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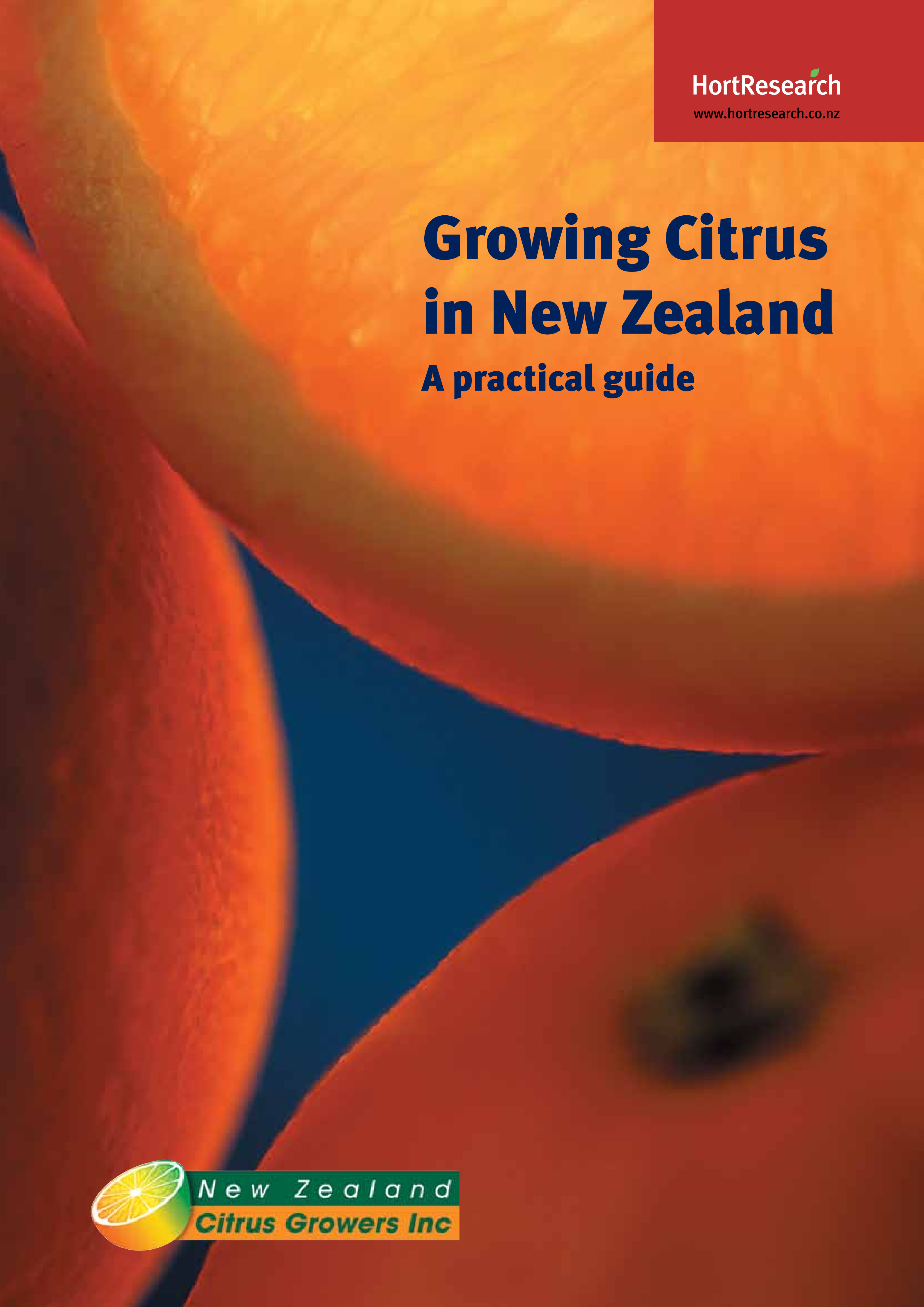
Growing Citrus in New Zealand

A practical guide



New Zealand Citrus Growers Inc

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Growing Citrus in New Zealand

A practical guide

Edited by Pauline Mooney

HortResearch

New Zealand Citrus Growers Inc

Contents

Foreword

It is with great pleasure that I introduce the revised New Zealand Citrus Manual. In these times of expanding export markets it is necessary to have such a valuable manual on citrus production.

The standards required by these markets as well as a more demanding domestic market have required growers to produce higher quality fruit.

This manual written by New Zealand experts for local conditions is an essential part of all serious orchardists libraries'. The information it contains is very important for existing and new growers alike.

Mike Willis

Chairman

New Zealand Citrus Growers Incorporated.

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Introduction

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Introduction

Richard Curtis

Since the First Edition of Growing Citrus in New Zealand was published the trend of increased planting of cultivars with export potential has continued.

Satsuma mandarin production has increased dramatically especially in Northland where mandarins are now being grown on the light sandy soils of the Houhora Peninsula in an attempt to increase early production. The successful trialing and the subsequent introduction of C-35 rootstock, which has given a dramatic increase in yield, have graphically illustrated the value of research and development.

Likewise New Zealand's premium export lemon the 'Yen Ben' has continued to increase in popularity and a strong market has developed for this product in Japan and Korea. 'Yen Ben' lemons are also being sold successfully in Australia in the summer months, a real coal to Newcastle story.

Navel orange production has centred in Poverty Bay and with a move by growers to increase external quality a strong niche market is being developed for this product in Japan and Korea. This export market development has increased grower returns as local market prices have lifted with increased quality and a decrease in fruit available.

All of these trends have led to an increasing realisation among growers that there are climatic differences between citrus growing regions and to maximise orchard gate returns growers must take this factor into account when making planting decisions.

The successful introduction of the *Thripobius semiluteus* wasp to predate on greenhouse thrips is an excellent example of the cooperation possible between different product groups and is the first significant step into the world of integrated pest management for the citrus industry. I suspect it will not be the last time that we will be required to find the funds to carry out this type of work as the worldwide reduction in chemical use continues.

In 1998, NZCGI went back to our growers to update research priorities and refocus the citrus industry on the future. As a result of a series of workshops in the three main growing regions a strategic plan was produced and it is this document that provides executive members with direction for future research and development.

The last fifteen years have seen huge changes in the New Zealand citrus industry and rationalisation and change will mark our future. There are things happening in our overseas markets that will have great impact on the way we carry out our business and to continue to be successful we must be alert to the dangers and the opportunities that these changes present.

The New Zealand Citrus Industry

Pat Sale

Scale of production

There are almost 2,000 hectares of commercial citrus orchards in New Zealand. Roughly, Northland, Bay of Plenty, and Gisborne are each 30% of this total, Auckland is 7-8%, and Hawke's Bay, Taranaki, Waikato, and Nelson are the remaining 2-3%.

The commercial production of citrus in New Zealand ranges between 25,000 and 35,000 tonnes a year. With world citrus production approximately 60 million tonnes, New Zealand's contribution to global production is less than 0.05%. On a world scale, therefore, New Zealand is a very small part of the citrus industry.

The annual value of citrus production in New Zealand is usually around $34 million. Export value in 2000 was $9.3 million, thus accounting for 27% of the industry value.

History

New Zealand has been growing citrus commercially for well over 100 years. It was probably first introduced from New South Wales, Australia, as initially the British Crown Colony of New Zealand was governed from New South Wales. The Poorman orange, now known as the New Zealand grapefruit, was bearing fruit on Kawau Island in 1856, so it was probably introduced at least five years earlier. The Washington Navel orange was introduced and planted at Hairini, Tauranga, in the early 1880's.

GE Alderton, author of 'Treatise and Handbook of Orange-Culture in Auckland, New Zealand' said in 1884 that areas suitable for citrus growing lay between Napier and Mangonui, but the best of them were north of Auckland.

Commercial citrus growing developed in Northland, around Auckland city, and in the western Bay of Plenty in the early years of New Zealand's European settlement. Later, Gisborne became a citrus area of significance. The importance of Auckland as a citrus-producing district has declined, mainly due to the rapid urban expansion.

From the end of World War II until the 1980's severe import restrictions protected the New Zealand citrus industry. A Citrus Marketing Authority had the power to compulsorily acquire all oranges and lemons, except lots of two cases or less when sold direct to the consumer. Both the Citrus Marketing Authority and the stringent restrictions on imports have now been eliminated, and the industry stands on its own to compete with imports and develop its own market opportunities.

Climate and soils

Citrus originated in the tropics but has been commercially exploited most successfully in the subtropics. Northern New Zealand is only marginally subtropical, and is thus only marginal for citrus growing. This limits production to those citrus varieties suitable for cooler climates.

New Zealand is a comparatively small land area surrounded by vast areas of ocean which results in a cool maritime climate. The main limitation imposed by this climate is a lack of summer heat, but on the other hand, New Zealand does not experience the severe frosts, which has a devastating effect in some of the major citrus growing areas of the world, such as Florida and California.

Accumulated summer heat has a vital impact on fruit quality, affecting sugar levels and skin thickness.

A typical Mediterranean climate, that has proved to be very suitable for many citrus varieties, has a long, hot, dry summer with a significantly cooler winter, when virtually all the rainfall occurs. Northland has a small but important average temperature advantage over the Bay of Plenty and Gisborne, but Gisborne usually has very good summer temperatures. The Bay of Plenty soil, however, is far better for citrus than the soils of the other two major districts. To overcome the general climatic limitations for citrus production, choice of site, choice of varieties, and the best cultural practices are all essential.

Industry organisation

New Zealand Citrus Growers Incorporated is the national citrus growers' organisation with a committee elected by the citrus growers of New Zealand. Membership is on an individual basis. The Annual General Meeting is the forum for discussing industry matters and has descended from the New Zealand Fruitgrowers Federation Citrus Conference. The Annual General Meeting is where motions are discussed and vital decisions are made.

On issues affecting fruit growing generally, New Zealand Citrus Growers Incorporated acts in conjunction with the other growers' organisations through the New Zealand Fruitgrowers Federation. In like manner, the New Zealand Fruitgrowers Federation acts in conjunction with Federated Farmers and other land user groups on issues that affect the whole primary production and rural sector.

Research for the future

Historically, very little research has been carried out on citrus in New Zealand. In 1983, however, an industry strategic planning document was published. In 1985, a detailed research strategy and priorities were formulated and published, convincing research organisations that the industry had its act together, and was worth supporting. This has led to the development of a significant team by HortResearch for citrus research based at the Kerikeri Research Centre which services the whole of the New Zealand citrus industry.

The strategy and priorities formulated in the 1985 research strategic plan were designed to overcome the natural and imposed constraints facing the industry such as climate and quarantine issues. With the aim of producing citrus to export standard (in order to compete with imported citrus and to develop export opportunities), these strategies fell into three broad areas: variety improvement, better cultural practices, and fruit-handling procedures suitable for export-quality fruit. Interestingly, these research aims are still current.

The industry recognises it must be forward-thinking and innovative to maintain itself in a competitive situation on the local and export markets. The search for improved varieties and cultural practices to meet the demands of the marketplace has already begun. The future of the industry will require strategic planning, research and development, and market research.

With a limited local market size and pressure from imports, the New Zealand citrus industry must continue to expand its export market opportunities if the industry is to continue to grow.

Growing Citrus in New Zealand

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Section 1.

Varieties and Rootstocks

New Zealand Citrus Growers Incorporated

ISBN 0-478-06829-8

Disclaimer

The New Zealand Citrus Growers Incorporated and the authors have taken reasonable steps and exercised skill, care and diligence in producing this publication to meet the needs of the growers and the market. However, there is no implicit or expressed warranty that the information is free from error or omission and the advice given in the publication is at the user's risk. Similarly, no specific endorsement for any of the branded products mentioned by our advertisers is implied, and no responsibility will be accepted for any crop loss caused by the use of any chemical mentioned.

Readers are reminded that this Manual was published in 2001 and has not been updated since that time. Some information included in the manual may be out of date and readers are strongly advised to obtain current advice from a consultant.

