]	Rootstock Circumference (cm)	Scion Circumference (cm)	Rootstock:Scion
Trifoliata22 (Tri22)	1	37	23	1.6
78-85	2	36	19	1.9
84-75	2	29	21	1.4
84-79	2	37	21	1.7
84-77	2	36	25	1.5
85-24	2	34	27	1.3
Bopi	3	36	26	1.4
Ghana	2	38	25	1.5
Guanyun	2	36	24	1.5
Jiangjin large leaf	3	40	31	1.3
Mantou hong[x]	2	24	23	1.1
No. 22	1	41	23	1.7
No. 24	2	33	25	1.4
No. 5	2	35	23	1.6
Small Leaf	2	41	29	1.5
Wangchang large leaf	2	39	23	1.7
Wanyan	2	33	23	1.5
Xianyong	2	42	28	1.5
Xiaogan	1	38	23	1.7
Probability	*	***	***	***
l.s.d (P = 0.05)	0.8	5.82	4.84	0.3

[x]Mandarin type

[1]Visual ranking to score graft union: (1), smooth union; (2), rootstock slightly larger than scion; (3) scion slightly larger than rootstock; (4), rootstock significantly larger than scion; (5), scion significantly larger than rootstock

2.6.4 Selected rootstocks for Navelina

Selection of rootstocks for future Navelina trials were based on cumulative yields, although yield efficiency, percent fruit size above 77 mm, the tolerance of rootstocks to CTV, Phytophthora and salinity and TSS:TA ratios were also considered. The selected rootstocks and their attributes are presented in Figure 2.12.

Jiangjin large leaf, Small leaf, Xianyong and Ghana were selected as rootstocks that will produce smaller, high yielding Navelina trees. Jiangjin large leaf and Small leaf produced 180 kg/tree while Xianyong and Ghana produced 168 kg/tree. Jiangjin large leaf was found to be resistant to CTV and Phytophthora and root rot and is a chloride accumulator and sodium excluder. Jiangjin large leaf also produces highly uniform seedlings and trees on these rootstocks can be planted at high densities. Small leaf is both a chloride and sodium excluder with high seedling uniformity. Ghana is chloride accumulator and sodium excluder and has high seedling uniformity. Xianyong is chloride accumulator, sodium excluder and has medium seedling uniformity. Generally, all the selected rootstocks given below have high resistance to CTV and Phytophthora collar and root rot. The selected rootstocks had excellent graft union compatibility.

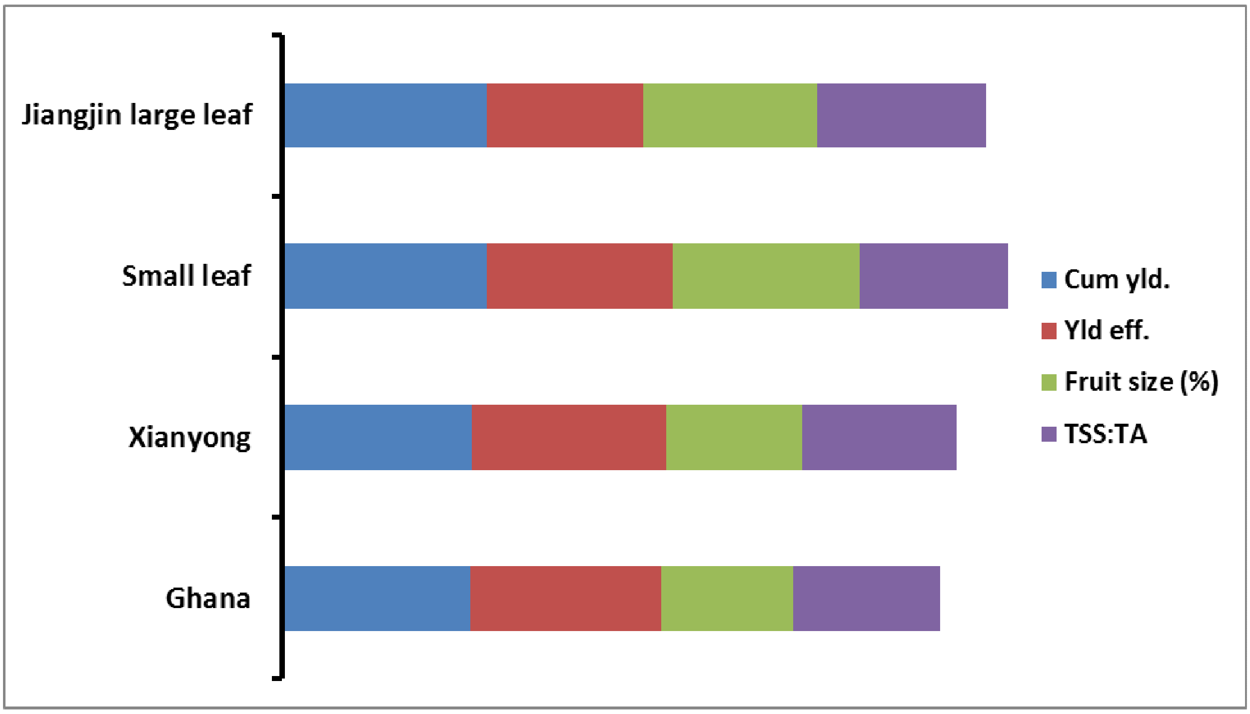

Figure 2.12: Visual depiction of the relative contribution that desirable characteristics made to the selection process when choosing rootstocks for further trials on Navelina orange scion.

2.7 Experiment 2 – Lane Late navel

2.7.1 Yield and tree growth

Lane Late scions grafted to Guanyun, Xianyong and Ghana rootstocks produced higher cumulative yields (164, 163 and 160 kg/tree, respectively) than scions grafted to Tri22 (106 kg/tree) (Table 2.16). The yield efficiencies of trees with Guanyun, 84-77, Xianyong and Ghana rootstocks were 2.2, 2.1, 2.1, 2.0 kg/cm^2, respectively, compared to trees with Tri22 rootstocks (1.8 kg/cm^2). Lane Late trees with No. 24, Mantou hong, 78-85 and 84-75 rootstocks had lower yield efficiencies (below 1.4 kg/cm^2). Mean trunk circumferences of trees with 78-85, No. 5, 84-75 and 85-24 rootstocks were 24.9, 25.8, 26.1 and 26.5 cm respectively, compared to the circumference of trees with Tri22 rootstocks which was 26.9 cm (Table 2.16). Grafting with these rootstocks resulted in trees of a relatively small size which are suitable for use in a high density planting system. Trees with trunk circumference of 30-33 cm were normally high yielding which included Guanyun, Xianyong, Ghana, Small leaf and Jiangjin large leaf. Generally high yield efficiency is associated with small tree size (trunk circumference); however the associations between yield efficiency and trunk circumference in this trial were very poor.

Generally, differences in biennial bearing values were not statistically significant across all rootstocks. Lane Late trees grafted to Jiangjin large leaf, No. 24, Wangchang large leaf, Wanyan and Ghana had mean BBI's of 0.30 to 0.32 compared to Tri22 which had a mean BBI of 0.37. Trees grafted to rootstocks 78-85, 84-79 and Mantou hong had BBI's of 0.41 to 0.43. However BBI values are less important if the rootstock improves other desirable characteristics such as yield and internal fruit quality (Table 2.16).

Lane Late trees grafted to No. 5, Ghana and Jiangjin large leaf rootstocks had large fruit sizes of 245, 233 and 230 g respectively compared to Tri22 (212 g). Rootstock No. 5 which produced large sized fruit also had the smallest tree size and therefore has potential for use in a high density planting system. Trees grafted to 84-75, No. 5 and 78-85 rootstocks produced 64%, 63% and 60% fruit of class size >77 mm, compared to Tri22 which produced 48% (Table 2.16)

2.7.2 Fruit quality

There were significant differences between the TSS values of fruits harvested from trees grafted to the various *trifoliata* rootstocks. Trees on control (Tri22) produced fruits with the highest TSS (12.9) compared to all other rootstocks in the trial; although the differences were not statistically significant and not large enough to impact fruit TSS:TA ratios. Other rootstocks which resulted in trees which produced fruit with high TSS were 84-75, No. 24, 84-79 and Bopi. The lowest TSS was noticed in fruit from Lane Late grafted to Guanyun and Small leaf (Table 2.17). The TSS:TA ratio was 14 for Bopi, 84-75, No. 24 and Wanyan which were slightly higher than Tri22 (13.7). However, lower TSS:TA ratios were noticed in Jiangjin large leaf, 84-77, Small leaf and Wangchang large leaf (Table 2.17).

The percentage juice levels of fruits harvested from trees grafted to all the *trifoliata* rootstocks were not significantly different compared to fruit harvested from trees grafted to Tri22. Fruits from trees on No. 5, Xianyong, Xiaogan, Tri22, 85-24, Mantou hong and No. 22 had 47% juice, while fruit from trees grafted to Wanchang large leaf had 44% juice. The rest of the rootstocks had juice levels between 45-46%.

2.7.3 Assessment of graft union

There were no obvious differences in graft union compatibility between the trial rootstocks and the Lane Late scion (Table 2.18). All Lane Late trees on the trial rootstocks had a visual score of 1 (very smooth unions) and mean stock:scion circumference ratios of 1.0 to 1.5. Matou hong had the smoothest union, while 85-24 was the only rootstock with visual score 2 and stock:scion circumference of 1.6. The diameters above and below the union were consistent and produced a correlation coefficient r = 85. The overall data suggests that none of the rootstocks in the trial are incompatible with Lane Late navel.

Table 2.16: Effect of rootstock on cumulative yield (Cum. yield), yield efficiency (YE), biennial bearing index (BBI), mean fruit weight (FW), percent fruit in the >77 mm size class (% Fruit) and trunk circumference (Trunk circ.) of Lane Late orange trees during 2005-12.

Rootstocks	Cum. Yield (kg)	YE (kg/m^2)	BBI	Fruit weight (g)	% Fruit (> 77 mm)	Trunk circ. (cm)
Trifoliata22 (Tri22)	106	1.8	0.37	212	48	26.9
78-85	65	1.2	0.41	225	60	24.9
84-75	67	1.2	0.36	228	64	26.1
84-79	109	1.6	0.41	229	53	29.4
84-77	123	2.1	0.38	221	54	27.2
85-24	106	1.9	0.36	219	47	26.7
Bopi	127	1.7	0.37	223	54	31.4
Ghana	160	2.0	0.32	233	56	31.6
Guanyun	164	2.2	0.35	221	52	31.1
Jiangjin large leaf	143	1.8	0.30	230	55	33.1
Mantou hong[x]	78	1.3	0.43	201	55	27.3
No. 22	115	1.6	0.38	227	51	31.8
No. 24	76	1.4	0.32	217	51	26.5
No. 5	103	2.0	0.37	245	63	25.8
Small Leaf	146	2.0	0.35	228	55	30.1
Wangchang large leaf	111	1.9	0.32	228	50	26.8
Wanyan	115	1.9	0.32	224	55	27.4
Xianyong	163	2.1	0.34	223	48	31.5
Xiaogan	104	1.6	0.38	226	58	29.5
Probability	***	*	ns	ns	ns	**
l.s.d (P = 0.05)	46	0.74	-	-	-	5.1

[x]Mandarin type

Table 2.17: The effect of rootstock on average total soluble solids (TSS), total titratable acid (TA), TSS: TA ratio and % juice in Lane Late navel fruit for 2005-2012 growing season.

Rootstocks	Total solids (TSS) %	Total acid (TA) %	TSS:TA ratio	% Juice (w/w)
Trifoliata22 (Tri22)	12.9	1.0	13.7	47
78-85	12.5	1.0	13.7	45
84-75	12.8	0.9	14.2	45
84-79	12.7	1.0	13.5	46
84-77	12.4	1.0	13.6	45
85-24	12.5	1.0	13.5	47
Bopi	12.6	0.9	14.3	45
Ghana	12.5	1.0	13.8	46
Guanyun	12.0	0.9	13.4	46
Jiangjin large leaf	12.2	0.9	13.9	45
Mantou hong[x]	12.1	0.9	13.5	47
No. 22	12.4	1.0	13.3	47
No. 24	12.7	1.0	14.1	46
No. 5	12.3	1.0	13.3	47
Small Leaf	12.0	0.9	13.8	45
Wangchang large leaf	12.5	0.9	13.8	44
Wanyan	12.6	0.9	14.1	45
Xianyong	12.5	1.0	13.6	47
Xiaogan	12.5	1.0	13.3	47
Probability	***	**	*	ns
l.s.d (P = 0.05)	0.44	0.1	0.99	-

[x]Mandarin type

Table 2.18: The effect of rootstock on the appearance of the graft union on Lane Late scion scored. Mean rootstock and scion circumferences 6 cm from the union measured in 2012 and the ratio of these measurements are also presented.