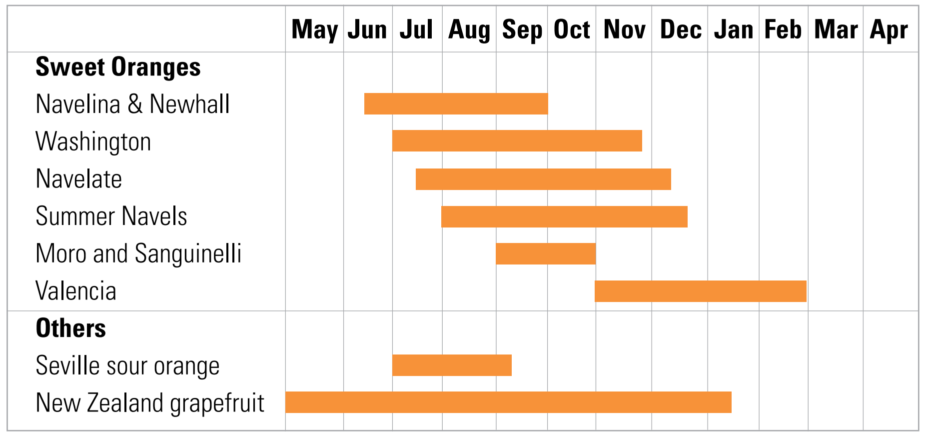
1.1 Orange and grapefruit cultivars

Alastair Currie & Peter Anderson

Oranges

Orange cultivars grown in New Zealand can be placed in four categories: Navel oranges, common oranges, pigmented oranges, and bitter oranges.

Table 1.1.1 Maturity times for sweet oranges, sour oranges and grapefruit varieties



Navel oranges

Navel oranges have a distinctive 'Navel', which is a small secondary fruit embedded in the apex of the primary fruit. Seedlessness is a feature of Navel oranges, which is due to dysfunctional pollen and rare viable ovules. They require less heat to attain optimum quality than most other oranges and dessert citrus, and are therefore well adapted to the cooler citrus-growing areas of the subtropics, including New Zealand. Navel orange fruit have a deep orange skin colour when fully mature. The flesh too, is a deep orange colour, with a good firm texture and moderate juice content. Navel oranges grown in New Zealand do not peel readily.

The season for Navel oranges in New Zealand can range from mid-July until November, with some strains, such as the Australian summer Navels, able to be hung on the tree until January.

Although Navel oranges yield less juice than most other oranges, it is primarily the development of bitterness in the juice during storage, due to limonin, that makes them unsuitable for processing. The bitterness in Navel orange juice becomes evident only when the fruit is juiced and limonin is released from other closely related compounds, unlike the bitterness in grapefruit caused by the compound naringin. Although Navel orange juice contains only extremely low levels of limonin, it is a very bitter compound that most people can easily detect. Limonin content in late maturing Navels drops sufficiently that the summer Navels have been used for juice overseas.

The **Washington Navel** has been the major commercial strain throughout the world, imported to the USA in the late 1800s and introduced into New Zealand soon after. It has large fruit of good quality and has, over the years, been the source of many other strains. **Parent Navel** is the name given to a virus-free source of Washington and distributed through the New Zealand Budwood Scheme. The different name was given to differentiate it from possibly infected source trees of Washington. It is a moderately vigorous tree for a Navel, producing good-sized fruit of good quality. The fruit can hang well on the tree until late in the season. The harvest season is from mid-July to late October.

Navelina and **Newhall** are sports of Washington that are reported to mature two weeks earlier overseas. Early results from the Navel cultivar trial at Kerikeri Research Centre show that compared to Parent Navel, Newhall and Navelina produced fruit with a more elongated shape (round to oval) than Parent, which is more acceptable to the market than the flatter shape of Parent Navel in New Zealand. Navelina and Newhall also produced a larger tree (nearly 40% bigger) with darker green foliage, higher yields and yield efficiency, a deeper orange rind colour, comparable fruit size and higher Brix and Brix:acid ratio.

Cara Cara is thought to be a sport of Washington. The pinkish-orange pigmented flesh is due to lycopenes as with pink-fleshed grapefruit, rather than the anthocyanins of true blood oranges. Hence the colour is most intense at the beginning of the season. Cara Cara has slightly lower acid than Washington and so can be harvested early to maximise colour. At Kerikeri Research Centre young trees of Cara Cara had deep orange coloured flesh and good fruit size. Colour intensity may intensify with tree age.

The **Johnson's Navel** is a selection of Washington imported from Australia by Gordon Johnson, a Kerikeri orchardist, in the 1940s. It has large fruit and good juice content. The harvest season is from July to September.

Navelate is a late maturing Navel that is reported to mature three weeks later than Parent and hang on the tree for three to four months (until November in New Zealand) with no loss of quality. Early results from the Kerikeri Research Centre trial show that compared to Parent, Navelate produces a slightly larger tree with similar yield efficiency, fruit are more oval, paler coloured with similar internal fruit quality.

Summer Navels originate from Australia and mature in August but hanging well on the tree until December. Several varieties are available in New Zealand including **Autumn Gold®**, **Barnfield®**, **Powell**, and **Summer Gold®**. A trial at Kerikeri Research Centre compared these four summer Navels to Parent Navel and although it is too soon to present data, to date the summer Navels have cropped well, had large fruit size and good quality into December.

Common oranges

Common oranges form a large and diverse group, with a wide range of tree-growth and fruit-quality characteristics.

Valencia (synonym: Valencia Late) forms a vigorous tree that produces good yields of moderate sized fruit. In New Zealand, obtaining an adequate fruit size can often be a problem. Fruit are oval and are not always well coloured. They are a late-season orange, harvested from November onwards, and tend to suffer from re-greening in the hot conditions close to harvest. They have a high juice content and hang well on the tree without drying out, especially when grown on trifoliata rootstock.

Harward Late originated in New Zealand as a Valencia seedling. The fruit is virtually indistinguishable from a Valencia, and has become the only important strain of Valencia in New Zealand where it must be grown on trifoliata rootstock for best results.

Blood oranges

Although most of the blood orange strains appear to have originated in the Mediterranean region, pigmented or blood oranges, like Navel oranges, may be indigenous to China. Red pigments can be found in the flesh and juice and sometimes on the rind.

Red pigments (anthocyanins) develop only when there are low night temperatures and it is not until winter that the fruit develops red colour. As a consequence, blood oranges seldom develop any degree of pigmentation in tropical and semi-tropical climates, although fruit may develop the slightest number of blood flecks in the flesh when cold stored. The degree of pigmentation of both the rind and flesh can vary markedly. Shaded fruit on the tree usually have better colour development on the rind. Flesh pigmentation is commonly restricted to the flesh immediately adjacent to the segment walls. Pigments in red and pink grapefruit are lycopene and carotene and are not due to anthocyanins as they are in blood oranges. The climatic conditions required for good colour development of pigmented grapefruit are high temperatures during fruit growth whereas blood oranges need chilling as a prerequisite.

The blood orange cultivars currently available in New Zealand are:

Sanguinelli trees are of a medium size, semi-vigorous, thornless and productive. The fruit is often small and difficult to peel. Trees have a biennial-bearing tendency and poor flavour compared with the Navel orange. The harvest season is from September to November.

Ruby Blood trees are similar in vigour and productivity to Sanguinelli. The fruit is small with an erratic red blush to the skin. Trees can be alternate bearing and the fruit seedy. The harvest season is from September to November.

Moro has recently been imported by HortResearch. From overseas reports the tree is reported to have medium vigour and size, spreading habit and be very productive. Fruit are medium to medium-large, with variable shape and few seeds. Rind is medium thick, moderately adherent and somewhat pebbled, and orange-coloured at maturity with a light pink blush or red streaks at advanced maturity. Flesh can be deeply pigmented (almost violet-red) but colouring can vary; it is juicy; and the flavour is pleasant. Moro has a similar maturity period to Sanguinelli and is reported to hold well on the tree, store and ship well.

Tarocco has also been recently imported by HortResearch. Tarocco is reported overseas to be a medium sized, somewhat irregular shaped tree that is only moderately productive. Thorniness is often a feature of most Tarocco selections. Delayed incompatibility after 25 years or more has been found on trifoliata rootstock. The fruit has a neck, an orange coloured pebbly rind that is easily peeled, tender juicy flesh and high quality flavour.

Sour or bitter oranges

Sour or bitter oranges are named because their juice is both acidic and bitter. Sour orange flowers are used in the perfume industry and the trees are planted in parks and along streets to show off the abundant fragrant blooms and deep orange fruit.

Seville sour orange are vigorous, thornless and productive trees. Used as ornamentals, rootstocks or for marmalade. The fruit are far too acid and bitter to be eaten fresh but are prized for marmalade production. The fruit are very seedy. They are harvested from July to September.

Chinotto is slow growing, with small, pointed, densely arranged leaves, similar to a Myrtle and bears many small orange fruit. Chinotto makes an ideal small specimen tree for the patio. Fruit are bitter and acidic but have been used in marmalade and glacé fruit.

Grapefruit

Strains of the true grapefruit *Citrus paradisi* generally cannot be grown satisfactorily in New Zealand as the heat needed is too high. A red-fleshed true grapefruit, Star Ruby is due for release 2002 but must be considered experimental and should be planted only in the warmest microclimates. The two grapefruit-like types we grow here, which are thought to be pummelo-mandarin hybrids (i.e. tangelos), are the New Zealand grapefruit (Goldfruit) and Wheeny.

Star ruby

Star Ruby is a pigmented true grapefruit. True grapefruit produce fruit of best quality under semi-tropical conditions but are also grown successfully in cooler Mediterranean climates. Overseas, Star Ruby has the most deeply coloured flesh of the pigmented types and also a blush on the rind. At Kerikeri Star Ruby has developed good pink flesh colouring, but juice acidity has remained high (1.7-1.9% and Brix:acid ratio of approx. 6.8). Fruit had a low seed number (up to five seed per fruit) despite ample opportunity for cross-pollination. Most of the fruit were harvested from inside the canopy and fruit sized ranged from 160 g-450 g. Star Ruby could be considered for experimental plantings in Gisborne.

New Zealand grapefruit

The New Zealand grapefruit was introduced into New Zealand from Australia by Sir George Grey in 1855 and was originally known as Poorman orange because of its slightly bitter flavour but heavy fruiting qualities. In the 1920's the name New Zealand grapefruit was given to thin-skinned, high-quality strains of Poorman orange. In 1981, the name New Zealand 'Goldfruit' was used in an endeavour to give the fruit a new image on export markets. This fruit is well suited to the New Zealand climate because it needs only low heat units. It is by far the most important of the grapefruit types in commercial orchards in New Zealand.

The tree is vigorous and large, producing good yields of medium-large fruit with a yellow skin and orange-yellow flesh. The skin tends to be thick but the fruit has a light juice yield. The best fruit quality is obtained from trees grown on trifoliata rootstock.

The fruit is seedy when cross pollinated, particularly with Wheeny grapefruit, Meyer lemons, Seminole tangelos, or Clementine mandarin, but when grown in blocks on its own, can be almost seedless. The New Zealand grapefruit has a tendency toward biennial bearing. It is a versatile fruit with a long season that can stretch from May to January, with the very early fruit sometimes used for marmalade.

An early selection of New Zealand grapefruit was **Morrison's Seedless** that became the dominant selection for many years. In more recent times, a particularly good selection from a commercial orchard in Tauranga became known as **Golden Special**, and most commercial planting since 1980 has been of this selection. In the 1970s the **Cutler Red** strain was selected in Kerikeri. It has a very deep orange coloured rind, but in other respects is identical to Golden Special. Fruits can be very seedy, especially when the tree is planted close to a strong polliniser. Harvest season is from October to December.

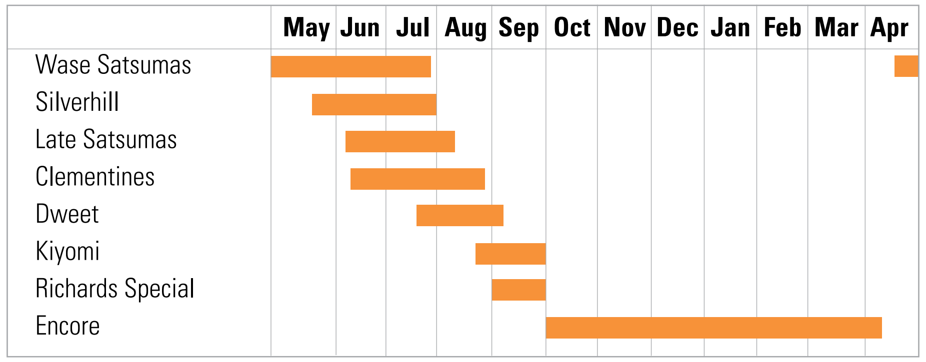
1.2 Mandarins, tangelos, and tangors

Alastair Currie and Andrew Harty

Mandarins

Easy-peel convenience makes the mandarin the most attractive dessert citrus to consumers. The range of mandarin cultivars now available in New Zealand can provide an almost year-round supply of these high-value fruit starting with early Satsumas in mid April through to the end of Encore in early April (Table 1.2.1).