Rootstocks	Visual Ranking of graft union[1]	Rootstock Circumference (cm)	Scion Circumference (cm)	Rootstock:Scion
Trifoliata22 (Tri22)	1	39	26	1.5
78-85	1	35	25	1.4
84-75	1	37	26	1.4
84-79	1	36	26	1.4
84-77	1	41	29	1.4
85-24	2	39	26	1.6
Bopi	1	44	31	1.4
Ghana	1	43	31	1.4
Guanyun	1	45	31	1.5
Jiangjin large leaf	1	42	32	1.3
Mantou hong[x]	1	31	29	1.0
No. 22	1	40	27	1.5
No. 24	1	36	27	1.3
No. 5	1	40	28	1.5
Small Leaf	1	41	29	1.4
Wangchang large leaf	1	41	28	1.5
Wanyan	1	38	27	1.4
Xianyong	1	48	32	1.5
Xiaogan	1	40	28	1.4
Probability	ns	**	***	*
l.s.d (P = 0.05)	-	6.7	4.6	0.26

[x]Mandarin type; Visual ranking to score graft union: (1), smooth union; (2), rootstock slightly larger than scion; (3) scion slightly larger than rootstock; (4), rootstock significantly larger than scion; (5), scion significantly larger than rootstock

2.7.4 Selected rootstocks for Lane Late navel

Potential rootstocks for future Lane Late trials were selected based on tree performance, namely high cumulative yields, yield efficiencies, fruit size and TSS:TA ratios. The rootstocks selected and the contributions of each of the above factors are given in Figure 2.13.

Lane Late scions grafted to Guanyun, Xianyong and Ghana produced higher yields between 160-164 kg per tree. These rootstocks also produced trees that had higher yield efficiencies. These rootstocks were highly resistant to Phytophthora and CTV. Guanyun and Ghana had high seedling uniformity while Xianyong had medium seedling uniformity. These three rootstocks were found to be chloride accumulators and sodium excluders. The selected rootstocks had excellent graft union compatibility.

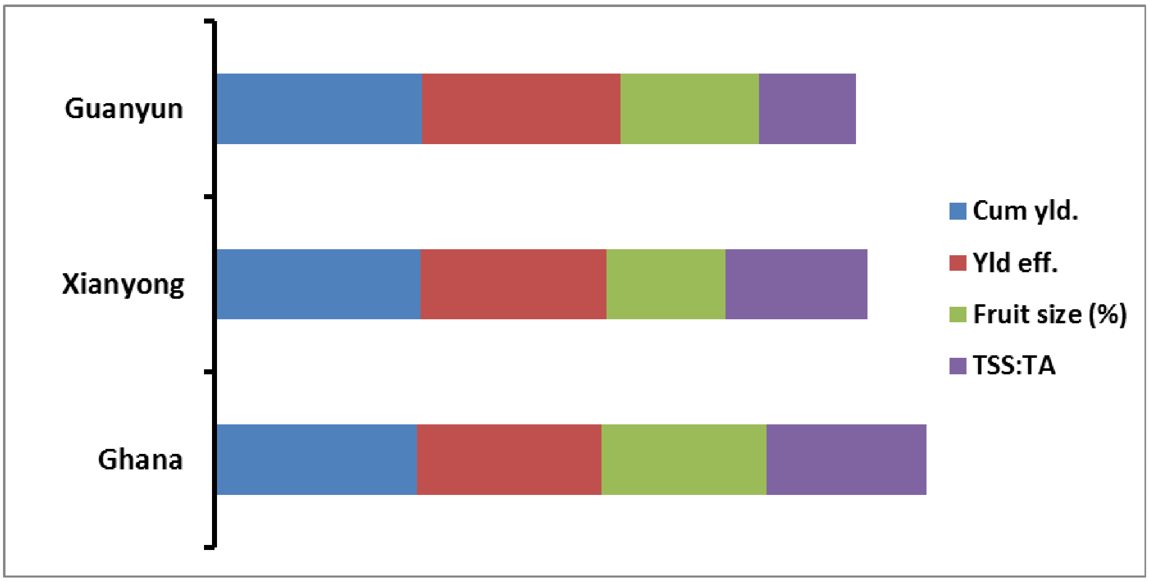

Figure 2.13: Visual depiction of the relative contribution that desirable characteristics made to the selection process when choosing rootstocks for further trials on Lane Late orange scion.

2.8 Experiment 3 – Imperial mandarin

2.8.1 Yield and tree growth

Imperial mandarin trees grafted to No. 5, No. 22 and Ghana rootstocks significantly out yielded trees on the standard Tri22 rootstock (Table 2.19). Imperial trees with No. 5, No. 22, Ghana and Xiaogan rootstocks produced 147, 129, 120 and 109 kg/tree with yield efficiencies of 5.1, 4.1, 3.9 and 4.0 respectively, compared to trees with a Tri22 rootstock which produced 79 kg / tree and 2.9 kg/cm^2. Therefore trees with the top 4 yielding rootstocks also had high yield efficiencies. Imperial trees with rootstock No. 24 had the lowest yield efficiency of 1.9 kg/cm^{2}and the lowest yield of 57 kg/tree. All other rootstocks produced yield efficiencies between 2.4 and 3.7 kg/cm^2.

The BBI of Imperial mandarin trees grafted to the trial rootstocks were not significantly different. The BBI of Imperial mandarin trees with No. 5, No. 22 and 78-85 rootstocks were 0.35, 0.37 and 0.38 respectively, compared to trees with Tri22 rootstocks with 0.45. Imperial mandarin trees grafted to Bopi, 84-79, Jiangjin large leaf, Xianyong, Guanyun and Small leaf rootstocks had BBI's between 0.50-0.54. Imperial mandarin trees with rootstock No. 24 had the highest BBI of all the rootstocks tested with a value of 0.60.

The mean fruit weight produced by trees grafted to *trifoliata* types were not significantly different compared to the standard Tri22. Generally, fruit from trees grafted to Ghana and Wangchang large leaf had heavier fruit (94 g) in comparison to fruit from trees grafted with Tri22 (88 g). The lowest fruit weights were recorded from trees with Bopi (87 g), Xianyong (87 g), No. 24 (87 g) and Mantou hong (85 g) rootstocks. The proportion of fruit in size class 67-72 mm was 53% and 48% respectively for trees with Wangchang large leaf and Ghana rootstocks, compared those with Tri22 rootstocks with 40%. Imperial trees on Xianyong and Bopi rootstocks had a lower percentage of large sized fruit (Table 2.19).

2.8.2 Fruit quality

The data indicated that there were significant statistical differences between the TSS of fruit produced on the trial trees. Fruit produced on trees grafted with No. 5 rootstock had the highest TSS value of 14.1 and this was not significantly difference to trees grafted with Tri22. Fruit produced on trees grafted with Mantou hong had the lowest TSS of 12.7. Trees which produced fruit with the highest TSS also had high yields and yield efficiencies (Table 2.20).

Total acid values of fruits produced by the trial trees were not significantly different and ranged between 0.8-0.9. There were also no significant treatment differences for the fruit TSS:TA ratios. The percent juice level in fruit produced on trees grafted with Ghana and 84-75 rootstocks were 36%, compared to 34% juice from trees grafted with Tri22 rootstock. The percent juice levels for fruit produced on trees grafted to No. 24, No. 5, Bopi and Guanyun were between 31 and 33%. All other trial rootstocks produced fruit with juice percentages between 33 and 35% (Table 2.20).

2.8.3 Assessment of graft union

A smooth graft union reflects a high degree of compatibility between a rootstock and a scion. Benching (overgrowth at the graft union due to incompatibility) is a major problem in Imperial mandarin trees in Australia with tree decline starting from 10-15 years after planting. The graft unions of the trial trees were all assessed, with a rating of 1 or 2 indicating there was a smooth, compatible union between the rootstock and Imperial (Table 2.21). Imperial mandarin trees grafted with 84-75, No. 22, No. 5, Wangchang large leaf and Xianogan rootstocks had unacceptable graft unions with a visual score of 4. The next worst rootstocks were for trees grafted with 78-85, Jiangjin large leaf, No. 24, Bopi and Xianyong rootstocks with a visual score of 3. A visual score of 2 was recorded for trees grafted with Guanyun, 84-77, 84-79, 85-25, Ghana, Small leaf, Tri22 and Wanyan rootstocks. The rootstock which had the best graft union was Mantou hong with a visual score of 1.

Table 2.19: Effect of rootstock on cumulative yield (Cum. yield), yield efficiency (YE), biennial bearing index (BBI), mean fruit weight (FW), percent fruit in the 67-72 mm size class (% Fruit) and trunk circumference (Trunk circ.) of Imperial mandarin trees during 2005-2012.

Rootstock	Cum. Yield (kg)	YE (kg/cm^2)	BBI	FW (g)	%Fruit (67-72 mm)	Trunk circ. (cm)
Trifoliata22 (Tri22)	79	2.9	0.45	88	40	26.4
78-85	97	3.7	0.38	91	45	25.4
84-77	96	3.3	0.44	90	47	28.5
84-75	87	2.9	0.39	89	45	28.2
84-79	105	3.4	0.50	91	47	31.0
85-24	109	3.7	0.47	91	42	29.3
Bopi	77	2.4	0.50	87	39	29.4
Ghana	120	3.9	0.41	94	48	31.1
Guanyun	78	2.4	0.53	89	41	31.6
Jiangjin large leaf	83	2.6	0.53	88	42	32.1
Mantou hong[x]	96	3.2	0.41	85	42	30.1
No. 22	129	4.5	0.37	89	40	27.7
No. 24	57	1.9	0.59	87	47	27.4
No. 5	147	5.1	0.35	90	44	27.9
Small Leaf	105	3.0	0.54	90	45	35.5
Wangchang large leaf	104	3.4	0.45	94	53	30.4
Wanyan	98	3.2	0.48	90	42	30.1
Xianyong	90	3.2	0.53	87	39	27.7
Xiaogan	109	4.0	0.48	91	45	27.3
Probability	*	***	*	ns		***
l.s.d (P = 0.05)	42.1	1.23	0.14	-		5.2

[*]Mandarin type

Table 2.20: The effect of rootstock on total soluble solids (TSS), total titratable acid (TA), TSS:TA ratio, and % juice in Imperial mandarin fruit for 2005-2006 growing season. Note: *Mandarin type

Rootstocks	Total soluble solids (TSS) %	Total acid (TA) %	TSS:TA ratio	Percent Juice (w/w)
Trifoliata22 (Tri22)	13.9	0.9	17	34
78-85	13.4	0.9	16	34
84-77	13.6	0.8	17	35
84-75	13.4	0.9	16	36
84-79	13.5	0.9	16	34
85-24	13.6	0.8	17	35
Bopi	13.3	0.9	16	32
Ghana	13.6	0.8	17	36
Guanyun	13.6	0.8	17	31
Jiangjin large leaf	13.6	0.9	16	35
Mantou hong[x]	12.7	0.8	16	34
No. 22	13.4	0.8	16	33
No. 24	13.4	0.8	16	32
No. 5	14.1	0.9	16	32
Small Leaf	13.4	0.8	17	35
Wangchang large leaf	13.1	0.9	16	35
Wanyan	13.5	0.8	16	34
Xianyong	13.5	0.9	16	35
Xiaogan	13.5	0.8	17	34
Probability	*	ns	ns	ns
l.s.d (P = 0.05)	0.58	-	-	-

Table 2.21: The effect of rootstock on the appearance of the graft union on Imperial mandarin scored during the 2012 growing season. Mean rootstock and scion circumferences 6 cm from the union and the ratio of these measurements are also presented.

Rootstock	Visual Ranking of graft union[1]	Rootstock Circumference (cm)	Scion Circumference (cm)	Rootstock:Scion
Trifoliata22 (Tri22)	2	45	25	1.8
78-85	3	44	25	1.8
84-77	2	45	28	1.6
84-75	4	49	27	1.8
84-79	2	46	30	1.5
85-24	2	45	29	1.5
Bopi	3	54	31	1.7
Ghana	2	56	31	1.8
Guanyun	2	47	32	1.4
Jiangjin large leaf	3	49	32	1.6
Mantou hong[x]	1	34	30	1.1
No. 22	4	51	29	1.8
No. 24	3	43	26	1.6
No. 5	4	51	27	1.9
Small Leaf	2	53	35	1.5
Wangchang large leaf	4	50	29	1.7
Wanyan	2	47	31	1.5
Xianyong	3	47	28	1.7
Xiaogan	4	47	27	1.7
Probability	***	*	**	***
l.s.d (P = 0.05)	1	10	5	0.2

[x]Mandarin type; [1]Visual ranking to score graft union: (1), smooth union; (2), rootstock slightly larger than scion; (3) scion slightly larger than rootstock; (4), rootstock significantly larger than scion; (5), scion significantly larger than rootstock

2.8.4 Selected rootstocks for Imperial mandarin

Potential rootstocks for future Imperial mandarin trials were selected based on tree performance, namely high mean cumulative yields, yield efficiency, total soluble solids, fruit weight, fruit size and compatibility (graft union). The selected rootstocks and the attributes are presented in Figure 2.14.