Table 1.2.1 Typical harvest times for mandarin cultivars



Satsumas

This large group of mandarins originated in Japan and is the major export mandarin grown in New Zealand. Satsumas have many attractive commercial features: a spread of maturity times from early to mid-season, seedlessness, very easy peeling rind, moderate to low tree vigour, and good disease resistance. On the downside, the flavour of Satsumas is not intense, and under cool coastal conditions alternate bearing is a serious problem. The fruit becomes excessively puffy if held on the tree, especially under wet conditions.

With good management, these production problems can be overcome. Large, blemish-free fruit can be produced with careful fruit thinning and with a well-timed disease spray programme. The low internal quality of Satsumas, in particular of the early or wase types, can be improved with reflective mulches and careful choice of rootstock.

Several distinct groups of Satsumas exist: *goko wase* (very early), *wase* (early), mid-season and late cultivars. This grouping is based on how these cultivars perform in Japan, and has led to some confusion here because, under particular microclimatic conditions and on older trees, fruit of the mid-season cultivar Silverhill can often be internally mature at the same time as, or even before, the wase cultivars within the same district This phenomenon means that internal quality of Satsumas should always be checked with a Brix:acid maturity test before harvesting starts; external rind colour is not a good indicator of internal quality (see the chapter on Maturity Testing).

Goko wase cultivars are said to be 2-3 weeks earlier than the wase cultivars. No *goko wase* Satsumas have been imported into New Zealand. Although early to colour, these cultivars are reported in Japan to have much poorer internal quality than wase cultivars.

The wase cultivars **Miyagawa, Miho** and **Okitsu** have been extensively planted in the past few years, especially in Northland, and the majority of the crop is exported to Japan. Of these three, Miho is the preferred choice because acceptable internal quality is achieved earlier. In Japan, the external appearance of the wase types is preferred to that of mid-season or late cultivars.

Silverhill has been grown for many decades in New Zealand. The fruit have been successfully exported to Japan in small quantities. Internal quality has not posed a problem later in the season. Thinning is required to achieve good fruit size, to improve the external appearance and to increase storage ability.

Dobashi Beni is a newly introduced mid season Satsuma harvested at a similar time to Silverhill but has a deeper orange rind colour. It is not yet widely grown in New Zealand.

Kawano produces a distinctly larger tree than other Satsumas, although the fruit is virtually indistinguishable from other mid-season cultivars. Kawano is the most proven mid to late season Satsuma cultivar to date and is recommended as a variety for Gisborne. It is a vigorous tree that produces big crops of good quality fruit, which receive good returns because of the July - August maturity. It is prone to alternate bearing if not thinned.

In Japan, **Aoshima** is reported to produce very high internal quality. Aoshima planted in Gisborne, aged 7-8 years, are vigorous with fruit maturing July - early August. Although the fruit is rather coarse, flat, large and bland, quality should improve with age and so Aoshima remains an interesting option.

Satsumas are low-vigour trees when grown on *Poncirus trifoliata* (or 'tri'), so a planting density of 4 x 2 m is recommended, except for the more vigorous Kawano, which could benefit from the wider row spacing of 5 m. None of the cultivars produces viable pollen, so all can act as buffers between seedy cultivars and pollinisers.

Clementines

Clementine mandarins are prized for their excellent eating quality, and the deep-orange rind colour adds to their visual appeal. Although Clementine mandarins are extensively grown throughout the world, our primary export market, Japan, does not value Clementines and the domestic market is limited. This demonstrates that growing a high quality cultivar is only part of the picture when choosing cultivars to plant. It is also essential to check the marketing situation.

In a trial of 22 Clementine varieties, HortResearch found **Corsica N°. 2** was the best cultivar. Clementine mandarins have to be managed carefully to ensure good fruit size, limit alternate bearing, and control fruit blemishing by the fungal disease verrucosis (citrus scab). Clementine mandarins should not be planted close to polliniser cultivars such as grapefruit, tangelos, Encore and Richards Special mandarins. A buffer planting of Satsuma mandarins or Navel oranges will prevent the Clementine fruit from becoming seedy.

Table 1.2.2 Disease susceptibility of mandarin cultivars (based on field observations)

	Verrucosis	*Botrytis*	*Melanose*	*Alternaria*
Satsumas	1*	1	1	0
Clementines	3	0	1	0
Richards Special	0	0	1	0
Encore	0	3	1	0

**0 = resistant; 1 = mild; 2 = moderate; 3 = severe susceptibility*

Richards Special

Richards Special is an old Queensland seedling selection which has been recommended for planting in the past. Richards Special fruit are easy-peel, have large fruit size, excellent eating quality, store well and have been well received in Japan.

They fill a gap in the season where no other commercial mandarins have been available. However, problems with irregular and biennial cropping and other production difficulties have limited the value of Richards Special as a commercial cultivar to date. Ongoing research may rectify the situation.

Table 1.2.3 Recommended tree spacing for mandarins on trifoliata rootstock

	Metres between and within rows	Number of trees/hectare
Kawano	5 x 2 m	1000
Other Satsumas	4-4.5 x 2 m	1111-1250
Clementines	5 x 3 m	666
Encore	5 x 3 m	666

Encore

This unique cultivar is a true summer mandarin. The fruit can be harvested from October to February and can be stored until April without loss of flavour or juiciness. It was bred in California and released in 1965. The fruit are medium-sized, with a very thin but peelable rind. Their flavour is excellent, and the seed number is not excessive (up to six per fruit).

The long hanging period on the tree unfortunately comes at a cost to the fruit's appearance and to the tree. The rind of Encore is quite sensitive, and after 12 to 18 months on the tree, blemish from pests, disease, hail, windrub and 'Encore spot' is hard to avoid. A degree of regreening is common in the rind over summer.

Alternate bearing is also severe because of overlapping crops competing on the tree. Encore is also our most vigorous mandarin cultivar and tree size control is a problem. Fruit thinning and pruning are two techniques that could solve some of these inherent problems.

Other cultivars

Kiyomi tangor

Kiyomi tangor is a Miyagawa Satsuma mandarin X Trovita orange cross from Japan. At Kerikeri Research Centre the fruit are large (diameter 7-10 cm), orange-like, and the shape is flat and slightly pyriform. The rind is moderately thick, and moderately easy to peel (with storage the peel becomes thinner, more leathery and easy to peel). Flesh is tender, melting, very juicy with a mild Satsuma flavour. Fruit matures late August to September achieving a Brix between 9-10, and titratable acids were 0.7-0.9%. Fruit are seedless when self pollinated and seeded when planted with pollinisers. There are as yet no commercial plantings in New Zealand.

Seminole tangelo

Seminole was imported to New Zealand by Dr. Harold Mouat of DSIR and made a big impact on the New Zealand citrus scene when it was promoted in the late 1950s. The tree crops well and bears extremely juicy fruit with an excellent flavour. Harvest period ranges from September to December. Used mainly for juice production, the fresh fruit has a following on the local market, and small quantities have also been exported. Seminole has two major faults: it is not easy to peel and the flesh is very tender, making it messy to eat; it is also very susceptible to Alternaria brown spot. In wetter districts, this disease has led to removal of Seminole plantings, and most of the plantings are now in the drier Gisborne district.

The trees are vigorous and bear heavily and are biennial. It is a popular home garden variety. Of all citrus cultivars grown in New Zealand, Seminole is probably the least susceptible to infestation by lemon tree borer.

Conclusion

The perfect mandarin cultivar has yet to be selected. All those described here have their specific faults, but generally these can be overcome by special management practices. This is perhaps the common denominator for mandarin cultivars: successful production requires more management input. This in turn is rewarded by much higher returns than for other dessert citrus types (oranges, tangelos, and grapefruit). However, successful production is just half the battle. The fortunes of a cultivar can change rapidly with changing market conditions, so before choosing the cultivars to grow check which cultivars can sell.

1.3 Lemons and limes

Alastair Currie and Andrew Harty

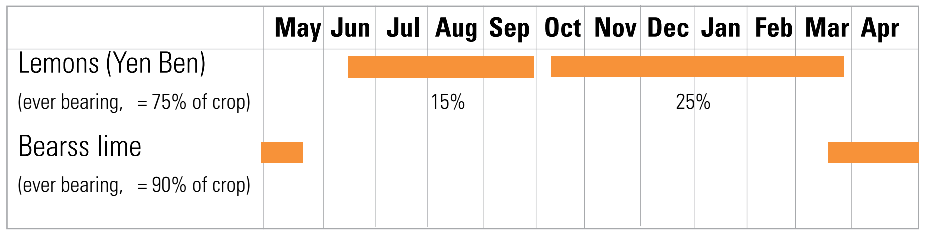
Introduction

Lemons and limes belong to the citrus group known as acid citrus. This group differs from other dessert citrus in several ways. The fruit is prized for its citric acid content rather than its sugar content, so the fruit is primarily used for culinary purposes rather than eating fresh.

Unlike other citrus types, lemons and limes flower several times a season. This means that acid citrus typically have several crops of different ages on the tree at the same time and are harvested several times during the season.

It is common in many countries to 'cure' lemon fruit after harvest. This involves storing the fruit under humid, warm conditions for several weeks, and results in a thinner, more resilient rind. Juice content relates directly to the rind thickness and is the main international quality standard for lemons.

The main lemon crop in New Zealand is picked in winter (June - Sept), with smaller crops in spring and late summer. For export purposes, lemons are picked when still partially green but starting to colour (silver-green). Small fruit are often left to grow larger. The local market is very lucrative in summer, but during the winter when lemons are over-supplied domestically the crop is exported to Southeast Asian countries, as their supplies from northern hemisphere producers are limited at that time.



Lemon cultivars

The main commercial lemon cultivars fall into two broad groups: the Eureka group, which consists of Villafranca, Genoa, and Eureka selections; and the Lisbon group, which includes Yen Ben and many different clones and nucellar selections.

Two important horticultural differences distinguish these two groups: (a) all the Lisbon selections are relatively thorny whereas the Eureka group is virtually thornless; (b) only the Lisbon selections have good compatibility with *Poncirus trifoliata* (or 'trifoliata') and trifoliata hybrid rootstocks.

The main true lemon cultivars grown in New Zealand are:

Yen Ben

Yen Ben is a sport of Lisbon selected by Walter Benham in the late 1930s in Queensland. Although no longer produced in Australia, the high-quality fruit attracted the interest of New Zealand researchers in the mid-1970s, and large numbers of trees were subsequently propagated by nurseries.

In trials at Kerikeri Research Centre comparing six lemon varieties (Villafranca, Genoa, Frost Nucellar Eureka, Prior Lisbon, Monroe Nucellar and Yen Ben), Yen Ben was found to be superior in terms of juice content, rind thickness, lower seed number and higher yield.

Yen Ben has since become the cultivar of choice for export plantings. The attractive appearance and high juice content of the fruit have been well received on the Japanese market.

Yen Ben appears to be reasonably compatible with trifoliata, and produces precocious trees with smaller canopies on this rootstock. The main cultural problem encountered is excessive fruit set, resulting in small fruit.

A rootstock trial at Kerikeri Research Centre showed Yen Ben to be slightly incompatible with Troyer Citrange and Cleopatra Mandarine and moderately to severely incompatible with RangpurXTroyer, Swingle Citrumelo and C-35 citrange. Yen Ben performed well on Benton citrange, Brazilian sour orange, Sweet orange and Trifoliata.

Villafranca

Originating in Sicily, this cultivar was introduced into Florida and California in 1875, and from there into New Zealand in the 1890s. Until the advent of Yen Ben it was New Zealand's predominant lemon cultivar but had a reputation for producing thick-rinded fruit. Trees of Villafranca are typically grown on sweet orange rootstock because of incompatibility problems when grown on trifoliata rootstock. Villafranca trees are typically very vigorous, and this excessive growth is difficult to manage. Many lines of Villafranca in New Zealand are also infected with exocortis viroid, and severe bark scaling can be seen on the rootstock trunk where trifoliata has been inadvertently used.

Genoa

Introduced into California in 1875 from Genoa, Italy, and then into New Zealand via Australia in 1919. Genoa has never been widely planted here but has attracted some attention because an exocortis viroid-free budline is compatible with trifoliata rootstock. Genoa on trifoliata rootstock produced thinner rinds than Genoa on Sweet orange rootstock. Tree growth is similar to that of Villafranca and yields are good.

Minor lemon cultivars

Verna and Fino

Verna and Fino (N°. 49) are recently introduced Spanish cultivars. Neither have fruit as attractive as Yen Ben. Verna fruit mature much later than other lemon cultivars, but thick rind and protruding necks have been unattractive features observed thus far. Fino fruit have a similar appearance to Eureka, but have proved quite seedy. A less seedy selection of Fino (N°. 95) has reportedly been selected in Spain.

Lisbon

Lisbon is not grown commercially in New Zealand to any extent, although it is an important cultivar internationally. Of the Lisbon selections evaluated at Kerikeri Research Centre, none outperformed Yen Ben (which is presumed to be a Lisbon seedling selection).

Variegated Pink Eureka

Variegated Pink Eureka has been recently introduced from California. The variegated foliage makes this an attractive ornamental cultivar. Fruit is striped green, fading with maturity and the rind sometimes has a pink flush. The interior flesh is light pink. This variety could have potential as an ornamental or for home gardens.

Lemon hybrids

Two lemon hybrids are produced in New Zealand, the Meyer and Lemonade. Neither is considered a true lemon.

Meyer

Meyer is probably a hybrid between a lemon and an orange, or a lemon and a mandarin. The fruit is quite different from that of true lemons. It is thin skinned and juicy, and the smooth rind is bright yellow, darkening to orange-yellow as the fruit ripens on the tree. The juice has a distinct floral fragrance and does not have the acid content found in true lemons. The rind lacks the typical lemon-peel aroma and is not suitable for lemon oil production.

The tree is moderately vigorous, small to medium in size, spreading, nearly thornless, hardy, productive. Flowers and new shoots are purple-tinted. Meyer is more or less ever-flowering but mainly in spring. The trees are compact, especially when propagated as cuttings, and are much more cold hardy than true lemons.

Meyer has been grown commercially in New Zealand for many years, particularly in Gisborne and the Bay of Plenty. Although in many respects Meyer is an easier crop to grow than true lemons, the fruit is unfortunately not well accepted on international markets. It is not of commercial importance internationally because it is too tender and juicy to cure, colour, store and ship without excessive waste. Nevertheless, small volumes have been exported in the past, although these come under pressure when supplies of true lemons are plentiful.

Lemonade

Lemonade is a cultivar of unknown origin, although it may be related to the sweet lemons or sweet limes. The tree is compact, weeping and extremely susceptible to verrucosis (citrus scab). Fruit at maturity in July - August are medium-sized, moderately seedy, and have pale yellow rind and are relatively easy to peel. The unique character of the fruit is that it can be eaten fresh and has a sweet and sprightly flavour. Despite the fruit being popular among children, Lemonade is not produced commercially on any scale in New Zealand.

Lime cultivars

Two main groups of lime are grown commercially around the world: West Indian lime (*Citrus aurantifolia*), also known as Key lime, and Tahiti lime (*Citrus latifolia*), also known as Persian lime. West Indian limes are usually grown only under hot climatic conditions and in regions free of citrus tristeza virus. The need for these conditions prevents commercial production of West Indian lime in New Zealand.

Tahiti lime

Tahiti lime is hardier than the West Indian lime, although still sensitive to frost. Trees are of medium vigour with dark green, compact foliage and few thorns. The fruit are oval and small, with very thin rinds and no seeds. The rind turns from dark green to pale green and, finally, to pale yellow as fruit mature.

Commercially, limes are harvested and marketed when dark to pale green. A yellow colour signifies over-maturity, and if the fruit is left on the tree, a rind collapse occurs at the base of the fruit called stylar-end breakdown. In other countries, gibberellic acid (GA_3) is commonly applied as an orchard spray four to six weeks before harvest to maintain green colour and rind firmness. The main crop matures May - July, and only very small summer crops are set.

Bearss lime

Bearss fruit and tree is similar to Tahiti lime and is believed to be either derived from a Tahiti seedling or to be a synonym for Tahiti. At Kerikeri Research Centre, Bearss has produced larger crops of superior looking fruit than several other selections of Tahiti lime. It appears to be more precocious than other selections, typically bearing crops when trees are two to three years old. Bearss is currently the recommended lime variety for New Zealand.

Tahiti and Bearss lime are both grown on trifoliate rootstock in New Zealand. Unusual bud unions with large bulges above the junction often occur, although trees appear to live and crop steadily for 30 years or more. A rootstock trial to evaluate the performance of 12 different rootstocks with Bearss lime will be completed in 2002.

Other lime types and hybrids

Rangpur lime

Rangpur lime is an acidic mandarin-like cultivar that produces small, orange-coloured fruit. Used as a salt-tolerant rootstock in some countries but does not produce high fruit quality.

Kusaie lime

Kusaie lime is a selection of Rangpur that produces an attractive, small tree with small, pale yellow, seedy fruit.

Eustis limequat

Eustis limequat is a hybrid between lime and kumquat, and has recently been introduced into New Zealand. The fruit is small, round to oval in shape with acidic flavour, and makes an excellent lime substitute in colder areas.

Kaffir lime (*Citrus hystrix*)

Kaffir lime (*Citrus hystrix*) is a frost-tender tree, the leaves of which are highly prized in South-east Asian cuisine. Two selections of Kaffir lime have been introduced into New Zealand and have been popular for the homegarden.

1.4 Rootstocks

Alastair Currie and Andrew Harty

Importance of rootstocks

Fruit quality is influenced by the variety, the rootstock and environment. In this section we look at the selection of the right rootstock. If an army marches on its stomach, then a citrus orchard performs on its rootstock. More than any other decision when planting an orchard, the choice of a good rootstock will ensure sweeter, larger and more storable fruit. The rootstock quietly works at producing more fruit and less wasteful wood, and allows the tree to live longer.

The New Zealand citrus industry is almost entirely dependent on one rootstock - trifoliate orange (*Poncirus trifoliata*), known locally as 'trifoliata' or simply 'tri'. Trifoliata rootstock is resistant to CTV, is cold hardy and produces large yields of high quality fruit in the scion variety. Other rootstocks in use by the industry are C-35, Carrizo and Troyer Citranges; Flying Dragon trifoliata, Sour orange and Sweet orange. Only one cultivar, Meyer lemon, is grown commercially from cuttings.

The rootstock can affect almost every aspect of tree performance, and a priority list of requirements must be checked before making a choice. There are some factors which are essential when choosing a rootstock, and others which are desirable.

Essential factors for New Zealand include: genetic compatibility between the scion and rootstock, tolerance of the stock and scion combination to citrus tristeza virus, and tolerance to *Phytophthora*, nematodes and cold, wet soils.

Desirable rootstock effects include: improved sugar: acid ratios, larger fruit size, thinner rinds, earlier or later fruit maturity, increased or decreased tree vigour, improved yield efficiency, and longer fruit storage-life.

Nurserymen also prefer rootstock varieties that have high seed numbers in their fruit, are highly nucellar and so produce a high percentage of true-to-type seedlings (see the chapter on Propagation), and that grow vigorously and produce non-bushy stems in the nursery.

Compatibility

The scion bud must fuse successfully with the rootstock and form a strong, functional bud union that lasts for the commercial life of the tree. Incompatibility can vary in severity. A well known incompatibility is that between Eureka lemon types, including Villafranca, and trifoliata and many of its hybrid stocks (citranges and citrumelos). Other incompatibilities will become apparent as new cultivars are tested on different stocks - Chironja grapefruit hybrid, for example, is clearly incompatible with trifoliata. Ugli tangor trees on trifoliata do not appear to be completely compatible. Yen Ben lemon on C-35 citrange has also proven to be incompatible.

Virus and viroid tolerance

Citrus tristeza virus (CTV) is an aphid-transmitted disease that occurs throughout New Zealand, and excludes the use of scion and rootstock combinations that are severely affected. One of the world's premier stocks for dessert citrus, sour orange, is not an option for most New Zealand commercial cultivars because of its high susceptibility to CTV. A possible exception is its safe use under lemons, an option HortResearch has tested in a rootstock trial at Kerikeri Research Centre. Most new rootstock selections are now screened for tristeza tolerance in anticipation of the continued spread of the virus around the world.

Trifoliata and its hybrids (citranges and citrumelos) are susceptible to exocortis viroid, and only indexed budwood should be used when propagating on these stocks. The New Zealand Citrus Budwood Scheme provides exocortis-free budwood of all commercial citrus cultivars.

Tolerance to soil pests, pathogens and conditions

Phytophthora root rot and nematodes are common in all our orchards, and suitable stocks must resist or at least tolerate these organisms. Orchard drainage can help reduce wet soil problems, but temporary waterlogging regularly occurs in all citrus growing districts. This combination of soil requirements is best covered by trifoliata and its hybrids.

Tree size and control

The most noticeable effect of a stock on young trees is the rate of growth. Vigorous stocks will form big canopies very quickly, while more dwarfing stocks will slow down the production of vegetative growth. Although trifoliata is rated a semi-dwarfing stock, it will in fact produce trees that eventually get as big as those on vigorous stocks; the time they take to get there is simply longer.

Dwarfing and semi-dwarfing stocks are preferable because they limit tree size, and allow high-density planting. This practice produces very high yields in the early years of orchard life, making capital recovery much quicker. However, when a scion cultivar lacks vigour, a more vigorous stock can be beneficial.

Yield

The amount of fruit produced per tree is less important than the amount per canopy volume. Scion rootstock combinations that produce many fruit per cubic metre of canopy are said to have high yield efficiency. Very often, dwarfing stocks have a higher yield efficiency, with energy being diverted into fruit rather than vegetative growth.

Fruit quality

Trifoliata will typically produce fruit with high soluble solids (Brix), but unfortunately citric acid levels are also high. Where Brix achievement is not a problem, as is the case with most mandarins other than Satsuma, then a stock that produces larger fruit and lower acidity than trifoliate will be of interest. For Satsumas, an improved stock would need to promote similar Brix levels to trifoliata but also reduce the acid levels.

Trifoliata

For most of our commercial cultivars, trifoliata remains the only recommended rootstock. Yen Ben lemon is a member of the Lisbon group of lemon cultivars and appears to be compatible with trifoliata.

The many different strains of trifoliata can be divided into two broad groups - small-flowered and large-flowered. The small-flowered strains (such as Rubidoux or Rich 16-6) produce smaller trees that are more yield-efficient, have a larger fruit size, and are reported overseas to mature fruit somewhat earlier. Large-flowered selections produce larger trees and are easier to grow in the nursery because of their non-bushy habit. Pomeroy is probably the most commonly used large-flowered selection in New Zealand.

A decline of 15-25 year old Navel orange trees has been reported in California when some strains of trifoliata were used as stocks. Although this problem has not been recorded in New Zealand, it is probably safest to use either Rubidoux or Rich 16-6 trifoliata. Both are small-flowered strains that have been relatively unaffected by delayed decline in California. The strain of trifoliata commonly used in Australia called Accession 22 also appears to be a very suitable option.

Flying Dragon trifoliata stock has attracted much interest in other countries, and has been used on a small scale in New Zealand. Many overseas trials indicate that Flying Dragon will substantially dwarf most cultivars without detracting from fruit size. Fruit quality typically equals or surpasses that of trees on trifoliata. Yield efficiency (kilograms of fruit per cubic metre of canopy) is typically very high, which makes this stock an exciting proposition for high density plantings. Unfortunately, Flying Dragon produces many off-type seedlings, and combined with its slow growth and twisted, thorny habit, this makes it an unattractive stock to work with in the nursery. However, with stringent roguing (see chapter on Propagation), uniform populations of nucellar seedlings can be achieved.

Trifoliata hybrids

Although trees on trifoliata produce high quality fruit and tolerate many soil diseases and pests, they also have some shortcomings - small fruit size, high fruit acidity, and incomplete compatibility with some scion cultivars. Many new rootstocks have been developed around the world in the past few decades, in particular a large range of trifoliata hybrids (citranges and citrumelos). Some of these have the potential to improve yields and fruit quality in New Zealand orchards, but like imported scion cultivars, they must first be thoroughly tested under local conditions.