Trees grafted with No. 5 and No. 22 rootstocks had higher yields of 143 and 137 kg/tree respectively. These rootstocks had high yield efficiencies and small tree size, but were rejected on the basis of undesirable graft unions. Graft union is very important for the longevity of an Imperial mandarin tree. Therefore, the selection criteria discarded all those rootstocks exhibiting undesirable overgrowths at the graft union. Mantou hong rootstock was the only rootstock with smooth union to an imperial scion; while Ghana had an acceptable graft union (Figure 2.15). Tree size on Mantouhong rootstock was smaller than Ghana and yields for Mantou hong (96 kg/tree) were below Ghana (120 kg/tree). Ghana had high seedling uniformity, was a sodium excluder and was found to be highly resistant to *Phytophthora citrophthora*.

Figure 2.14: Visual depiction of relative contribution of the desirable characteristics of the selected rootstocks for entry into further trials with Imperial mandarin scion.

(a) (b) (c)

Figure 2.15: (a) smooth graft union (score 1); (b) acceptable union (score 2); and (c) unacceptable union (Score 4)

2.9 Experiment 4 – Eureka lemon

2.9.1 Yield and tree growth

In the trial, the cumulative yields of Eureka lemon trees grafted with Wangchang large leaf, No. 22, Wanyan rootstocks were 264, 233 and 227 kg/tree compared to 175 kg/tree for trees grafted with Tri22. For trees with Wangchang large leaf rootstocks yields were 66% greater than trees with Tri22 rootstocks. Lemon trees grafted with Donghu and Xianyong rootstocks had the lowest yields of 99 and 86 kg/tree respectively. Trees grafted to Guanyun, No. 5, 84-79, Bopi, Small leaf, No. 24 and 84-79 rootstocks had yields between 127 to166 kg/tree which were also below the control trees (Table 2.22).

The yield efficiencies of Eureka lemon trees grafted with Wanyan, Jiangjin large leaf, Ghana and Wanchang large leaf rootstocks were 6.7, 6.4, 6.4, and 6.4 kg/cm^2 respectively, compared to 5.6 kg/cm^2 for Tri22. Eureka lemon trees grafted with Xianyong had the lowest yield efficiency of 3.2 kg/cm^2, while those grafted with Donghu and No. 22 rootstocks had yield efficiencies of 4.3 kg/cm^2. Trees grafted with Guanyun, No. 5, Mantou hong, Bopi, 84-79 and Xiaogan rootstocks has yield efficiencies between 5.0 and 5.4 kg/cm^2, which were well below that of the control. The BBI values were not significantly different between trial trees. However trees grafted with Xianyong and 85-24 rootstocks had the lowest BBI values of 0.30, while trees grafted with No. 22 and Xiaogan rootstocks had higher BBI values of 0.44.

Eureka lemon trees grafted with Small leaf and 78-85 rootstocks had mean fruit weights of 184 g compared to trees grafted with Tri22 rootstocks (177 g). Trees grafted with rootstocks No. 5, Xianyong and Donghu produced average fruit weights of 160, 147 and 140 g respectively (Table 2.22). There was a significant difference between trial trees in the percentage of fruit in class 64-67 mm diameter. Trees grafted with Donghu, No. 24, Xianyong, 84-79 and No. 5 rootstocks had 25 to 28 percent of fruit in the 64-67 mm size class (Table 2.22). Eureka lemon trees grafted with 84-75, Small leaf, Bopi, Mantou hong and Guanyun rootstocks produced 16-19% of fruit in size class 64-67 mm.

Eureka trees grafted with Donghu, 84-79, Xianyong and Small leaf rootstocks had trunk circumferences of 23, 25, 26, and 27 cm respectively, compared to trees grafted with Tri22 rootstocks(31 cm). While trees grafted with Wangchang large leaf, Matou hong, No. 22 and Xiaogan rootstocks had large trunk circumferences of 40-42 cm (Table 2.22).

2.9.2 Fruit quality

Highest fruit Brix levels were between 8.9 and 9.2 for fruit harvested from trees grafted with No. 24, 84-79, Ghana, Donghu, Xianyong, 84-75, Tri22, No. 5 and 85-24 rootstocks. While fruit with the lowest Brix values were harvested from trees grafted with Jiangjin large leaf, Bopi and Mantou hong rootstocks, values were 8.5, 8.5 and 8.2 respectively (Table 2.23). The Brix:Acid ratios were not significantly different between Eureka lemon trees grafted to trial rootstocks with values between 1.4 to 1.6. There was not a significant difference in the juice content of trial trees, although trees on Wangchang large leaf produced the highest at 38% (Table 2.23). The fruit of all other rootstock varieties produced fruit with a juice content between 35 and 37% (Table 2.23).

There was not a significant difference in the weights of fruit produced on the trial trees. Trees grafted with Wangchang large leaf, Guanyun and Wanyan rootstocks had large sized fruit and the fruit length was 87, 87 and 85 mm respectively compared to fruit harvested from trees grafted with Tri22 rootstocks (82 mm). Lemon trees grafted to 84-75, 84-77, Ghana and 84-79 rootstocks had a mean length of 79 mm and a diameter of 62 mm.

The smoothness of the skin of lemon fruit is an important attribute in the market place. Lemon trees grafted with 84-79, 84-75, Wangchang large leaf and Jiangjin large leaf rootstocks produced 96%, 88%, 88%, and 86% respectively of smooth-skinned fruit, compared to fruit from trees grafted to Tri22 (76%). Trees grafted to No. 24, No. 5, 85-24 and No. 22 rootstocks had 64% and 66% smooth skinned fruit in the crop and the fruit produced on all other rootstocks in the trial were not smooth skinned (Table 2.13).

2.9.3 Assessment of graft union

Rootstock/scion compatibility is a major problem for lemon producers. Eureka lemon trees can produce large fruit with high juice content, but this scion is not compatible with most rootstocks. Eureka lemon trees on most trifoliata types develop an overgrowth at the graft union. There are some commercial rootstocks available for Australian lemon growers but the industry needs more options. Lemon trees grafted to Ghana, 84-77, No. 22, Tri22, Xiaogan and Wangchang large leaf rootstocks had smooth unions and the visual score was 1. Visual ranking also suggested that trees grafted to Guanyun and Small leaf rootstocks had the worst graft unions with a score of 4.

Table 2.22: Effect of rootstock on cumulative yield (Cum. yield), yield efficiency (YE), biennial bearing index (BBI), mean fruit weight (FW), percent fruit in the 64-70 mm size class (% Fruit) and trunk circumference (Trunk circ.) of Eureka lemon trees during 2005-2013.

Rootstock	Cum. Yield kg)	YE kg/cm^2)	BBI	FW (g)	% fruit 64-70 mm	Trunk circ. (cm)
Trifoliata22 (Tri22)	175	5.6	0.34	174	23	31
78-85	194	6.3	0.35	184	21	31
84-75	205	5.9	0.40	174	19	35
84-77	210	6.3	0.35	170	23	33
84-79	127	5.1	0.33	166	25	25
85-24	206	6.3	0.30	176	22	32
Bopi	159	5.1	0.35	177	19	31
Donghu	99	4.3	0.40	140	28	23
Ghana	199	6.4	0.39	178	23	31
Guanyun	166	5.4	0.37	165	16	30
Jiangjin large leaf	216	6.4	0.31	177	20	35
Mantou hong*	224	5.1	0.41	171	18	41
No. 22	233	5.6	0.43	164	21	42
No. 24	142	4.3	0.39	174	25	34
No. 5	166	5.4	0.33	160	25	30
Small leaf	155	5.6	0.37	184	19	27
Wangchang large leaf	264	6.4	0.42	172	21	40
Wanyan	227	6.7	0.34	170	21	34
Xianyong	86	3.2	0.29	147	25	26
Xiaogan	208	5.0	0.44	179	20	42
Probability	**	*	ns	*	***	***
l.s.d (P = 0.05)	87.1	1.99	0.11	23.4	5	6.5

*Mandarin type

Table 2.23: The effect of rootstock on % juice, total soluble solids (TSS), TSS: total titratable acid (TA), fruit length, fruit diameter, % rind smoothness and % rind roughness in Eureka lemon fruit for 2005-2013 growing season. Note: *Mandarin type

Rootstocks	Percent Juice (w/w)	Total soluble solids (TSS) %	TSS:TA	Fruit length (mm)	Fruit diameter (mm)	Percent rindsmoothness	Percent rindroughness
Trifoliata22 (Tri22)	36	9.0	1.6	82	64	76	24
78-85	37	8.8	1.5	84	65	74	26
84-75	37	9.0	1.6	80	63	88	12
84-77	36	8.7	1.5	80	63	72	28
84-79	35	9.1	1.6	77	60	96	4
85-24	37	8.9	1.6	84	64	64	36
Bopi	36	8.5	1.5	85	65	76	24
Donghu	37	9.1	1.5	81	64	86	14
Ghana	37	9.1	1.6	79	63	78	22
Guanyun	36	8.7	1.5	87	67	70	30
Jiangjin large leaf	36	8.5	1.4	84	67	86	14
Mantou hong	36	8.2	1.5	82	66	72	28
No. 22	36	8.9	1.5	85	65	64	36
No. 24	36	9.2	1.6	84	65	66	34
No. 5	36	9.0	1.5	83	66	66	34
Small leaf	36	8.7	1.5	82	66	85	15
Wanyan	36	8.8	1.5	85	65	82	18
Wangchang large leaf	38	8.7	1.5	87	67	88	12
Xianyong	35	9.0	1.5	83	66	71	29
Xiaogan	37	8.8	1.5	84	65	72	28
Probability	*	***	ns	ns	ns	ns	ns
l.s.d (P = 0.05)	1.9	0.39	-	-	-	-	-

Table 2.24: The effect of rootstock on the appearance of the graft unions on Eureka lemon scion scored during the 2006 growing season. Mean rootstock and scion circumferences 6 cm from the union and the ratio of these measurements are also presented. Note: *Mandarin type

Rootstock	Visual Ranking of graft union	Rootstock circumference (cm)	Scion circumference (cm)	Rootstock:Scion
Trifoliata22 (Tri22)	1	45	34	1.3
78-85	2	41	31	1.3
84-75	3	49	36	1.3
84-77	1	43	34	1.3
84-79	3	31	27	1.1
85-24	2	44	35	1.2
Bopi	3	46	34	1.4
Donghu	2	40	24	1.7
Ghana	1	45	34	1.3
Guanyun	4	41	32	1.3
Jiangjin large leaf	3	45	36	1.2
Mantou hong*	2	48	42	1.1
No. 22	1	56	41	1.4
No. 24	2	46	39	1.2
No. 5	2	42	31	1.4
Small leaf	4	40	30	1.4
Wangchang large leaf	1	56	45	1.3
Wanyan	2	44	37	1.2
Xianyong	3	37	28	1.4
Xiaogan	1	57	43	1.3
Probability	*	***	***	***
l.s.d (P = 0.05)	2	8.0	6.7	0.14

2.9.4 Selected rootstocks for Eureka lemon

Potential rootstocks for future Eureka lemon trials were selected based on cumulative yields, yield efficiency, fruit size, rind smoothness and trunk circumference. The selected rootstocks and the attributes are presented in Figure 2.16. Only rootstocks with a smooth graft union were considered, therefore, union shapes are not included in the figure below.

Eureka lemon trees grafted with Wangchang large leaf rootstocks produced a high cumulative yield of 264 kg/tree and yield efficiency of (6.4 kg/cm^2). Fruit was of an acceptable quality with 82% of fruit having smooth skins. Trees grafted to Wangchang large leaf had uniform graft unions. Seedling uniformity was very high and Wangchang large leaf rootstock was found to be a chloride accumulator and sodium excluder. Wangchang large leaf rootstock was also highly resistant to *Phytophthora citrophthora*. Trees grafted with No. 22 rootstocks also produced a smooth graft union. Fruit yield was 233 kg/tree with a yield efficiency of 5.6 kg/cm^2. Fruit rind smoothness was 64%. No. 22 rootstock was resistant to CTV, had medium seedling uniformity and was a chloride accumulator and sodium excluder. Trees grafted with Wanyan rootstocks produced yields of 227 kg/tree and had a high yield efficiency of 6.7 kg/cm^2. Fruit smoothness was 82% and tree size was small. Seedling uniformity was very high and Wanyan was a chloride accumulator and sodium excluder.

Due to their effect on tree size, the *trifoliata* rootstock types selected for further trials may be suited to high density plantings in an attempt to encourage high yields per hectare of good quality fruit for fresh consumption. Of the rootstocks tested, Wangchang large leaf appears to be the best choice for Eureka Lemon.