Benton citrange is a hybrid of Ruby Blood orange and trifoliata bred in the late 1940s by the Dept. of Agriculture, New South Wales, Australia. Benton has been used in Australia for Eureka lemons in a replant situation and for Lisbon lemons in California. Benton rootstocks produce good crops of high quality lemons on compact trees of intermediate size. Benton is reported to be resistant to *Phytophthora*. In a trial with Yen Ben lemon at the Kerikeri Research Centre, Benton formed a good union with the scion and produced a tree approx. 20% more vigorous than Rich 16-6. Benton produced the highest total yield and export yield per tree and also had high yield efficiency. Fruit was large but acidity was slightly lower than on Rich 16-6. Rind thickness and juice content were similar to trifoliata.

Benton may not be an easy option for the nurseryman as Benton has few seeds and the seedlings are very branched and spindly.

C-35 citrange was bred by the University of California and released in 1987. C-35 has the same parentage as Benton citrange (Ruby Blood orange and trifoliate orange). It is reported to be tolerant to *Phytophthora* foot and root rot, CTV tolerant, resistant to citrus nematodes, and is frost tolerant. In New Zealand C-35 shows promise as a Satsuma rootstock, producing vigorous trees, high yield efficiency and high Brix. Yen Ben lemons are incompatible with C-35, dying at age five.

Savage citrange was included in a Miyagawa Satsuma rootstock evaluation trial at Kerikeri Research Centre. In this trial Savage produced a vigorous, yield efficient Miyagawa tree with high Brix and Brix:acid ratio. Savage was the best rootstock in the trial overall, out-performing even trifoliata.

Troyer citrange, a Navel orange - trifoliata hybrid, is an important rootstock around the world and was planted experimentally in 1970's in New Zealand. In a Silverhill block in Kerikeri, trees on Troyer have matured fruit externally and internally several weeks earlier than trees of the same age on trifoliata. Troyer also increased tree vigour for Miyagawa but slightly lowered the Brix compared to Trifoliata. Troyer seeds are highly nucellar, and produce excellent straight-stemmed seedlings. Carrizo citrange is a sister hybrid of Troyer citrange, and is very similar in most respects.

Sweet orange

Sweet orange is still the recommended stock for Villafranca lemon, but the recent favouring of Yen Ben lemon over Villafranca for export plantings will mean less use of sweet orange in the future. Where is has been used under dessert citrus cultivars, internal fruit quality has been poor. Its susceptibility to *Phytophthora* is evident in many older Villafranca blocks.

Sour orange

Sour orange was one of the most important rootstocks overseas as it imparted moderate vigour to the tree and gave good yields of high quality fruit. However sour orange is very susceptible to CTV (endemic in New Zealand) so it is only suitable for using with CTV resistant cultivars like lemons. **Brazilian** sour orange was evaluated with Yen Ben lemons at Kerikeri Research Centre and found to compare favourably to trifoliata. Brazilian was slightly more vigorous, and although yield efficiencies were similar, the fruit size was slightly larger. Fruit on Brazilian had similar juice content to Rich 16-6 but, like Benton, had slightly lower acidity.

Rootstock trials

Many new rootstocks have been developed in the past few decades, in particular trifoliata hybrids (citranges and citrumelos). These have the potential to improve yields and fruit quality in New Zealand orchards, but like imported scion cultivars, they must first be thoroughly tested under local conditions. HortResearch at the Kerikeri Research Centre is testing new rootstocks for limes, Satsuma mandarins and oranges. These trials were planted in March 1993, with the aim of identifying stocks that overcome commercial faults in the scion. Results of these trials are published in *The Orchardist*.

Cuttings

Compared with most other fruit types, citrus is unusual in that clonal rootstocks can be achieved from seedlings (see chapter on Propagation), so vegetative propagation of rootstocks is not needed. However, cuttings of most commercial scion cultivars will readily form roots in a mist bed.

Unfortunately, very few scion cultivars form suitable root systems. Many are highly susceptible to *Phytophthora* root rot, while others produce poor-quality fruit. A notable exception is Meyer lemon, which is typically propagated from cuttings. The tree that develops is low branching and semi-dwarfed, making it ideal for the home garden. However, in commercial orchards, a trunk is often advantageous for management purposes and budded Meyer trees are preferable.

Interstocks

An interstock is an additional cultivar sandwiched between the rootstock and the scion. Nurserymen generally do not favour them because of the extra budding step involved, but they can be useful when an incompatible stock and scion need to be bridged. Tangelo and New Zealand grapefruit have both been used as interstocks between Chironja and trifoliata.

Top-working of orchard trees can result in the previous scion becoming the interstock. Although the choice of interstock will almost certainly affect scion performance, very little is known about this subject. In one case monitored in a Kerikeri orchard, young tangelo trees were top-worked to Miyagawa Satsuma. These trees gave significantly lower Brix and lower acid levels than young Miyagawa trees on trifoliata that were inter-planted into the original tangelo block. The Brix:acid ratio was not altered, but fruit off the interstock trees tasted blander.

Inarching

The rootstock of a citrus tree can be changed in situ by a technique called inarching. Seedlings of the new rootstock (two to four per tree) are planted next to the tree trunk, and their tops are grafted into the scion trunk above the original bud union. Once these inarches are firmly established, the original rootstock can be slowly girdled over a number of years by placing a wire girdle below the original bud union. This method of 'bottom working' a citrus planting has been quite commonly used in Mediterranean countries. It has yet to be practised commercially in New Zealand.

Growing Citrus in New Zealand

A practical guide

Section 2.

Propagation and Topworking

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Disclaimer

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Readers are reminded that this Manual was published in 2001 and has not been updated since that time. Some information included in the manual may be out of date and readers are strongly advised to obtain current advice from a consultant.

New Zealand Citrus Growers Inc

2.1 The New Zealand Citrus Budwood Scheme

This chapter is no longer relevant and has been updated by best practice guidelines on the NZCGI website link- http://citrus.co.nz/Nursery_Tree_Guidelines.pdf

2.2 Propagation

Pauline Mooney

Citrus propagation differs from the general techniques used for other fruit trees only in certain details, such as seed germination and careful selection of nucellar rootstock seedlings. The most common method of producing a citrus tree is by budding a scion bud on to a rootstock seedling. In some instances, stick grafting and rooted cuttings are the preferred method of producing a tree. This chapter focuses only on producing a high health superior clonal, true-to-type budded tree.

Rootstock propagation

Seed suppliers

Some local nurseries grow their own rootstock trees for supplying seed, but many obtain their seed from registered overseas suppliers. Good quality citrus rootstock seed may be obtained from either Australian Citrus Propagation Association, NSW, Australia, or from Willits & Newcomb, California, USA. Seed orders to both the USA and Australia must be accompanied by a current New Zealand Ministry of Agriculture and Fisheries Seed Import Permit. Application forms for importation of citrus seeds are obtainable from MAF Quality Management, Auckland. The addresses, telephone and facsimile numbers for these organisations are listed at the end of this chapter.

Seeds that need to be stored should be held in sealed plastic bags or containers at 5-10 ºC. The vegetable crisper section of a domestic refrigerator is suitable.

Poncirus trifoliata (or ' trifoliata') is the main rootstock used in New Zealand, but other options are becoming available (see the chapter on Rootstocks).

Seed germination

Pre-germination of the seeds before pricking out overcomes the problems of seedling competition for light and space, and variations in seedling growth and size at time of budding.

Two alternative pre-germination treatments are as follows:

(a) Space the seeds in a single layer on a plastic tray lined with a paper towel, and cover them with a gauze cloth. Completely wet the seeds and paper to settle the seeds and then drain off the excess fluid. Cover the trays with cling wrap, and place in an oven set at 24 to 26ºC. Water the trays daily, ensuring that excess water is drained off so as to avoid seed rots. The seeds should germinate within two to three days. Daily prick out seeds with emerging roots into root-trainers or seedling beds daily. This will ensure an even seedling size at time of transplanting.

(b) Space the seeds in a groove compressed into a well drained germination bed of moist vermiculite, perlite or sterile sand. Then cover the seed with a layer of approximately 15 mm of the germination bed medium. Germination beds should be kept moist and warm, but not overheated as this can cause seed rots. Germination beds should be shaded in spring and summer to protect the seedlings against sunburn and to encourage them to grow straight and tall. The seeds should begin to germinate within two weeks. When the seedlings are approximately 20 mm high they should be pricked out into root-trainers or seedling beds. When pricking out, any seedlings showing poor root growth, benching or browning should be discarded.

Some rootstock cultivars such as Troyer citrange and trifoliata develop curled or 'benched' roots due to the new roots being restricted by the seed coat. This may result in a restriction of nutrient flow to the developing shoot and therefore poor seedling growth.

The problem is easily overcome by peeling the seeds before pre-germination. Peeling involves carefully removing the straw-coloured, fibrous outer coat of the seed, leaving the delicate papery brown skin intact around the cotyledons. The peeled seeds may be pre-germinated by either of the above methods. Time to germination of a peeled seed is quicker than that of an unpeeled seed.

Importance of seedling roguing

Most plants produce a monoembryonic seed from the fusion of a male (pollen) and female (egg) sexual cell, and this eventually results in the development of a single zygotic seedling developing from a single seed. Citrus, however, has an unusual seed biology in that many citrus cultivar are polyembryonic, i.e., as well as forming a zygotic embryo, they have the ability to form several nucellar embryos that are not derived from sexual fusion within a seed. Therefore polyembryonic citrus cultivars produce multiple seedlings from each seed. The nucellar embryos closely resemble the mother plant in all characteristics. For this reason, nucellar embryos result in seedlings that are remarkably uniform, and they are referred to by nurserymen as being "true-to-type". The zygotic embryos, which have some characteristics of both the male and female parent, are therefore called "off-types".

The degree of polyembryony, and therefore the percentage of zygotic to nucellar seedlings germinating within a seed batch, varies from season to season and can amount to 25% of the total seedling population. The propagation of uniform citrus rootstocks depends upon the production of clonal plants from nucellar seedlings. Uniformity of rootstock genotype is essential for reliable tree performance after budding and orchard establishment. For this reason, zygotic seedlings are highly undesirable and they should be rogued out as off-types.

Seedlings that are markedly larger or smaller than average, or show defects in leaf and petiole shape, should be rogued out as they are probably zygotics. Although some smaller seedlings may result from late germination, a large proportion of these are often off-types. It is false economy to try to use every seedling; only the best, uniform seedlings should be used for transplantation and budding. It is also good practice to re-evaluate the seedling rootstocks at budding and once again discard non-uniform stock.

Seed purchase and the initial stages of seedling propagation are not an expensive part of the nursery operation. Therefore, propagators should begin with twice the number of seeds as final saleable trees required.

Scion budwood propagation

Citrus is affected by many virus and virus-like diseases, most of which are transmitted in budwood. If a budwood supply tree is infected, then so are all the hundreds of trees propagated each year from its buds. It is also common for citrus trees to throw sports - these are limbs that are genetically different from the parent tree because a mutation has occurred. Only very occasionally are mutations better than the original; the vast majority produce inferior fruit. It is essential that nursery trees are propagated using only carefully selected, healthy true-to-type budwood.

Viroid-free, superior clonal selections of a large range of commercial and home garden citrus cultivars may be obtained from the New Zealand Citrus Budwood Scheme. The address, telephone and facsimile numbers for the scheme are listed at the end of this chapter. For further information see the chapter on the New Zealand Citrus Budwood Scheme.

Outdoor propagation

Field propagation is a long-term operation, normally taking between three and four years from the time rootstock seed is planted out until a budded tree is ready for planting.

Seedlings are transplanted into nursery rows in late August or September. At this stage, seedlings should be re-evaluated for off-types and carefully graded into size categories. This ensures that blocks of buddable seedlings are of uniform size and can be better matched at budding time with cultivar type and budwood size. For economy of space and ease of budding, plants should be placed in double rows about 200 mm apart within and between the double row, with an inter-row space of about 900 mm. Care should be taken to ensure that seedlings do not dry out during transplanting, and they must be watered immediately after planting to remove air pockets around the roots.

Routine management of nursery stock after transplanting into the field includes regular watering, fertiliser applications, weeding, pest and disease management and removal of side shoots. Under normal growing conditions rootstocks should reach buddable size within 9 to 12 months. January is the best month for budding field grown rootstocks as this allows for rebudding in early March of those stocks on which the buds missed.