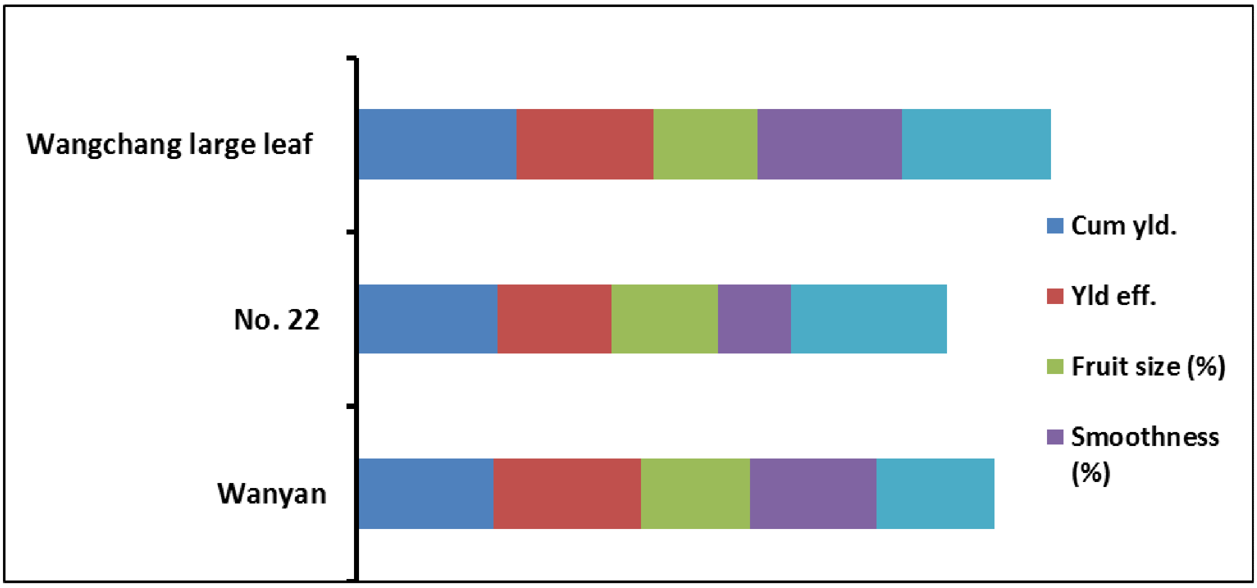

Figure 2.16: Visual depiction of the relative contribution of the desirable characteristics of the selected rootstocks for entry into further trials on Eureka lemon.

Chapter 3 Rootstock effects on leaf chloride concentrations in the scions

3.1 Introduction

The National Citrus Rootstock Improvement Program in Australia involves multi-stage evaluation of germplasm for its agronomic performance. Initial screening for disease and salt tolerance occurs in the greenhouse, followed by short-term preliminary field screening using a range of scion varieties and grown under different soil, climate and management conditions. One component of HAL funded project CT07002 "Assessing the horticultural performance of new citrus rootstocks via short-term orchard trials" is reported here and covers parts of the short-term preliminary field screening.

CSIRO Plant Industry has evaluated the new rootstock germplasm for salt tolerance. This work was initiated in project CT03025 (Khurshid *et al.*, 2007) and continued in project CT07002. This chapter details the three years of data for chloride uptake for trees in modules 3 and 4. Trees planted in module 3 were established in 2003 to assess CSIRO-bred salt and disease tolerant rootstock hybrids. Module 4 was established in 2005 to conduct a short-term orchard assessment of rootstocks introduced from Vietnam. These trees were propagated at CSIRO Plant Industry and were either nucellar seedlings (Module 3) or grown from single node cuttings taken from source trees (Module 4).

3.2 Materials and Methods

Trees were assessed during 2008, 2009 and 2010. Tables 3.1 and 3.2 give details of the rootstocks in each module along with brief details of the experimental designs in each case.

Table 3.1: Rootstock hybrid selections bred by CSIRO and assessed for chloride uptake in module 3.

CSIRO code no.	*Parents of selection*
80.05.05	Cleopatra mandarin x Carrizo citrange
80.06.05	Symons sweet orange x Trifoliata
81.02.400	Clementine mandarin x Rangpur lime
82.01.16	Rangpur lime x Trifoliata
82.02.02	Clementine mandarin x Rangpur lime
82.05.05	Ellendale tangor x Cleopatra mandarin
82.08.68	Clementine mandarin x Chinotto orange
82.09.148	Ellendale tangor x Chinotto orange
82.09.57	Ellendale tangor x Chinotto orange
82.10.07	Chinotto orange x Smooth Seville
82.02.05	Clementine mandarin x Rangpur lime
82.04.22	Clementine manadrin x Cleopatra mandarin
82.08.45	Clementine mandarin x Chinotto orange
82.13.01	Chinotto orange x Trifoliata
82.13.03	Chinotto orange x Trifoliata

Rootstocks tested in module 3 were propagated as nucellar seedlings and grafted to scion varieties Imperial mandarin, Eureka lemon, Navelina and Lane late sweet oranges.

In addition to the rootstocks listed above, Symons sweet orange, *Poncirus trifoliata* (Australian selection 22) and Carrizo citrange were included as standards. These standard stocks were propagated as nucellar seedlings and grafted with the varieties listed above.

The module was laid out as 4 separate trial plantings according to scion variety. Each variety trial was laid out as a randomised block design with 5 blocks and each rootstock replicated once per block.

Table 3.2: Rootstock introductions from Vietnam assessed for chloride uptake in module 4 trial

CSIRO code	*Common name*	*Species name*
CO170	Tieu Son mandarin	*Citrus reticulata*
CO172	Ta mandarin	*Citrus reticulata*
CO206	Hong Nhieu mandarin	*Citrus reticulata*
CO163	Mat orange	*Citrus sinensis*
CO168	Hong Kim orange	*Citrus sinensis*
CO209	Chanh orange	*Citrus sinensis*
CO210	Hong Nhieu orange	*Citrus sinensis*
CG44	Tau Bong Tim lime	Citrus sp. (similar to Rangpur lime)

The rootstocks tested in this module were propagated as cuttings and grafted to scion varieties Imperial mandarin, Eureka lemon, Navelina and Lane late sweet oranges.

In addition to the rootstocks listed above, Carrizo citrange was included as a standard. This standard stock was propagated as nucellar seedlings and grafted with the varieties listed above.

The module was laid out as 4 separate trial plantings according to scion variety. Each variety trial was laid out as a randomised block with at least 4 replicates per rootstock per block.

Leaf analyses

Samples of spring flush leaves were collected from several points around each tree at a height of approximately 1.0 – 1.2 m during the first week of April 2008, April 2009 and April 2010. Leaf samples were placed in paper bags and taken to the laboratory where they were rinsed with distilled water to remove surface contaminants, blotted dry and then dried in an oven at 60°C. Dried leaf samples were powdered in a hammer mill to pass through a 1mm mesh.

Dried powdered leaf samples were stored until they were analysed for chloride concentrations. Prior to analysis, powdered samples were held at 60°C for at least 72h to ensure they were dry. Chloride concentrations in dried powdered leaf samples were estimated as means of at least two determinations per sample, after cold extraction in dilute acid, by silver ion titration employing a Buchler-Cotlove chloridometer (Nuclear Chicago, New Jersey, USA).

Data were subjected to analysis of variance according to the experimental design. The effects of rootstocks on leaf chloride concentrations were tested for each scion variety separately.

Average weekly salinities of irrigation water taken from the Merbein/Dareton stretch of the River Murray are presented in Table 3.3. They were higher in the period August 1 2007 until early April 2008, when leaves were sampled, than in the corresponding period in 2006/07. They were similar in the period August 1 2008 until early April 2009, when leaves were sampled, to those experienced in the corresponding periods of 2005/06 and 2007/08. Salinity levels were lower in 2010 than for the two previous years in the period August until early April, when leaves were sampled (Murray Darling Basin Authority, 2009; http://www.mdba.gov.au/).

Table 3.3: Average weekly salinity of irrigation water from the River Murray for the period each year from when spring flush leaves developed until they were harvested.

Year	Period	Salinity (EC) in µS/cm at 25°C
2006	August 2005 – April 2006	130
2007	August 2006 – April 2007	100
2008	August 2007 – April 2008	140
2009	August 2008 – April 2009	130
2010	August 2009 – April 2010	100
Source: http://www.mdba.gov.au/		

3.3 Data analysis

Data were analysed according to the experimental design. The effects of rootstocks on leaf chloride concentrations were tested for each scion variety (trial within a module) separately. Data were analysed by a two-way analysis of variance according to the experimental design with rootstocks and blocks as main effects.

3.4 Results and Discussion

3.4.1 Season 2008 (Modules 3 and 4)

Leaf chloride concentrations for trees in module 3

As in previous years, leaf chloride concentrations were generally higher for sweet orange trees than mandarin and lemon trees with overall variety means being 0.05%, 0.08%, 0.10% and 0.12% for Imperial mandarin, Eureka lemon, Lane late and Navelina, respectively. Mean leaf chloride concentrations for rootstock-scion combinations in leaves collected in 2008 are presented in Table 3.4.

Values for t, the intraclass correlation coefficient (Table 3.4), which measures the degree of genetic determination, indicated that, for the trials with Eureka lemon and the two orange varieties, genetic variation in chloride exclusion capacity was quite large between the different stocks. This statistic was lower for the Imperial trees suggesting that environmental variation had a greater influence on chloride uptake in this trial.

Table 3.4: Mean leaf chloride concentrations (% DW) in spring flush leaves (approx. 9 months old) collected during April 2008 from four scion varieties grafted to a range of CSIRO-bred hybrid selections and standard rootstocks.

Rootstock	Scion variety			
	Eureka lemon	*Imperial mandarin*	*Lane late navel*	*Navelina*
80.05.05	0.03	0.03	0.04	0.05
80.06.05	0.17	0.07	0.20	0.20
81.02.400	0.02	0.02	0.03	0.04
82.01.16	0.03	0.03	0.04	0.04
82.02.02	0.03	0.03	0.05	0.05
82.05.05	0.03	0.03	0.04	0.04
82.08.68	0.03	0.02	0.04	0.08
82.09.148	0.03	0.03	0.11	0.05
82.09.57	0.04	0.04	-	0.06
82.10.07	0.02	0.03	0.05	0.03
82.02.05	0.03	0.03	0.05	0.07
82.04.22	0.03	0.02	0.03	0.03
82.08.45	0.04	0.03	-	0.04
82.13.01	0.06	0.07	0.10	0.27
82.13.03	0.04	0.05	0.05	0.09
Trifoliata 22	0.44	0.21	0.48	0.64
Carrizo citrange	0.25	0.14	0.24	0.18
Symons sweet orange	0.08	0.03	0.10	0.11
Sig.	***	***	***	***
LSD (P=0.01)	0.11	0.08	0.09	0.09
t[†]	0.74	0.39	0.81	0.89

[†] t is the intraclass correlation coefficient

Eureka lemon

Eureka lemon trees grafted to trifoliate orange had significantly higher leaf chloride concentrations than with any other rootstock. Trees grafted to Symons sweet orange had lower leaf chloride concentrations than those grafted to the other standard stocks. All Eureka lemon trees grafted to hybrid rootstock selections had lower leaf chloride concentrations than those on trifoliate orange and, with the exception of those grafted to 80-06-05, Carrizo citrange. The data again supported their selection as good chloride excluding rootstocks.

Imperial mandarin

Similar results were obtained for the Imperial trial. All trees grafted to hybrid selections had low leaf chloride concentrations similar to those grafted on Symons sweet orange and significantly lower than for those on trifoliate orange. Trees grafted to Carrizo citrange had similar leaf chloride concentrations as those on trifoliate orange and hybrid selections 80-06-05 and 82-13-01.

Navelina
As with the trees in the Eureka lemon and Lane late trials, Navelina trees grafted to trifoliate orange had significantly higher leaf chloride concentrations than when grafted to the other rootstocks. Similarly, most Navelina trees grafted to the hybrid selections had significantly lower leaf chloride concentrations than those grafted to Carrizo citrange. Trees grafted to hybrid selections 82-13-01 and 80-06-05 had similar leaf chloride concentrations as trees grafted to Carrizo citrange.

Lane late
Lane late trees grafted with Carrizo citrange rootstocks had similar leaf chloride concentrations to those grafted to hybrid selections 80-06-05 and 82-09-148 rootstocks. As in previous years, the result achieved with hybrid 82-09-148 was surprising in that trees of the other 3 varieties grafted to it all had significantly lower leaf chloride concentrations than equivalent trees grafted to Carrizo citrange rootstocks. This suggests that rootstock x scion interactions may have been present, although, there being separate trials for each variety; it is difficult to substantiate this. Again, as with the other varieties, trees grafted to most of the hybrid selections had lower leaf chloride concentrations than those grafted to Carrizo citrange rootstocks.

Comparisons between 2006, 2007 and 2008 data for trials in module 3

Mean leaf chloride concentrations between seasons were compared using linear regressions and correlation coefficients (Table 3.5). Rootstock effects on leaf chloride concentrations were consistent over the three years of sampling for all varieties.