A T-cut or inverted T-cut is the most usual method for bud insertion. Bud size should be carefully matched to rootstock diameter. A thick, vigorously growing rootstock may overgrow a small, weak scion bud. Buds should be inserted into the rootstock at least than 100 mm above ground level, a standardised height of 200 mm is preferable. Buds are held in place with commercial budding tape which should be carefully removed three to four weeks after budding. The success of budding should be assessed over the following four weeks, so that those stocks which require rebudding may be set aside for attention in March.

Removal of the rootstock above the bud should be carried out in early September. The developing bud is then allowed to grow out, and once the shoot is about 200 mm long, the shoot should be staked to ensure that the developing tree is well formed. Rootstock suckers should be removed at regular intervals. When the plant has grown more than 500 mm above ground level and has hardened off, it should be topped at about 400 mm from ground level to encourage the development of three to four side branches from buds immediately below the cut.

Indoor container propagation

An alternative method for citrus propagation is producing citrus in containers in a propagation house. The advantage of this method is that the trees can be produced ready for sale 18 months from time of seed germination. As the trees are container-grown, they are sold with an undisturbed root system. This means they establish better when planted out, are more easily transported from nursery to point of sale, and are better able to withstand delays between leaving the nursery and planting out without harm to the tree quality.

However, propagating citrus in containers is labour-intensive, and a major disadvantage is the initial high cost of establishing the propagation facility. The cost of erecting the glasshouse or plastic tunnelhouses and the installation of a good quality automated irrigation system is high.

Trees are generally propagated in black plastic bags rather than rigid pots as bags are cheaper and require less space. The rootstock seedlings are transplanted into the bags from late November to early December.

Good quality citrus potting mix is obtainable from commercial horticultural suppliers. A good quality potting mix should consist of equal volumes of pine bark, peat moss and pumice, with the following nutrients added to each cubic metre of the mixture:

3 kg of superphosphate

5 kg Nutricote slow-release fertiliser

6 kg dolomitic lime

400 g fritted trace element mixture.

Settling the potting mix at the time of transplanting the seedlings will avoid problems of settling in later months. Excessive settling over time will reduce the area available for root development and will therefore result in an inferior tree.

Budding and general tree management is similar to that outlined for field-grown trees. However, budding can be continued through into April if glasshouse conditions are optimal.

Watering frequency for container grown plants varies with seasonal changes, plant growth and the plant cultivar. A major problem is overwatering which rapidly leaches out nutrients from the potting mix and retards root growth. Roots need both water and air to grow, so waterlogged conditions kill the roots. Watering should ensure that the bags are wet through and should be turned off when water begins to drain out of the bottom. Container plants are most easily watered by a correctly spaced, overhead irrigation system regulated with a timer and solenoids to control frequency.

Supplemental fertiliser needs to be given to container grown trees once the slow-release fertiliser is depleted. It can be applied in three ways: as additional solid, slow-release fertiliser; as liquid feed via the irrigation (fertigation); or as foliar sprays. Trace elements are essential for optimal growth and are best applied as foliar sprays.

Useful addresses

Australian Citrus Propagation Association Incorporated
15 Bowen Crescent
West Gosford
NSW 2250
Australia.
Telephone: 00 61 43 25 0247
Facsimile: 00 61 43 24 2563

Willits and Newcomb Inc
PO Box 428
Arvin
California 93203
USA.
Telephone: 00 1 805 327 9345
Facsimile: 00 1 805 366 6419

MAF Quality Management
PO Box 2526
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2.3 Topworking

Peter Anderson

Topworking means the reworking of an existing cultivar to a new one. The reasons for doing so are usually economic. Topworking of citrus trees is not new. In many citrus growing regions of the world, it is an established method that allows quickly changing to a new cultivar. Topworked trees usually come into production sooner than nursery trees because of the established root system.

Careful thought must be given in deciding whether to topwork, or to replant.

Topworking involves the removal of some part of the existing canopy, the budding or grafting operation, follow-up work of removing tapes and bags, desuckering of the old cultivar, and perhaps staking of the shoots of the new.

Replanting involves the complete removal of all the trees in the block, and replanting with young nursery trees. When planning to replant, trees need to be ordered from the nursery at least one year before planting.

The expected tree spacing of the new cultivar must be considered. For example, if the old cultivar is spaced 3 m between trees in the row and your new cultivar should be spaced at 2 m then the decision to topwork should be questioned. Removing the entire root system and replanting the block with nursery trees might be the best option.

It is very important to select trees to topwork that are both healthy and free of lemon tree borer in the main scaffold. Beginning with healthy vigorous trees will increase the survival rate of the new cultivar. Wherever possible, indexed bud or graftwood should be obtained from the New Zealand Citrus Budwood Scheme. This will ensure the new cultivar is from the best budline and free of viroid diseases.

Citrus trees can be topworked by either budding or grafting. Each has its merits, but the availability of scionwood of the new superior cultivar may be the deciding factor.

Topworking by budding

In California, the most widely used method of topworking is budding into the tree scaffold. Budding is normally carried out in spring as soon as the bark slips well.

Before budding, select the best branches to bud. If a high canopy is needed, then the buds should be inserted high up into the existing canopy. There is no point budding down low into the framework, then waiting several years to fill the canopy. Remove unwanted limbs, and slightly trim back those branches that will hold the buds. Keeping leaves on these branches will help to draw up the sap.

Budwood selected for topworking should be larger in diameter than that used for nursery budding. To insert the bud, a 'T' cut is made in the branch, the bark is lifted, and the bud is positioned against the stock (Figure 2.3.1). If the bud is particularly small, as is the case with many Satsuma mandarins, the bark of the branch can be chipped back to avoid the new bud being grown over. The bud is taped in blind (totally covering the bud) and left for about three weeks. By this time the bud should have callused sufficiently to remove the tape. Once the new bud has grown about 200 mm long, the rest of the branch can be removed.

The number of buds placed per branch depends on the size of the tree. The more buds you place, the quicker the canopy will be replaced. As a general rule, a 10 year old tangelo tree may have six to eight buds inserted into it. Space out the buds so that when they grow they replace the old canopy. Avoid putting a lot of the buds in the centre of the tree. These will have to be trimmed out later because of competition.

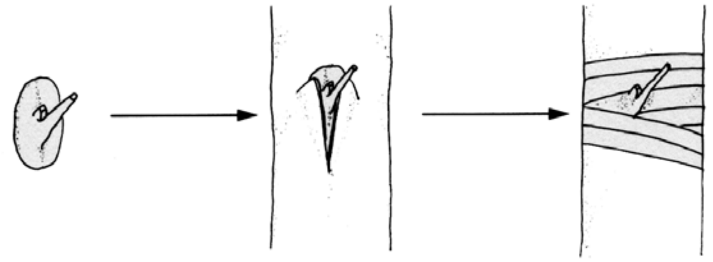

Figure 2.3.1 Placing the cut bud under the bark then taping.

Topworking by grafting

Bark grafting is commonly used for topworking citrus, results of trials done in Kerikeri suggest the best time to do the job is October/November. This allows sufficient callusing and vegetative growth before the onset of winter.

Scionwood selected for the graft is from rounded, green-barked hardwood, about 5 mm in diameter. It can either be cut in winter/early spring before the buds burst, treated with fungicide, wrapped in damp paper and stored in a plastic bag at 5ºC until required for grafting, or it can be harvested fresh.

The bark graft is made by cutting vertical slits (about 50-60 mm long) through the bark and down to the wood. The scions are cut about 100 mm long with about four buds per scion.

A sloping basal cut about 50 mm is made on one side of the scion. The bark on one side of the cut in the stock is lifted with the grafting knife. The scion is inserted and pushed down this side of the slit, with the long cut surface of the scion facing the wood of the stock. One edge of the scion should fit snugly against the unlifted bark on the stump (Figure 2.3.2).

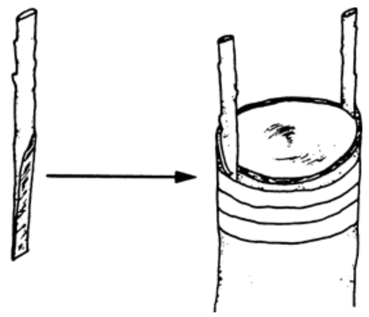

Figure 2.3.2 The prepared and fitted scion.

The grafts are held tight by wrapping 50 mm black insulation or masking tape around the main trunk. Always ensure the tape is wrapped in the direction of the lifted bark. Once secure, seal all cut surfaces with a suitable sealant, such as Bacseal or Garrison™. An insecticide can be added to the sealant to prevent the lemon tree borer from laying its eggs on the wound site.

Grafted scions can be sprayed with a fungicide such as Benlate to prevent fungal infection. Once dry, a thin plastic material such as cling wrap should be wrapped around the entire scion, but not too tightly. Do not finish the tie in a knot as it will be virtually impossible to remove later without damaging the new tender shoots. An alternative to using a material such as cling wrap is to place a plastic bag over the entire grafted stock. This can be held on by a large rubber band.

Using bags can reduce the topworking time considerably as wrapping cling wrap can be a very time-consuming and frustrating procedure. The use of bags is standard practice in Australia, however, trial work in New Zealand has proven excellent results using cling wrap.

Paper bags are placed over the entire grafted branch to provide shade and protection from bad weather and bird damage. About three weeks after grafting, a slit is made in the top of the bag to allow you to see if the buds have shot. When the shoots are about 10 mm long, the cling wrap is carefully removed, leaving the paper bag intact. The bag can be removed once the new growth is about 150-200 mm long.

There are two options available when the decision is made to graft using graftsticks: to graft into the existing scaffold or to graft directly into the crown rootstock. The grafting technique outlined above is the same for both options.

Existing scaffold grafting

Grafting into the existing tree structure above the rootstock union ensures the grafting can be done at a manageable height and the canopy quickly refilled with the new cultivar (Figure 2.3.3).

Wood of the original cultivar acts as an interstock. Little is documented on the effect an interstock has on the resulting fruit quality. The scaffold regrowing can be a problem, especially if it has been severely cut back.

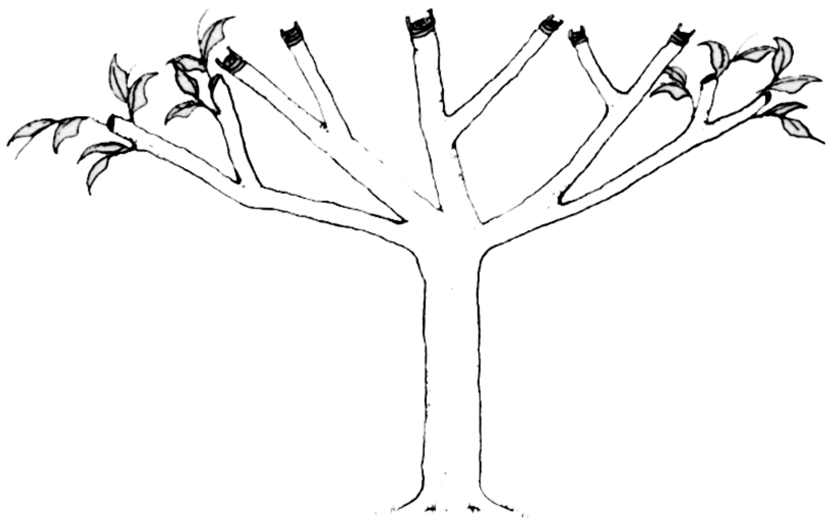

Figure 2.3.3 Grafting into the existing tree scaffold.

Crown grafting

Removing the entire existing cultivar except the rootstock will eliminate interstock problems. However management of the grafts and growth in subsequent years is more difficult because of the height of the crown above ground level. It still takes a few years for the new tree to develop into a reasonable canopy (Figure 2.3.4).

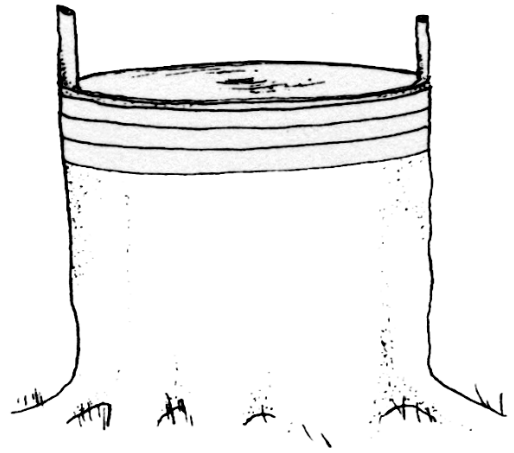

Figure 2.3.4 Grafting into the existing rootstock.