Table 3.5: Relationship between leaf chloride concentrations for rootstock/scion combinations in 2006, 2007 and 2008.

Years	Scion	r	sig.	r^2	linear regression	sig.
2006 vs. 2007	Eureka lemon	0.97	***	0.94	y = 0.03 + 0.84x	***
	Imperial mandarin	0.92	***	0.85	y = -0.01 + 1.07x	***
	Lane late navel	0.95	***	0.90	y = 0.03 + 1.14x	***
	Navelina	0.94	***	0.89	y = 0.03 + 0.94x	***
2006 vs. 2008	Eureka lemon	0.95	***	0.90	y = 0.06 + 0.61x	***
	Imperial mandarin	0.95	***	0.90	y = 0.04 + 1.03x	***
	Lane late navel	0.93	***	0.86	y = 0.09 + 0.93x	***
	Navelina	0.96	***	0.93	y = 0.08 + 0.64x	***
2007 vs. 2008	Eureka lemon	0.96	***	0.92	y = 0.04 + 0.72x	***
	Imperial mandarin	0.96	***	0.91	y = 0.05 + 0.89x	***
	Lane late navel	0.96	***	0.91	y = 0.06 + 0.80x	***
	Navelina	0.95	***	0.89	y = 0.06 + 0.63x	***

The consistency in the data for trees in the four trials over the three years of sampling suggests that sufficient data have been collected for this module.

Leaf chloride concentrations for trees in module 4

As for trees in other modules, leaves of sweet orange varieties Navelina and Lane late had higher leaf chloride concentrations than those of Eureka lemon and Imperial mandarin. This suggests that the scion variety grafted onto rootstocks had an influence on salt accumulation in shoot tissues, although as each variety was represented in its own trial, the differences between varieties may have been due to environmental factors.

Rootstocks had a significant effect ($P<0.001$) on leaf chloride concentrations in Eureka lemon and sweet orange varieties Navelina and Lane late, but not for Imperial mandarin trees (Table 3.6).

Table 3.6: Mean leaf chloride concentrations (% DW) in spring flush leaves (approx. 9 months old) collected during April 2008 from four scion varieties grafted to a range of rootstock types introduced from Vietnam.

	Scion Variety			
Rootstock	Eureka lemon	Imperial mandarin	Lane late	Navelina
Tieu Son mandarin	0.03	0.04	0.05	0.04
Ta mandarin	0.03	0.04	0.05	0.05
Hong Nhieu mandarin	0.03	0.04	0.04	0.04
Mat orange	0.04	0.07	0.09	0.06
Hong Kim orange	0.03	0.04	0.05	0.05
Chanh orange	0.03	0.05	0.05	0.05
Hong Nhieu orange	0.03	0.04	0.05	0.05
Tau Bong Tim lime	0.03	0.05	0.05	0.06
Carrizo citrange	0.08	0.06	0.15	0.11
Sig.	***	ns	***	***
LSD (p=0.01)	0.02	-	0.04	0.03

With the exception of the trial with Imperial mandarin, in which there were no significant rootstock effects, trees grafted with Carrizo citrange rootstocks had significantly higher leaf chloride concentrations than those grafted with the other rootstocks. The only other significant rootstock effect recorded in this module was for Lane late trees grafted with CO163 rootstocks, which had significantly higher leaf chloride concentrations than those grafted to the other rootstocks from Vietnam.

Summary

Low leaf chloride concentrations recorded for all four varieties grafted to the CSIRO-bred hybrids selected as good chloride excluders supported the greenhouse technique used to identify these genotypes. This is encouraging and indicates that by the end of the evaluation, and depending on how they perform with regard to their effects on fruit yield and quality, it will be possible to nominate superior locally bred disease resistant and chloride-excluding rootstocks for entry into larger commercial-scale, regionally based trials in cooperation with industry.

The data for the rootstocks from Vietnam were promising suggesting that they all have a capacity for chloride exclusion under the conditions of the trial. Continued sampling of the trials in module 4 will occur to provide further data to verify the results so far. This is important as the salinity of the irrigation water in recent years has been low (Table 3.3). Indeed this may have been a factor affecting the results from the other modules and should river Murray salinities increase in the near future; it may be worthwhile re-sampling all the trials to collect comparative data for when root zone salinities are higher.

3.4.2 Season 2009 (Module 4)

Rootstocks had a significant effect (P<0.001) on chloride concentrations in all four scion varieties for leaves sampled in April 2009, which contrasted with the data collected in 2008 where there was no effect for Imperial mandarin trees (Table 3.7).

Table 3.7: Mean leaf chloride concentrations (% DW) in spring flush leaves (approx. 9 months old) collected during April 2008 and 2009 from four scion varieties grafted to a range of rootstock types introduced from Vietnam.

	Scion Variety							
Rootstock	Eureka lemon		Imperial mandarin		Lane late		Navelina	
	2008	2009	2008	2009	2008	2009	2008	2009
Tieu Son mandarin	0.03	0.04	0.04	0.05	0.05	0.05	0.04	0.05
Ta mandarin	0.03	0.04	0.04	0.04	0.05	0.06	0.05	0.04
Hong Nhieu mandarin	0.03	0.04	0.04	0.05	0.04	0.05	0.04	0.04
Mat orange	0.04	0.05	0.07	0.07	0.09	0.13	0.06	0.07
Hong Kim orange	0.03	0.03	0.04	0.03	0.05	0.05	0.05	0.04
Chanh orange	0.03	0.03	0.05	0.05	0.05	0.05	0.05	0.05
Hong Nhieu orange	0.03	0.04	0.04	0.05	0.05	0.07	0.05	0.05
Tau Bong Tim lime	0.03	0.04	0.05	0.06	0.05	0.05	0.06	0.05
Carrizo citrange	0.08	0.12	0.06	0.11	0.15	0.22	0.11	0.20
Sig.	***	***	ns	*	***	***	***	***
LSD (p=0.05)	0.02	0.04	-	0.06	0.04	0.04	0.02	0.04
LSD (p=0.01)	0.03	0.05	-	-	0.05	0.05	0.03	0.05
r^2 2008 vs. 2009 data	0.99 ***		0.55 *		0.98 ***		0.96 ***	

Trees grafted to Carrizo citrange had significantly higher leaf chloride concentrations than those grafted to the other rootstocks, with the exceptions of Imperial mandarin trees grafted to Tau Bong Tim lime and Mat orange. Trees of Lane late grafted with Mat orange rootstocks had significantly higher leaf chloride concentrations than those grafted to the other rootstocks from Vietnam.

There was close correlation between the data for Eureka lemon, Navelina and Lane late trees collected in 2008 and 2009 (Table 3.7) showing that the rootstock effects were consistent between years. This suggests that any of the stocks investigated would be superior to Carrizo citrange rootstocks in terms of their ability to exclude chloride. The correlation between years for the data for Imperial mandarin trees, though significant (P<0.05), was less convincing. This was most likely attributable to the fact that there were no significant rootstock effects for these trees in 2008.

Summary

The data collected in 2009 for the rootstocks from Vietnam were again promising and indicated that they all have a capacity for chloride exclusion under the conditions of the trial.

3.4.3 Season 2010 (Module 4)

Rootstocks had a significant effect (P<0.001) on chloride concentrations in all four scion varieties for leaves sampled in April 2010, which was similar to the data collected in 2009 but which contrasted with the data collected in 2008 where there was no effect for Imperial mandarin trees (Tables 3.8a and 3.8b).

Table 3.8 a: Mean leaf chloride concentrations (% DW) in spring flush leaves (approx. 9 months old) collected during April 2008, 2009 and 2010 from four scion varieties Eureka lemon and Imperial mandarin grafted to a range of rootstock types introduced from Vietnam.

Rootstock	Scion Variety					
	Eureka lemon			Imperial mandarin		
	2008	2009	2010	2008	2009	2010
Tieu Son mandarin	0.03	0.04	0.05	0.04	0.05	0.07
Ta mandarin	0.03	0.04	0.05	0.04	0.04	0.05
Hong Nhieu mandarin	0.03	0.04	0.05	0.04	0.05	0.08
Mat orange	0.04	0.05	0.08	0.07	0.07	0.08
Hong Kim orange	0.03	0.03	0.06	0.04	0.03	0.03
Chanh orange	0.03	0.03	0.05	0.05	0.05	0.05
Hong Nhieu orange	0.03	0.04	0.05	0.04	0.05	0.05
Tau Bong Tim lime	0.03	0.04	0.06	0.05	0.06	0.06
Carrizo citrange	0.08	0.12	0.22	0.06	0.11	0.14
Sig.	***	***	***	ns	*	***
LSD (p=0.05)	0.02	0.04	0.08	-	0.06	0.04
LSD (p=0.01)	0.03	0.05	0.11	-	-	0.05

Trees grafted with Carrizo citrange rootstocks had significantly higher leaf chloride concentrations than those grafted to the other rootstocks. Trees of Lane late and Navelina grafted with Mat orange rootstocks had significantly higher leaf chloride concentrations than those grafted to some of the other rootstocks from Vietnam.

There was close correlation between the data for the trees of all four scion varieties collected in 2009 and 2010 (Table 3.9) showing that the rootstock effects were consistent between these two years. This suggests that any of the stocks investigated would be superior to Carrizo citrange in terms of their ability to exclude chloride. The correlation between 2009 and 2010 for the Imperial mandarin data was more convincing than those for the other years when the trees were sampled. This was most likely attributable to the fact that there were no significant rootstock effects for these trees in 2008.

Table 3.8 b: Mean leaf chloride concentrations (% DW) in spring flush leaves (approx. 9 months old) collected during April 2008, 2009 and 2010 from four scion varieties Lane Late and Navlina grafted to a range of rootstock types introduced from Vietnam.

Rootstock	Scion Variety					
	Lane Late			Navelina		
	2008	2009	2010	2008	2009	2010
Tieu Son mandarin	0.05	0.05	0.08	0.04	0.05	0.07
Ta mandarin	0.05	0.06	0.07	0.05	0.04	0.06
Hong Nhieu mandarin	0.04	0.05	0.05	0.04	0.04	0.06
Mat orange	0.09	0.13	0.13	0.06	0.07	0.13
Hong Kim orange	0.05	0.05	0.08	0.05	0.04	0.06
Chanh orange	0.05	0.05	0.07	0.05	0.05	0.07
Hong Nhieu orange	0.05	0.07	0.07	0.05	0.05	0.06
Tau Bong Tim lime	0.05	0.05	0.08	0.06	0.05	0.08
Carrizo citrange	0.15	0.22	0.37	0.11	0.20	0.27
Sig.	***	***	***	***	***	***
LSD (p=0.05)	0.04	0.04	0.06	0.02	0.04	0.05
LSD (p=0.01)	0.05	0.05	0.07	0.03	0.05	0.07

Summary

The data collected in 2010 for the rootstocks from Vietnam were again promising and indicated that they all have a capacity for chloride exclusion under the conditions of the trial. To complete the data set, associations between chloride uptake and tree growth will be explored to assess any tree vigour effects on the salt exclusion characteristic.

Table 3.9: Correlation (r^2) between chloride data for different scion varieties between the years in which data were collected.

Comparison	Scion variety			
	Eureka lemon	Imperial mandarin	Lane late	Navelina
r^2 2008 vs. 2009 data	0.99 ***	0.55 *	0.98 ***	0.96 ***
r^2 2009 vs. 2010 data	0.98 ***	0.88 ***	0.93 ***	0.98 ***
r^2 2008 vs. 2010 data	0.96 ***	0.33 NS	0.97 ***	0.95 ***

3.4.4 Conclusions

The leaf chloride concentration data collected for trees at NSW DPI Dareton in modules 3 and 4 of the short-term preliminary field screening trials for new rootstocks have shown that a number of introduced and newly bred rootstocks are salt tolerant, however, it remains to be seen if any of those rootstocks are able to produce high yields of good quality fruit.

3.5: Short-term horticultural performance trials (Module 3 - CSIRO Hybrids)

This section of the report describes the fruit yield and quality data collected during the course of the trial;yield, tree growth and fruit quality was also assessed for the varieties.

Experiment 1: Navelina

The cumulative yield for Navelina trees grafted with Symon sweet orange x P. Trifoliata rootstock was 118 kg compared to Tri22 rootstocks with 65 kg; while trees grafted onto Clementine x Rangpur lime rootstocks were the second best and yielded 113 kg during the course of this trial (Table 3.10). The worst rootstocks were Chinnotto x Smooth Seville and Ellendale tangor x Chinotto orange-57; however Chinotto mandarin x P. Trifoliata-01 hybrid rootstocks failed to produce any fruit (Table 3.10).