Growing Citrus in New Zealand
A practical guide

Section 3.
Orchard Management

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New Zealand Citrus Growers Inc

3.1 Planting a new block

Andrew Harty

Introduction

The productivity of a citrus orchard greatly depends on getting everything right at planting time. A well-chosen, well-prepared site planted with top-quality trees will be dramatically more productive than one where poor quality trees were simply stuck in the ground and left to fend for themselves. It is hard to later correct mistakes made at planting time. By following the information supplied here, you can lay the foundations for a productive and profitable citrus block.

Cultivar selection

The first step in choosing cultivars should be to contact citrus marketers to discuss trends in consumption, supply, and price for both local and export markets. Selecting the most profitable cultivars will have a dramatic effect on orchard viability. (For a comparison of gross margins see the chapter on Citrus economics).

The seasonal activities (thinning, pruning, and picking) required for each cultivar should fit in with other operations on the orchard. Once a decision has been made on which cultivar(s) to plant, cash-flow budgets need to be drawn up before proceeding further. The operations outlined here will assist you in this process.

Tree ordering

To ensure that you get top quality trees, it is important to order trees several months ahead of planting time. To obtain trees of newly released cultivars, it may be necessary to confirm an order 12 months before the planting date. This allows the nurseryman to bud additional stocks. Most nurseries will give discounts on forward orders.

Most nurseries will have trees available that were grown from certified budwood from the New Zealand Citrus Budwood Scheme. This budwood came from high-health trees selected for their productivity and excellent fruit quality. (See the chapter on the New Zealand Citrus Budwood Scheme).

The nursery trees should be obtained from a reputable nursery, and ideally should be inspected before purchase. Avoid 'bargain basement' trees that are stunted and do not have good leaf colour, and enquire what measures have been taken to eliminate off-type rootstocks in the nursery. If you are propagating trees for your own use, grade out all undersized trees. It is false economy to fill an orchard block with runts.

Site selection

The climatic boundaries for citrus cultivation are delineated by the occurrence of air frosts. Frost can kill young trees and severely damage fruit and young growth on older trees. This means that citrus can be grown in much of the upper North Island and Nelson - Marlborough area, where the microclimate does not have a record of heavy frosts. The choice of a suitable microclimate within a district, or even on a particular property, is more important than using regional guidelines. Citrus may be frost-damaged in low lying pockets in Kaitaia and survive in warm spots on Banks Peninsula. The ideal physical site requirements are a gentle north-facing slope out of cold air drainage pockets, in well-drained soil.

Greater heat unit accumulation in northern districts will bring forward the maturity time of most cultivars. In addition, most mandarin cultivars appear to need higher heat units to produce good internal fruit quality.

Shelter

Citrus was originally an understorey tree in the South-east Asian jungles, so it is not surprising that strong winds are unfavourable. Tree growth is stunted by constant wind, and wind rub on young fruitlets is a major cull factor. Sheltered blocks of 0.5-1.0 ha are recommended for citrus, with the block length ideally oriented north-south for maximum row length and sunlight interception.

Ideally, shelter should be well-established before the citrus trees are planted. Where bare land is being converted to orchard, low intermediate shelter can be formed by using artificial shelter cloth, or with inter-row plantings of maize,barner or sudax grass. These are removed as the permanent boundary shelter reaches sufficient height. Grass species are gross feeders, so should not be planted too close to the young citrus.

The choice of shelter species is important. Although providing reasonable shelter, bamboo, gums, poplar, and casuarina all compete strongly with the neighbouring rows of citrus, and annual root ripping is needed to keep root spread under control. These species are thus recommended only for boundary shelter where a roadway separates shelter and crop. Root competition is far less of a problem with Cryptomeria japonica. Although somewhat slow in initial growth, this species appears to make an ideal evergreen shelter for citrus. In the Gisborne district, deciduous shelter is preferred because it lessens the risk of cold air accumulation on winter nights. Dutch alder has proven a good deciduous shelter choice, with the added benefit that the roots are able to fix nitrogen. Recent use of radiata pine as a shelter species for citrus has shown potential.

Drainage

Poorly drained soil will not produce profitable citrus. Soil types in the main citrus districts vary enormously from heavy clays to very free-draining volcanic-ash soils, and consulting an agricultural engineer to assess the need for drainage is a worthwhile investment.

Various strategies can be used to improve drainage: subsurface drainage, open boundary drains, in-row mounding, as well as combinations of these. Mounding or ridging down the length of the tree row is becoming increasingly popular where shallow topsoils exist, but care must be taken not to compact the soil by using heavy machinery. Road graders and mechanical diggers have proved suitable for this job because they do not need to travel on the ground where the trees will be planted.

Soil testing

All New Zealand soils need correcting for mineral content or acidity before planting with citrus. A soil analysis is the only accurate means of assessing these requirements. Soil cores to 200 mm deep should be collected from throughout the new block and well mixed in the sample bag before sending to an analytical laboratory. The test factors to request are: soil pH; calcium, phosphorous, potassium, and magnesium content; cation exchange capacity; and base saturation. The recommended levels for each of these factors are shown in Table 3.1.1.

Table 3.1.1 Recommended base soil levels for citrus

Soil pH 6.0 - 6.5		Base saturation data %*	
Ca	15-25 me/100 g	Ca	55-67
K	0.8-1.2 me/100 g	K	3-7
Mg	2.0-2.5 me/100 g	Mg	10-14
P	50-70 µg/ml (Olsen test)	Total	70-95

*Cation exchange capacity > 10.

Pre-plant liming and fertilising

From the results of the soil analysis, lime and the poorly soluble nutrients phosphorus, calcium, and magnesium should be added. Because they will remain in the soil for many years with only gradual downward movement, this is the ideal opportunity to incorporate them into the future root zone. It is also important therefore to broadcast spread them over the whole surface of the block and not just where the tree rows will be.

Magnesium can be incorporated as dolomitic lime (dolomite), or as calcined magnesite (magnesium oxide) both have neutralising value. Phosphorus can be applied as double or triple superphosphate; the latter is usually a cheaper option per unit of phosphorus, but it does not have the amount of sulphur contained in double superphosphate. A much slower releasing form of phosphorus is reactive rock phosphate (RPR). This compound best releases phophorus under acid soil conditions. It is an acceptable option for organic growers.

Lime not only raises the soil pH, but also supplies calcium as calcium carbonate. Where soil pH is already above 6.5 (as found in some Poverty Bay soils), then calcium can be added as calcium sulphate (gypsum 23% Ca). Alternatively, future nitrogen fertilising in these orchards should be with calcium nitrate. Single superphosphate also contains over 20% calcium.

Soil preparation

Where there is any evidence of clay pans or other hard layers below the topsoil, the block should be deep ripped at one metre intervals or deep ploughed to a depth of 500-700 mm. This should be done only after the spreading of lime, magnesium, gypsum, or phosphate. The block should then be rotary-hoed to further incorporate the fertilisers. At this point, mounding can be done with a road grader or digger, with some final smoothing off done with a tractor and blade. The block is then ready for marking and planting.

Tree spacing

Ideally, tree rows should be oriented north-south for best light interception. Headlands of at least eight metres should be left for easy tractor turning. The distance of the first tree row from the long axis shelter belt should preferably be one metre more than the inter-row spacing, to avoid root competition and to allow access later for root-ripping and shelter-trimming machinery.

Planting density is an important decider of profitability in the early life of an orchard block. There is a worldwide trend to plant fruit trees at higher densities than in the past, because of the high yields per unit area obtained from them. However, high-density plantings eventually need tree size control and/or tree removal for the block to remain manageable. The most commonly used form of tree size control in other fruit crops is dwarfing rootstocks, and this option has been pursued with citrus. The most promising candidate is the *Poncirus trifoliata* (or'trifoliata') strain Flying Dragon, now under trial at Kerikeri Research Centre. Limited nursery propagation of this rootstock has begun.

Table 3.1.2 shows the currently recommended planting distances for different citrus cultivars. A 'best estimate' for trees on Flying Dragon is included.

Table 3.1.2 Recommended tree spacings (metres) for citrus cultivars on standard trifoliata or Flying Dragon rootstocks

	Trifoliata	Flying Dragon
Mandarins		
Satsumas - Silverhill, Kawano, Aoshima-Miho,	5.0 x 2.0	3.5 x 1.5
Okitsu, Miyagawa	4.0 x 2.0	not recommended
Clementine	5.0 x 3.0	4.0 x 2.0
Richard Special	4.5 x 2.0	3.5 x 1.5
Encore	5.0 x 3.0	4.5 x 2.5
Lemons - Yen Ben	6.0 x 3.0	not recommended
Limes - Bearss	4.5 x 2.5	4.0 x 2.0
Grapefruit - Golden Special, Cutler Red	5.0 x 3.0	4.0 x 2.0
Oranges - Navels, Harward Late, Blood, Seville	5.0 x 3.0	4.0 x 2.0
Tangors and tangelos - Dweet, Seminole, Ugli	5.0 x 3.0	4.0 x 2.0

Hole digging and planting

Bare-root trees should be planted during autumn or early spring to avoid moisture loss and heat stress. For bag-grown trees the planting time is more flexible, and providing irrigation is available, planting can continue through the summer months.

Planting holes can be dug by spade, or with hand-held or tractor-mounted augers. In all cases, the hole must be slightly deeper than the tree root ball. For bare-root trees, it should be wide enough to prevent any bending of roots, and for bag-grown trees, should allow at least 100 mm free space all around the root ball. When using augers in moist clay soil, a hard sheen can develop on the walls of the holes which must be broken by scraping the hole walls with a blade.

Trees must be planted at the depth they were growing in the nursery soil or in the bag. Deeper planting can result in *Phytophthora* root-rot infecting the bud union and scion. The roots of bare-root trees should be carefully spread over a shallow mound made by replacing some soil in the hole. Tangled roots that later girdle themselves and die have been identified as a possible cause of the 'sudden death' syndrome. The root ball of bag-grown trees should be distributed as little as possible after slitting and removing the bag.

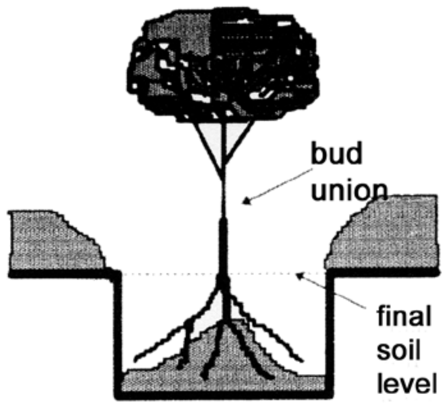

Figure. 3.1.1 Planting a bare-root citrus tree. Roots must be arranged over a mound of topsoil in the bottom of the planting hole, with the bud union well above final soil level, before backfiring.

Small quantities of lime and organic manures can be added at planting (maximum 500 g of each), but only after mixing them well with the soil dug out of the hole. Do not throw any soluble fertilisers into the holes and use only well-composted or pelletised manures.

Irrigation

Newly planted trees should be watered immediately after planting to settle soil against the roots. This is best achieved by making a shallow soil basin around the tree and applying enough water to wet the entire depth of the planting hole, either with a hose from an orchard sprayer or by using the irrigation laterals.

Drippers should initially be placed as close as possible to the tree trunk, this is especially important for bag-grown trees. As the trees grow and begin cropping, the laterals can each be extended by 1 m. This moves the original dripper 1 m away from the trunk, and allows an extra dripper to be installed one metre away on the opposite side of the tree.

Fertilising

Do not fertilise bare-root trees for three months after planting, to allow root establishment. After planting bag-grown trees, apply 50 g slow-release fertiliser (e.g., Osmocote, Nutricote, etc.,) around the trunk to cover the bag circumference. For both tree types, three months after planting, begin regular applications of high nitrogen fertilisers between September and April to the yearly totals outlined in Table 3.1.3.