Fruit quality data found TSS values were 9.6 and 9.9 for Clementine x Rangpur lime and Rangpur lime x P. Trifoliata rootstocks compared to P. Trifoliata and Carrizo citrange rootstocks (10.8). The TSS values were higher for Chinotto orange x P. Trifoliata rootstocks (11.9). There was no significant difference in total acid across any rootstock hybrid (Table 3.11). TSS:TA ratios were higher for Ellendale tangor x Cleopatra mandarin and Ellendale tangor x Chinotto orange-57 (10.3). Most of the rootstocks had low TSS:TA ratios. The lowest TSS:TA ratio (8.7) was found in Clementine mandarin x Chinotto orange-45 (Table 3.11). The percent juice content varied between the different hybrids. Clementine mandarin x Rangpur lime and Tri22 rootstocks had the lowest values of 35 and 37% respectively; while Ellendale tango x Chinotto orange, Clementine mandarin x Rangpur lime, Clementine mandarin x Rangpur lime-05 and Clementine mandarin x Cleopatra mandarin rootstocks had 48 to 49% juice content. The remaining rootstock hybrids had juice content between 42-47% (Table 3.11). Trifoliata rootstock had the largest fruit weight of 360 g compared to all other hybrids (Table 3.11).

Given the kg/tree and tons/hectare, the yields were quite low from all the rootstocks. Fruit quality was also not to an acceptable standard therefore rootstocks were not recommended for entry to further field commercial field trials.

Experiment 2: Imperial mandarin

Imperia mandarin trees grafted to Symons sweet orange x P. Trifoliata hybrid rootstocks produced 118 kg as compared to Imerial trees gradted to P. Trifoliata (66 kg), Carrizo citrange (45 kg) and Symons sweet orange (29 kg) (Table 3.11). The worst performing rootstocks were those hybrids which included Chinotto orange as one of the parents. Total yield for the best performing rootstock Symons sweet orange x P. Trifoliata and Clementine mandarin x Rangpur lime-05 was 18 and 11 t/ha respectively (Table 3.12).

Fruit quality data suggested that Clementine mandarin x Cleopatra mandarin and Clementine mandarin x Chinotto orange-45 rootstocks had the highest TSS values of

11.8 and 11.6 respectively compared to fruit form trees with Tri22 rootstocks (11.4). Skin colour of the fruit was orange apart from those harvested from trees with Tri22 rootstocks. Lower TSS values were observed in fruit harvested from trees with Clementine mandarin x Chinotto orange-68 (10.3) and Rangpur lime x P. Trifoliata (10.4), Ellendale tangor x Chinotto orange-148 (10.6), Cleopatra mandarin x Carrizo citrange (10.7), Symons sweet orange (11.7) rootstocks. Fruit from trees with these rootstocks had green skin and was not marketable. Other rootstocks resulted in green skin colour including Clementine mandarin x Rangpur lime-2, Carrizo citrange, Symons sweet orange x Trifoliata and Ellendale tangor x Cleopatra mandarin. Out of 19 rootstocks 10 rootstocks have immature green colour and rough skin.

There was not a significant difference in the TA values of fruit harvested from the trial trees across all rootstocks. TSS:TA ratios ranged from 8.8 9.8 for fruit from trees with Chinotto orange x Smooth Seville, Clementine mandarin x Chinotto orange-68, Ellendale tangor x Cleopatra mandarin and Ellendale tangor x Chinotto orange-168 hybrid rootstocks. Fruit from trees with Clementine mandarin x Cleopatra mandarin and Clementine mandarin x Rangpur lime rootstocks had TTA:TA ratios of 13. Fruit from trees with Ellendale tangor x Chinotto orange-168 rootstocks had the highest juice content of 48%; while fruit from Chinotto orange x P. Trifoliata hybrid rootstocks had the lowest juice content of 32%. Most of the fruit harvested from the rootstock hybrids with high juice content were green; whilst the orange coloured fruit had a lower juice content of less than 40%. Fruit produced on trees with Trifoliata rootstocks had an average fruit weight of 145 g; while fruit from trees with Chinotto orange x P. Trifoliata hybrid-3 rootstocks had an average fruit weight of 72 g.

Despite high yields, the fruit quality was below industry standard; fruit remained green and had rough and hard skin. On the basis of poor quality and poor consumer appeal, no recommendation was made for any rootstock to go further into industry-based grower trials. Therefore, further research work is not recommended for any of these rootstocks with Imperial mandarin.

Experiment 3: Lane Late

The cumulative yield for Lane Late sweet orange trees grafted with Rangpur x P. Trifoliata and Chinotto mandarin x P. Trifoliata rootstocks was 20 kg and 16 Kg respectively compared to P. Trifoliata 22 (13 kg), Carrizo citrange (16 kg) and Symons sweet orange (5 kg) (Table 3.14).

Fruit quality data suggested that fruit harvested from trees grafted with Clementine mandarin x Cleopatra mandarin, Chinotto orange x Smooth Seville, Cleopatra mandarin x Carrizo citrange, Symons sweet orange rootstocks had the highest TSS values between 11.4-11.6. However, fruit from trees grafted with Clementine mandarin x Rangpur lime rootstocks had the lowest TSS value of 10.1 (Table 3.15). The TA values across all rootstocks were not different. The TSS:TA ration were higher (16.2) for fruit from trees grafted with Cleopatra mandarin x Carrizo citrange rootstocks and lowest for Clementine mandarin x Rangpur lime-05 rootstocks (Table 13.5). Fruit from trees with this rootstock also had the highest juice content of 54%; whilst fruit with the lowest juice content below 40% were harvested from trees on Clementine mandarin x Cleopatra mandarin (35%), Ellendale tangor x Chinotto-57 (37%), Clementine mandarin x Rangpur lime (38%) and Symons sweet orange x P. Trifoliata (38%) rootstocks.

Average fruit size was large (328 g) for trees on Symons sweet orange x P. Trifoliata hybrid rootstocks and fruit from trees grafted with Ellendale tangor x Chinotto-57 rootstocks were smallest (126 g).

The total yield per tree and tons/ha were extremely low and ranged between 1-14 tons/ha. None of these rootstocks are recommended for further trials on Lane Late navel.

Table 3.10: Cumulative fruit yield/tree, cumulative fruit number/tree, yield kg/tree and yield in tons/ha of Navelina trees grafted to a range of hybrid rootstocks developed at CSIRO Merbein.

Rootstocks	Cumulative yield (kg)	Cumulative fruit number	Yield kg/tree	Yield tons/ha
Symons sweet orange x P. Trifoliata	118	636	24	14
Clementine mandarin x Rangpur lime0-2	113	677	23	14
Rangpur lime x P. Trifoliata	84	441	17	10
Ellendale tangor x Chinotto orange-148	67	393	13	8
Carrizo citrange	66	362	13	8
P. Trifoliata 22	65	371	13	8
Clementine mandarin x Chinotto orange-68	58	319	12	7
Cleopatra mandarin x Carrizo citrange	53	357	11	6
Symons sweet orange	53	274	11	6
Clementine mandarin x Chinotto orange-45	51	330	10	6
Clementine mandarin x Cleopatra mandarin	41	263	8	5
Chinotto orange x P. Trifoliata- 3	39	234	8	5
Clementine mandarin x Rangpur lime	35	216	7	4
Ellendale tangor x Cleopatra mandarin	30	183	6	4
Clementine mandarin x Rangpur lime-05	16	178	3	2
Chinotto orange x Smooth Seville	10	45	2	1
Ellendale tangor x Chinotto orange-57	5	35	1	1
Chinotto orange x P. Trifoliata-01	0	1	0	0
Probability	***	***	***	***
l.s.d (P = 0.05)	29	175	6	4

Table 3.11: The effect of rootstock on total soluble solids (TSS), total titratable acid (TA), TSS:TA, % juice, and average fruit weight (g) for fruit harvested from Navelina trees grafted to a range of hybrid rootstocks developed at CSIRO Merbein.

Rootstocks	Total soluble solids (TSS) %	Total acid (TA) %	TSS:TA ratio	Percent Juice (%)	Fruit weight (g)
Clementine mandarin x Rangpur lime	9.6	1.0	9.3	35	331
Rangpur lime x P. Trifoliata	9.9	1.0	9.9	42	314
Clementine mandarin x Chinotto orange-45	10.3	1.2	8.7	46	262
Clementine mandarin x Rangpur lime-05	10.4	1.1	9.7	48	285
Ellendale tangor x Chinotto orange-57	10.5	1.0	10.3	42	298
Chinotto orange x Smooth Seville	10.6	1.1	9.6	43	258
Clementine mandarin x Rangpur lime	10.8	1.1	9.5	49	270
Carrizo citrange	10.8	1.1	9.6	42	309
P. Trifoliata 22	10.8	1.2	9.3	37	360
Symons sweet orange x P. Trifoliata	10.9	1.1	9.7	46	268
Clementine mandarin x Chinotto orange-68	11.0	1.1	10.1	46	287
Cleopatra mandarin x Carrizo citrange	11.2	1.2	9.6	44	247
Symons sweet orange	11.4	1.1	10.0	47	243
Ellendale tangor x Chinotto orange	11.4	1.1	10.1	49	235
Clementine mandarin x Cleopatra mandarin	11.6	1.1	10.1	48	243
Ellendale x Cleopatra mandarin	11.7	1.1	10.3	47	247
Chinotto orange x P. Trifoliata-3	11.9	1.2	9.8	47	251
Chinotto orange x P. Trifoliata	-	-	-	-	-
Probability	***	**	ns	*	***
l.s.d (P = 0.05)	0.88	0.09	-	7.84	46

Table 3.12: Cumulative fruit yield/tree, cumulative fruit number/tree, yield kg/tree and yield in tons/ha of Imperial mandarin trees grafted to a range of hybrid rootstocks developed at CSRIO Merbein.

Rootstocks	Cumulative yield (kg)	Cumulative fruit number	Yield kg/tree	Yield tons/ha
Symons sweet orange x P. Trifoliata	118	1091	30	18
Clementine mandarin x Rangpur lime-05	76	679	19	11
Trifoliata 22	66	567	17	10
Clementine mandarin x Rangpur lime	59	514	15	9
Clementine mandarin x Rangpur lime-02	52	489	13	8
Rangpur lime x P. Trifoliata	45	382	11	7
Carrizo Citrange	45	410	11	7
Clementine mandarin x Chinotto orange-68	43	373	11	6
Clementine mandarin x Chinotto orange-45	39	399	10	6
Cleopatra mandarin x Carrizo citrange	39	362	10	6
Clementine mandarin x Cleopatra mandarin	38	407	10	6
Symons sweet orange	29	258	7	4
Chinotto mandarin x P. Trifoliata	28	284	7	4
Ellendale tangor x Cleopatra mandarin	21	203	5	3
Chinotto orange x P. Trifoliata-03	17	207	4	3
Ellendale tangor x Chinotto orange-148	11	111	3	2
Chinotto orange x Smooth Seville	4	31	1	1
Probability	***	***	***	***
l.s.d (P = 0.05)	33	280	8	5

Table 3.13: Total soluble solids (TSS), total titratable acid (TA), TSS:TA, % juice, and average fruit weight (g) of fruit harvested from Imperial mandarin trees grafted to a range of hybrid rootstocks developed at CSIRO Merbein.

Rootstocks	Total soluble solids (TSS) %	Total acid (TA) %	TSS:TA ratio	Percent Juice (%)	Fruit weight (g)
Clementine mandarin x Chinotto orange-68	10.3	1.1	9.8	39	120
Rangpur lime x P. Trifoliata	10.4	1.0	10.9	41	126
Ellendale tangor x Chinotto orange-148	10.6	1.1	9.8	48	104
Cleopatra mandarin x Carrizo citrange	10.7	0.9	11.6	38	128
Symons sweet orange	10.7	1.0	10.3	43	124
Clementine mandarin x Rangpur lime	10.8	0.8	13.2	41	131
Clementine mandarin x Rangpur lime - 2	10.8	1.0	10.5	42	111
Clementine mandarin x Rangpur lime-05	10.8	0.9	12.6	45	120
Carrizo citrange	10.9	1.0	11.1	45	127
Symons sweet orange x P. Trifoliata	11.0	1.0	10.7	38	105
Chinotto orange x Smooth Seville	11.0	1.3	8.7	41	101
Chinotto orange x P. Trifoliata	11.1	0.9	12.6	39	113
Chinotto orange x P. Trifoliata- 3	11.2	1.0	11.3	32	72
Ellendale tangor x Cleopatra mandarin	11.3	1.2	9.5	47	108
P. Trifoliata 22	11.4	1.0	11.8	45	154
Clementine mandarin x Chinotto orange-45	11.6	1.0	11.9	36	104
Clementine mandarin x Cleopatra mandarin	11.8	0.9	13.0	40	105
Probability	***	***	***	*	***
l.s.d (P = 0.05)	0.59	0.2	1.5	8.8	21.6

Table 3.14: Cumulative fruit yield/tree, cumulative fruit number/tree, yield kg/tree and yield in tons/ha of Lane Late trees grafted to a range of hybrid rootstocks developed at CSIRO Merbein.

Rootstocks	Cumulative yield (kg)	Cumulative fruit number	Yield/tree (kg)	Yield tons/ha
Rangpur lime x P. Trifoliata	20	78	7	4
Carrizo Citrange	16	58	5	3
Chinotto mandarin x P. Trifoliata	15	63	5	3
Trifoliata 22	13	50	4	3
Clementine mandarin x Rangpur lime-05	13	57	4	3
Clementine mandarin x Rangpur lime	11	63	4	2
Ellendale tangor x Cleopatra mandarin	11	45	4	2
Clementine mandarin x Chinotto orange-68	11	37	4	2
Symons sweet orange x P. Trifoliata	7	23	2	1
Cleopatra x Carrizo citrange	6	29	2	1
Clementine mandarin x Rangpur lime	6	26	2	1
Symons sweet orange	5	22	2	1
Ellendale tangor x Chinotto orange	4	7	1	1
Clementine mandarin x Cleopatra mandarin	3	10	1	1
Chinotto orange x Smooth Seville	0	1	0	0
Probability	***	***	***	*
l.s.d (P = 0.05)	33.1	11.0	6.6	123

Table 3.15: Total soluble solids (TSS), total titratable acid (TA), TSS:TA, % juice, and average fruit weight (g) of fruit harvested from Lanes Late trees grafted to a range of hybrid rootstocks developed at CSIRO Merbein.

Rootstocks	Total soluble solids (TSS) %	Total acid (TA) %	TSS:TA ratio	Percent juice (%)	Fruit weight (g)
Clementine mandarin x Rangpur lime	10.1	0.8	13.3	38	215
Rangpur lime x P. Trifoliata	10.1	0.7	14.2	42	298
Ellendale tangor x Chinotto orange-57	10.2	0.8	13.3	37	126
Clementine mandarin x Chinotto orange-68	10.6	0.7	14.9	45	255
Symons sweet orange x P. Trifoliata	10.7	0.7	14.8	38	328
Ellendale tangor x Cleopatra mandarin	11.0	0.8	13.4	45	233
Carrizo citrange	11.0	0.7	14.7	43	292
Chinotto orange x P. Trifoliata	11.1	0.8	14.1	45	287
P. Trifoliata 22	11.2	0.7	15.5	43	257
Clementine mandarin x Rangpur lime-05	11.3	0.9	13.1	54	208
Clementine mandarin x Rangpur lime	11.3	0.8	14.4	47	276
Symons sweet orange	11.4	0.8	15.2	44	195
Cleopatra mandarin x Carrizo citrange	11.5	0.7	16.2	44	216
Clementine mandarin x Cleopatra mandarin	11.6	0.9	13.4	35	202
Chinotto orange x Smooth Seville	-	-	-	-	-
Probability	***	**	**	***	***
l.s.d (P = 0.05)	0.76	0.08	1.82	6.94	54

Chapter 4 Recommendations

4.1 Conclusions and recommendations

Rootstocks have a major impact on the profitability of citrus orchards. Rootstocks can influence fruit size, yield and yield efficiency. The ideal citrus rootstock should ensure tree longevity and encourage consistently high annual yields, large fruit size (or size appropriate for the target market) and acceptable internal quality. Fruit size is an important fruit quality characteristic as buyers have shown a distinct preference for larger fruit in recent years, particularly for navel orange. Results presented from the rootstock trials at Dareton have led to the selection of a number of new types for entry into longer-term, industry based commercial trials.

4.2 Rootstocks selected for entry to further trials

The performance of the following rootstocks indicated that they should now be commercially evaluated with the scions identified from Module 2:

<u>Navelina</u>
***P. trifoliata*:** Jiangjin large leaf, Small leaf, Ghana and Xianyong

<u>Lane Late</u>
***P. trifoliata*:** Guanyun, Xianyong and Ghana

<u>Imperial mandarin</u>
C reticulata: Mantou hong and ***P. trifoliata:*** Ghana

<u>Eureka Lemon</u>
P. trifoliata: Wangchang large leaf, No. 22 and Wanyan

It is also feasible that other rootstocks that performed well could be entered into further evaluation trials with other commercial varieties. The trials reported here only involved 4 scions that were considered to best represent the major scions grown by industry at the start of the project. The number of scions was limited by the resources available for the research and the large number of rootstocks included in the short-term trials.

The question now arises as to how further work could be conducted and resourced.

One avenue to proceed from hereon may be to establish a steering committee comprising industry, research agency and HAL membership to oversee the establishment of commercial trials. Cooperating citrus growers in the major regions of production could be sought to participate in the trials, especially where new plantings are being established so that the promising new rootstocks can be evaluated further alongside popular rootstocks that are currently favoured in the different regions. By developing a network of cooperating growers, the rootstocks can be distributed under testing agreements that will restrict the further distribution and propagation of the plant material. This will be important for maintaining the genetic purity of the new rootstocks and assist in further commercialising any that may be released to the local or international citrus industry, potentially in collaboration with international research institutes (e.g. Spain, China and USA).

The above is one option for the further development of the rootstocks evaluated so far in project CT07002. It is recommended that this and other options are discussed at the next National Citrus Breeding and Evaluation meeting.

In anticipating that there would be a stage during the evaluation of the rootstocks introduced from Asia when some may be released and commercialised, the project team decided early on that source trees for the rootstocks needed to be characterised and established in arboreta. Thus, during the ACIAR-supported research, source trees of the different introductions were established at NSW DPI's Dareton Primary Industries Institute. These trees are vitally important as true-to-type seed supply trees, particularly for the rootstocks with commercial potential. It is anticipated that AusCitrus will be licensed by agreement to handle the distribution of seeds from any rootstocks released to the Australian citrus industry.

4.3 Future research to be conducted in CT 14004 (Proposal submitted to HAL for 2014/2015)

This research will potentially continue in a new project supported by HAL. Specifically, the following activities remain to be completed with these trials:

- Module 4 was planted in 2005 therefore further data needs to be collected in order to identify promising rootstocks for nomination to the next stage of evaluation. Yield and fruit quality data will be collected for a further three years to complete the trials in Module 4.

- A trial which was established in the Riverina will be included into the new project and evaluated.

- Commercial trials on grower properties of the most promising rootstocks

- High density dwarfing trial

4.4 Strategies for wider industry testing of promising rootstocks

Strategies for wider industry testing of promising rootstocks from the Gosford trials conducted during project CT96008 were developed based on the above recommendations with some modifications and are as follows:

- Citrus rootstock breeding by NSW DPI (formerly NSW Ag) started in 1945 and hybrids were produced up until 1965. Some of the most promising rootstocks were selected from families generated from Scarlet mandarin x *Poncirus trifoliata* and Smooth Seville orange x *Poncirus trifoliata* crosses.

- The transfer of the most promising selections from NSW DPI's Gosford and Somersby sites to Dareton ARAS began in 2001 and was completed in 2005.

- The selected rootstocks identified in HAL funded projects CT317 (1993-1996) and CT96009 (1996-1999) as worthy of further investigation were assigned accession numbers before their transfer and the recommendation that they should be evaluated further in different climatic areas of Australia has been progressed. Eighteen listed rootstocks have been established as seed source trees at ARAS Dareton. They have also been budded with Atwood navel and planted at Dareton for further evaluation.

- Twenty two hybrids were selected and recommended for further testing in Queensland at Bundaberg Research Station. NSW DPI's intellectual property in these rootstocks has been protected via a Material Transfer Agreement (MTA) between NSW DPI and DPI&F Queensland. An agreement is also currently in place for some of the Chinese citrus rootstock accessions that were transferred to Bundaberg for evaluation in 2001. The selections and rootstocks from China were transferred as budwood for the establishment of seed source trees in Queensland.

- Follow through on evaluation of rootstocks that were not adequately evaluated in the previous project (SARDI component of CT03025). The rootstock germplasm set out in Table 3.13 have been collected from SARDI's Loxton Research Station, Loxton, SA, for preservation. Seeds were collected and transferred to Dareton Primary Industries Institute, germinated and are currently growing in a glasshouse.

Table 4.1: Rootstock germplasm from Loxton Research Centre, Loxton, SA.

Accession #	Parentage
58-220-2	(Rangpur × Shekwasha 54-63-24) x OP
59-24-8	(Rangpur × Swingle *P. tri.* 54-61-4) x OP
59-47-3	(Rangpur × Shekwasha 54-63-46) x OP
62-109-40	(Sunki × Flying Dragon *P. tri.*) FI
63-199-31	(Sunki × Mars *P. tri.*) FI
63-199-49	(Sunki × Mars *P. tri.*) FI

4.5 Develop a comprehensive plan for semi commercial evaluation of rootstocks identified in current and previous trials:

A comprehensive plan for the semi-commercial evaluation of rootstocks identified from previous and current project has been formulated.

Previous trials: CT96009 Rootstocks identified as potentially useful were transferred to Dareton in 2007 and established as future source trees. In addition promising selections have been propagated to Atwood navel (a navel orange selection identified in the variety evaluation program) and established in a trial at Dareton in 2005.

Rootstocks identified as potentially useful for mandarin are being propagated as cuttings for planting in a rootstock trial to be established at Dareton. This work is part of a current ACIAR funded citrus project between NSW DPI and the Bhutan Ministry of Agriculture.

Two rootstocks that came from the lemon rootstock program which was run at the NSW DPI centre near Gosford have already been selected and made available to the citrus industry. Those rootstocks are Cox (Scarlet mandarin × *Poncirus trifoliata*) and Fraser hybrid (Smooth flat Seville × *Poncirus trifoliata*).

<u>Current trials:</u> A range of Chinese rootstocks have been selected to go to the next phase of evaluation in semi-commercial trials, as part of a VC-HAL funded project (CT07006 'title'). Evaluation of superior processing oranges for fresh juice with selected Chinese rootstocks). The rootstocks being used in this project were those identified in Module 1. The establishment phase of this project was completed in June 2011. The trial has now been included in the new proposed HAL funded project CT14004. During this project the horticulture performance of the established trees will be assessed.

Once the rootstocks are identified from Module 2, semi-commercial trials in other parts of Australia will follow provided resources available to conduct trials on a larger scale.

4.6 Mechanism to identify potentially useful rootstocks from other important overseas programs that may be available for evaluation by industry

It is important that rootstock evaluation is part of a co-ordinated program aimed at meeting industry (national and regional) needs; *ad hoc* approaches consume scarce resources and have limited applicability. New rootstocks identified from overseas studies as having potential, should be imported and introduced into a national program. AusCitrus could take a co-ordinating role in the importation of new rootstocks for testing. This would overcome multiple imports of the same material and its trueness to type could be ensured avoiding, for example, the confusion experienced with multiple imports of Swingle citrumelo more recently. The import and evaluation of new rootstocks requires support; it is futile identifying potentially useful germplasm overseas unless resources are made available to assess that material under Australian conditions.

Some progress has been made in identifying and interacting with the rootstock research staff overseas.

Spain: Contact has been made with Ms Maria Forner from the Spanish breeding program regarding the possibility of testing two PBR rootstocks, Forner-Alcaide 5 and Forner-Alcaide 13, under Australian conditions under a reciprocal research agreement. The reciprocity arrangement would mean that Ms Forner would test selected Chinese rootstocks under Spanish conditions.

Argentina: A meeting was held with Ms. Catalina Anderson, Concordia, Entre Rios, Argentina, during the International Citrus Congress held in PR China. Ms. Anderson will suggest some rootstocks that may potentially be useful under Australian conditions.

South Africa: Mr Wayne Parr (Variety Access, Queensland) has imported a hybrid rootstock (Minneola × *Poncirus trifoliata*) from the South African breeding program.

Chapter 5: Technology Transfer and Extension

The project included a comprehensive technology transfer program. Trial results were presented to citrus growers, packers, processors and industry service providers at conferences and seminars in Australia and overseas. Data was also presented to local and international visitors to the NSW Primary Industries Institute at Dareton and numerous visitors inspected the trial sites. The project team established international linkages with scientists and industry representatives during the course of the experimental program. It is anticipated that the key scientific outputs from the project will also be presented at the 29th International Society of Horticultural Science Congress to be held in Brisbane, Australia in 2014.

5.1 CITTgroup, farm walks and field days

A number of presentations were given around Australia during the course of the project. These presentations, which often included farm walks, were given as part of CITTgroups organised by industry development officers or during other organised events like the Mildura Horticultural Field Days that are held annually during May. The project team also took every opportunity to inform citrus producers about the project at meetings and other less formal events. Some of the extension activities are listed below.

5.2 Industry Publications/reports

- **Khurshid, T. 2009.** Evaluation of locally bred and imported rootstock. *Citrus Insight*, submitted to HAL.
- **Khurshid, T. 2010.** Evaluation of locally bred and imported rootstock. *Citrus Insight,* submitted to HAL.
- **Khurshid, T. 2011.** Evaluation of locally bred and imported rootstock. *Citrus Insight,* submitted to HAL.
- **Khurshid, T. 2012.** Evaluation of locally bred and imported rootstock. *Citrus Insight,* submitted to HAL.
- **Khurshid, T. 2013.** Evaluation of locally bred and imported rootstock. *Citrus Insight*, submitted to HAL.
- **Khurshid, T. 2009.** Milestone report 102, CT07002, submitted on 28 Mar to HAL.
- **Khurshid, T. 2009.** Milestone report 103, CT07002, submitted on 31 May to HAL.
- **Khurshid, T. 2009.** Milestone report 104, CT07002, submitted on 1 Dec to HAL.
- **Khurshid, T. 2010.** Milestone report 105, CT07002, submitted on 31 May to HAL.
- **Khurshid, T. 2010.** Milestone report 106, CT07002, submitted on 1 Dec to HAL.
- **Khurshid, T. 2010.** Milestone report 107, CT07002, submitted on 31 May to HAL.

- **Khurshid, T. 2011.** Milestone report 108, CT07002, submitted on 1 Dec to HAL.
- **Khurshid, T. 2013.** Milestone report 109; Final Report, CT07002, submitted on 22 Jan to HAL.

5.3 National and International Conferences/Workshops

Khurshid, T. 2013. Data and updates from the Chinese rootstock trials were presented to research scientists and staff of the Instituto Valenciano de Investigaciones Agrarias, Valencia, Spain in November 2013. A paper on Chinese rootstocks was also presented at the International Horticultural Congress held in Valencia, Spain in 2013.

Khurshid, T. 2013. The current rootstock project was discussed during a national variety committee meeting on 3 September 2013. Progress of the project was presented as a PowerPoint presentation to the committee and to a HAL representative at the NSW DPI citrus research station at Dareton.

Khurshid, T. 2013. Results from the rootstock trials were presented during a Citrus Field day held in Perth, WA on 4-5 June.

Khurshid, T. 2012. Data and updates from the Chinese rootstock trials were presented to research scientists and staff of the Citrus Research Institute, Beibei, Chongqing on 17 May 2012 in China. The rootstock trials were originally initiated at this research station via an ACIAR funded project.

Khurshid, T. 2012. The current rootstock project was discussed at a national variety committee meeting on 21 March 2012. Progress was presented as a PowerPoint presentation to the committee and to a HAL representative at the NSW DPI citrus research station at Dareton.

Khurshid, T. 2011. Presentation of rootstock work to the NSW citrus industry. Latest results of the Chinese rootstocks were presented to growers at Dareton research centre on 29 June 2011. A field visit was also organised for the growers to inspect the trees at Dareton site.

Khurshid, T. 2011. Presentation of rootstock work to the WA citrus industry. A formal presentation about the latest results of Chinese rootstocks was made to growers and industry personnel at Harvey, Perth on 20 July 2011.

Khurshid, T. 2011. The current rootstock project was discussed during a national variety committee meeting on 7 December 2011. Progress was presented as a PowerPoint presentation to the committee and to a HAL representative at the NSW DPI citrus research station at Dareton.

Khurshid, T. 2011. A field walk was organised for the national variety improvement committee meeting held on 16 February 2011. Latest data from the rootstock trials was presented to the committee prior to the field session.

Khurshid, T. 2010. Imperial mandarin forum: Data and updates from the Chinese rootstocks were presented to the citrus industry on 16 November 2010 at the Berri

Hotel, Berri, SA and on 17 November 2010 at the Dareton Primary Industries Institute, NSW. The events were organised by Citrus Australia Limited.

Khurshid, T. 2010. National Citrus Pathology Workshop: Results from the rootstock trials were presented to citrus researchers, pathologist and physiologists on 30 November 2010 as a part of the National Citrus Pathology Workshop held at Dareton. The presentation was followed by a field walk to the Chinese rootstock trial site.

Khurshid, T. 2009. Results from the rootstock trials were presented during an "Imperial Dry Mandarin" Forum held at Loxton, SA on 23 July 2009. The latest results from the Imperial mandarin / Chinese rootstock trials were presented to CAL.

Khurshid, T. 2009. Results from the rootstock trials were presented during a citrus field day held on 16 June 2009 at Dareton. Growers also had the opportunity to visit the rootstock trial to see the recommended rootstocks

Khurshid, T. 2009. Results from the rootstock trials were presented during a citrus field day held on 2 June at Dareton. Growers also had the opportunity to visit the rootstock trial to see the recommended rootstocks.

Khurshid, T. 2009. Results presented to South African growers at Dareton on 28 April 2009.

Khurshid, T. 2009. Updates were presented to Riverina CITTgroup growers during CITTgroup events on 25 and 26 November at Leeton and Griffith, respectively.

Khurshid, T. 2009. Latest data presented to more than 200 growers during the field session of the industry's peak body conference on 9 November 2009.

Donovan, N. J**. 2009.** Project activities were presented during a presentation entitled 'Citrus Pathology and Soil Health at EMAI'. This was presented as part of 'Sydney Paddock to Plate Tour' run by Riverina Citrus. The group visited NSW DPI's Elizabeth Macarthur Agricultural Institute, Menangle NSW Australia on the 23rd June 2009.

Donovan, N. J. **2009**. Project activities were presented during a presentation entitled 'Citrus Pathology and Soil Health Unit at EMAI'. This was presented to the Riverina Citrus Young Growers group at NSW DPI's Elizabeth Macarthur Agricultural Institute, Menangle NSW Australia on 22nd April.

Khurshid, T. 2008. The results from the rootstock project were presented during the Citrus International Congress in Wuhan, China in October 2008.

Khurshid, T. 2008. Results were presented to CITTgroup growers at a field day held at Dareton on 22 August 2008.

Khurshid, T. 2008. Results were presented to a group of citrus industry development officer's on 30 May 2008. A field walk followed the data presentation.

Khurshid, T. 2007. Rootstock trial data was presented at the National Citrus Liaison Meeting held during the 59th Australian Citrus Growers' Conference (16-19 April), Renmark, South Australia.

Khurshid, T. 2007. Rootstock trial results presented to MIA growers/members at Griffith and Yanco, NSW (July).

5.4 Presentations/Farm walks for International visitors

Dr Maria Angeles Forner-Giner (25-26 June 2013)
Dr Forner visited Dareton, 25-26 June 2013. She inspected the rootstock program and also presented the Spanish rootstock program to growers during a mega field day run by NSW DPI and the Murray Valley Citrus Marketing Board. Dr Forner is collaborating with Dr Tahir Khurshid with regard to testing the Spanish rootstocks in Australia.

Pakistan ACIAR project staff (12 September 2012)
Dr Munawar Kazmi (Australian High Commission, Islamabad), Dr Abdul Samad (Director General Agriculture Research Institute, Peshawar, Pakistan) and Asif Khan (Director Fruit and Vegetable Project, Lahore, Pakistan) visited Dareton on 12 September 2012 for a one week training program in crop management and also inspected the rootstock program at Dareton.

Director General CCRI China visit to Dareton (24-25 July 2012)
Dr Zhou Changyong (Director, Citrus Research Institute of CAAS, Beibei, Sichuan, PR China) visited NSW DPI Dareton on 24-25 July 2012 for discussions on rootstock improvement and other mutual research interests.

Postgraduate student visit to Dareton (30 May 2012)
A group of post graduate students from Charles Sturt University visited Dareton Primary Industries Institute on 30 May 2012. They were accompanied by Dr Bruno Holzapfel (senior research fellow, NSW DPI Wagga Wagga) and Zubair Shahzad (Viticulture officer, Australia Vintage). The group visited the citrus rootstock trial sites and took a keen interest in the project data collection program and analysis.

ASLP Project visit to Dareton (20 May 2012)
Latest rootstock updates were presented to Dr Abdul Samad (Director General Agriculture Research Institute, Peshawar, Pakistan), Mohammad Asif Khan (Director Fruit and Vegetable Project, Lahore, Pakistan) and Dr Munawar Kazmi (Australian High Commission, Islamabad) on 20 May 2012 at Dareton. A field session was organised to inspect the Chinese rootstocks followed by a presentation.

Californian citrus growers at Dareton (1 April 2012)
A grower’s group (3) from the Californian citrus industry (Sunkist) visited Dareton on 3 April 2012. Data from the rootstock were presented followed by a field visit to the trial site.

Senior management visit to Dareton (29 March 2012)
Michael Bullen (Deputy Director General, NSW DPI) visited Dareton on 29 March 2012. He visited the rootstock trials and Dr Tahir Khurshid presented him with the latest results.

Agromerrila group at Dareton (1 March 2012)
A private nursery group from Agromirilla, Spain visited Dareton on 1 March 2012. Agromerrila interact with Dr Maria Angeles Forner-Giner in the testing of her IP

rootstocks. The group was briefed about the rootstock work prior to a field visit to the trial site.

Vice Chancellor University of Faisalabad, Pakistan at Dareton (September 2011)
Rootstock updates were presented to Dr Iqrar Khan (Vice Chancellor, University of Agriculture, Faisalabad) in September 2011, at Dareton. A field session was organised to inspect the Chinese rootstocks followed by a presentation.

ASLP Project team visit to Dareton (June 2011)
Latest rootstock updates were presented to Dr Iftikhar Ahmad (Chairman PARC, Islamabad) and Dr Munawar Kazmi (Australian High Commission, Islamabad) in June 2011, at Dareton. A field session was organised to inspect the Chinese rootstocks followed by a presentation.

Sunkist vistors from United States (20 January 2010)
A group of growers visited the rootstock program on 20 January 2010 at Dareton.

Visit of Visalia citrus growers to Dareton (2 September 2008)
A group from a packhouse in Visalia, USA visited Dareton to inspect the Chinese rootstock program on 2 September 2008.

Visit of citrus researchers from Israel (4 July 2008)
A group of researchers visited Dareton to inspect the Chinese rootstock program on 4 July 2008.

Dr Graham Barry (16 April 2008)
Dr Graham Barry from the University of Stellenbosch, South Africa visited the rootstock program on 16 April 2008 at Dareton.

International group's visit to Dareton (May 2007)
An international delegation and a policy advisory committee from ACIAR visited ARAS, Dareton and CSIRO, Merbein, during May, 2007. The group took a keen interest in the rootstock work being carried out in Australia.

5.5 Future Planned Activities:

- Papers from the Chinese rootstock trials will be presented at the 29th International Horticultural Congress at Brisbane, 17-22 August 2013.

- Visit to Valencia Spain and University of Florida to collaborate with the rootstock groups and visit the growers orchard and interact with citrus industry – 2014

- Import Spanish rootstocks for inclusion in the new HAL project (Proposal submitted – HAL CT 14004)

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5.7 Acknowledgements

During the course of the research reported here a number of staff members participated in trial establishment, field data collection, harvest and fruit grading, fruit quality assessments and extension of the preliminary results.

The following are duly acknowledged for their inputs and without their help; the research goals could not have been achieved.

Research staff
Mr Graeme Sanderson has been helpful in his timely suggestions and discussions during the course of this project.

Farm and technical staff

Jane Khurshid was involved in tree growth measurements, harvesting, grading and assessing fruit quality since 2007. Jane managed the trials, organised and collected the tree growth data and full quality analysis. Jane also organised and managed the full harvest programs for the last 7 seasons. This involved organising harvesting, transfer to packing shed, grading the data and despatch to packing sheds.

A hearty thanks is also extended to Doug Carmin (Lead Farm Hand) at the Dareton Research Institute. Doug was actively involved in maintaining the trials and provided logistic assistance. Doug took the responsibility to arrange the full harvest program for the 16 rootstock trials. Doug was also involved in pruning, fertilising, and irrigating and harvesting the trials. Doug also communicated with the local packing shed and harvested the trials accordingly to secure premium prices for the crop. I am also thankful to other farm staff Brad Bowes, Darren Howard and Glen Henderson who were equally involved in looking after the trial. They harvested the trials in a scientific manner each season.

I am also thankful to Troy Witte (Technical Officer, research) for assisting in operating grading machine and his timely assistance, wherever I needed him.

During the course of the experimental program a number of technical staff assisted in data collection and harvesting and maintaining trees including Jessica Forsyth, Jenny Watts, Annette, John, Anna Treeby, Rebecca Davey, Fred Bacon.

Shona Duffield and Suzie Cox (CSIRO) collected, prepared and analysed leaf samples for chloride concentrations. They, along with Bill Lewis (CSIRO retired) also propagated the trees planted in the trials within modules 1, 2, 3 and 4.

Extension staff
Thanks are extended to Mr Andrew Creek (ex NSW DPI, Griffith), Mr Kevin Lacey (TO, WA), Bronwyn Walsh (IDO, WA), Gavin Foord (IDO, WA), Kym Thiel (IDO, SA), Mary Cannard (MVCB IDO, Sunraysia) for their assistance in organising field days and CITTgroup meetings where results from the project were presented. Thanks are also extended to citrus growers in NSW, Victoria, SA and WA for making their properties available for CITTgroup meetings and field presentation.