Table 3.1.3 Nitrogen fertiliser options for young citrus trees (as number of fertiliser applications per season)

Year	N	Urea 48% N	CAN 28% N	Blood & Bone 5% N	Nitrophoska Blue
1	60 g	3 x 40 g	3 x 70 g	1 x 1200 g	3 x 170 g
2	120 g	3 x 80 g	3 x 150 g	1 x 2400 g	3 x 330 g
3	180 g	3 x 120 g	3 x 200 g	1 x 3600 g	3 x 500 g
4	240 g	2 x 250 g	2 x 400 g	1 x 4800 g	2 x 1000 g

Spread fertiliser evenly around the tree by hand, avoiding a 100 mm circle around the trunk and breaking up any lumps of fertiliser. Soluble fertilisers can severely damage young citrus roots if not spread evenly.

Foliar sprays of trace elements and N, P and K (nitrogen, phosphorous, and potassium) should be applied on each new growth flush as the young leaves reach full size (typically November, January, and March). Copper sprays should also be applied twice a season for disease control and nutrient supply.

Young tree protection

The prime objective during the first three to four years of a new planting is to get the tree canopy as large as possible before serious cropping begins. Besides regular fertilising, the following steps will allow the young trees to grow as fast as possible.

- Weed control - either by herbicide spraying or applying weed mat. Weeds will severely slow down tree growth, kikuyu grass is particularly devastating on young citrus. Young trees which still have green bark will be damaged by glyphosate sprays (e.g., Roundup), so care must be taken to avoid contact with green trunks. Either carefully use a hand gun, or if using a boomspray, apply trunk guards. Most residual herbicides are not recommended on trees younger than 3-4 years.

- Desuckering - regularly remove all rootstock sprouts. The easiest time to do this is when they are still soft and can be rubbed off by hand.
- Rodent damage - protect young trees from rabbits and hares. As well as controlling pest numbers, use trunk guards or repellant trunk sprays to prevent young trunks from being girdled. Trunk guards should be removed when trees are 18-24 months old.
- Pests and diseases - aphids can stunt new growth flushes on young trees and should be controlled with sprays. Armoured scales (greedy and latania) can severely infest and stunt the rootstock butts of young trees. Drenching sprays with oil and insecticide will control scale build-up on the trunks. Fungal diseases such as verrucosis, melanose, withertip, sclerotinia, and greasy spot can all affect young trees, and at least two copper sprays should be applied between petal fall and January.

Mulching-organic mulches will benefit the root systems of young trees by adding humus and improving the mix of soil microorganisms. However, uncomposted straw and sawdust are not recommended.

Planning ahead - budgeting

With the information outlined above, a planting plan and a financial plan can be drawn up. This will give you a schedule to work to, the relaxation of knowing that everything is being covered, amicable relations with your bank manager, and the reassurance that you have given your orchard the best start possible.

3.2 Citrus nutrition

Pat Sale

The main aim in citrus orcharding is to have healthy trees that annually produce high yields of quality, good sized fruit. Good nutrition plays an important role in all these factors.

Elements

Citrus like other plants, requires the following essential major and trace elements for proper functioning.

Major elements		Trace elements	
Nitrogen	N	Magnesium	Mg
Phosphorus	P	Zinc	Zn
Potassium	K	Iron	Fe
Calcium	Ca	Copper	Cu
Manganese	Mn	Boron	B
Sulphur	S	Molybdenum	Mo

Some of these nutritional elements are not usually a limiting factor in New Zealand, but the role of the more important ones is outlined below.

Nitrogen

Nitrogen is a vitally important element for all plants and is closely associated with growth. It profoundly affects the performance of citrus trees, both in deficiency and excess.

Deficiency

Stunted growth, yellow coloured foliage, poor flowering, poor yield.

Excess

Excessively soft lush growth, coarse fruit, thick skins, poor fruit colour, delayed maturity, increased tendency to regreening in Valencia oranges and Encore mandarins. The most critical time for nitrogen deficiency stress is in the flower induction period in June, just before and during flowering, fruit set, and December drop. However, like most trees, citrus will store nitrogen in the woody parts and utilise it in spring, so a deficiency expression at that stage could be the result of a previous shortage which exhausted the stored nitrogen.

To provide a small boost of nitrogen at these critical times in the flowering and fruiting cycle, a foliar spray of 1% low biuret urea (1 kg/100 ltr) can be applied in the second half of June, in full flower and also three weeks later.

Most citrus have two growth flushes, one in spring and the other in autumn, when they utilise nitrogen rapidly. In the case of lemons, there are usually three such flushes.

Recent research in New Zealand has shown the best time to apply nitrogen to dessert citrus is in the autumn when it can be taken up by the trees, stored through the winter, and be readily available for the spring growth flush, flowering, and fruit set. There is also a definite benefit in fruit quality compared with a spring application, as the following Figures from HortResearch, Kerikeri, show.

Table 3.2.1 Comparison of autumn and spring applications of nitrogen

Fruit quality	Brix %		Acid %		Brix:acid Ratio		% Juice	
	1991	1992	1991	1992	1991	1992	1991	1992
Johnson Navel								
Autumn	11.2	12.2	1.02	1.11	11.1	1.2	41.0	45.5
Spring	9.6	12.0	0.93	1.06	10.3	11.3	36.8	41.3
Harward Late								
Autumn	11.1	13.6	0.98	1.18	11.3	11.5	27.8	29.8
Spring	10.6	13.0	1.02	1.02	10.9	10.8	28.4	29.3

New Zealand grapefruit should receive autumn nitrogen applications similar to dessert citrus. Lemons with several growth flushes per season should have several dressings of nitrogen to coincide with the start of the major flushes which are usually in spring, summer, and late summer/autumn.

Most citrus have a tendency to biennial bearing, and where this is apparent, less nitrogen should be applied in the 'off year'. In cases of extreme biennial bearing, with almost no crop in the 'off year' (as is often the case with Wheeny grapefruit), no nitrogen should be applied in the 'off year'.

Nitrogen can be applied to the soil in several forms with different rates of response as follows:

Quickest Response

Nitrates, urea, ammonium

Slowest Response

Animal manure

Foliar applications can be made for an even more rapid response, but only comparatively limited quantities can be applied at one time by this method.

Phosphorus

Phosphorus is of importance in all plants, playing a major role in root growth. In citrus it can also profoundly affect fruit quality.

Deficiency

Stunting and poor tree growth, puffy hollow-centred fruit, thick skins, low juice content, acid juice.

Excess

Less acid in fruit, less vitamin C, depression of zinc in leaves. Visual symptoms of phosphorus deficiency on the tree are not usually seen in New Zealand, but the effects on fruit quality can be seen in most districts.

The timing of phosphatic fertiliser applications is not important and for convenience they are usually applied in early spring. Maintaining soil phosphorus above an adequate level is of no benefit, and excess levels only limit the uptake of zinc.

Potassium

Potassium plays a complex role in plant metabolism and is generally considered to play an important part in plant health and resistance to adverse conditions. In citrus, it too has a profound effect on fruit quality.

Deficiency

Premature leaf fall, bronzed leaves with maybe marginal scorch, accentuated preharvest drop, reduced storage quality. (Classical potassium deficiency symptoms have not been seen in New Zealand citrus orchards).

Excess

Large fruit; thick, coarse skin of dessert citrus; high citric acid content in fruit, low juice in dessert citrus; and depression of magnesium uptake. High rates of potassium will benefit lemon fruit quality.

Potassium is usually applied in one dressing in the spring, but the application can be split, with the second dressing coinciding with the late summer/autumn growth flush. The need for lemons to have more potassium than dessert citrus should always be borne in mind.

Magnesium

Magnesium is an important constituent of chlorophyll, the green pigment of foliage and other plant parts. It also plays an important role in seed development and influences the uptake of manganese and zinc.

Magnesium is a relatively mobile element, readily moving from older foliage to supply new shoots and developing fruit. Visual symptoms of deficiency are therefore quite common, particularly in years of heavy crops.

Deficiency

Yellowing of leaves with an inverted 'V' at the base of the leaf remaining green; premature leaf fall; accentuation of biennial bearing, especially in seedy varieties; accentuation of zinc and manganese deficiency.

Excess

Magnesium toxicity is not likely to occur in New Zealand. Magnesium is normally applied in the spring, but to get a rapid response on a severe deficiency, a foliar application can be made.

Calcium

Calcium is an important constituent of cell walls and also appears to be involved with root growth. Classical calcium deficiency symptoms have not been recorded on citrus in New Zealand, but calcium is sometimes less than optimum in the soil or in the leaves. Calcium is adequately supplied when soils are limed to improve pH and as a component of other fertilisers, there is for example a significant calcium content in superphosphate. The level of calcium affects, and is directly affected by, the levels of potassium and magnesium.

To improve the condition of the fruit rind, sprays of 2% calcium nitrate can be applied up to five times from December to March on dessert citrus, or after any fruit set period in lemons. The theory behind this practice is to increase the calcium content of the cell walls making them more robust and able to withstand handling. There are also proprietary products that contain calcium that can be used instead of calcium nitrate, but at the rates recommended they do not supply as much calcium.

Manganese

Manganese is a trace element and only required in minute quantities. Nevertheless, deficiency symptoms occur in all citrus districts of New Zealand. These manifest themselves as yellowing on the leaves between the veins, which are initially quite blotchy in appearance with a band of darker green along the midrib and veins.

An acute deficiency can severely affect the efficiency of the leaves and hence the performance of the tree. It is not readily corrected by soil application, so is mainly tackled by foliar application. However, manganese deficiency can sometimes be caused by a high pH in alkaline soils. Conversely, a highly acid soil can lead to manganese toxicity.

Zinc

Zinc is another trace element that can affect cropping and fruit shape. Deficiency symptoms are similar to manganese deficiency but the interveinal yellowing is less blotchy and more clearly defined. In extreme cases, leaves can be small, narrow, pointed, and rosetted in the classical 'little leaf' symptom of zinc deficiency.

Like manganese, zinc deficiency is very common in New Zealand citrus orchards and is best corrected by foliar spraying.

Molybdenum

Molybdenum is only required in very small quantities, but recent surveys show some 50% of New Zealand citrus orchards to be molybdenum deficient. Prior to this, molybdenum was not analysed in citrus leaf samples. It is now wise to include a molybdenum analysis in the February leaf analysis every few years to monitor the level. If it is low, a molybdenum analysis should be included each year until it is well into the optimum range of 0.10-0.29 ppm.

Deficiency

Yellow spots on the leaves with a gumming on the lower surface, and in very severe cases overseas, defoliation has occurred.

Deficiency symptoms are more likely to be seen on the sunny side of the tree and are more prevalent with acid soils. Liming acid soils will increase the availability of any molybdenum in the soil.

Sulphur competes with molybdenum for uptake at the root surface, whereas optimum levels of phosphorus enhance uptake. An excess of manganese, also more likely in acid soils, can induce a molybdenum deficiency.

Molybdenum is also necessary for nitrogen-fixing organisms in the soil and, as such, plays an important role in the nitrogen cycle.

A molybdenum deficiency, can be tackled in a number of ways:

- Check that the soil pH is around 6.0-6.5, and add lime to acid soils to create this pH. This may not be possible to achieve on some peat soils.
- Have molybdenum added to any superphosphate to be applied, by treating with sodium molybdate to achieve 200 g/ha.
- Spraying with a molybdenum containing material such as Molytrac at 200-250 ml/ha, or sodium molybdate or ammonium molybdate at up to 200 g/ha, when there is plenty of young leaf on the trees.

Methods of establishing nutritional requirements of citrus

Optimum nutritional programmes will use fertilisers, or manures, to the best economic effect in order to avoid deficiencies and excesses. Deficiencies will prevent optimum tree performance and fruit characteristic being achieved, whilst excesses can also adversely affect performance. Excesses are, in addition, expensive, likely to interfere with the availability of other elements, and can have undesirable effects on soil conditions and be responsible for the pollution of ground water.

There are several methods of determining which nutrients to apply:

- Routine programmes
- Visual assessment of trees
- Soil analysis
- Leaf analysis
- Crop removal

Routine programmes are easy to follow from year to year, but can waste money by the excessive use of fertilisers and can create imbalances in the soil and plants.

Visual assessment will often only pick up acute deficiency symptoms and usually only after tree performance has already been limited.

Soil analysis is an objective test of the nutritional status of the soil, and is extremely valuable. However, it is possible for the soil to be in a good state with the tree still unable to utilise the nutrients, e.g., through malfunctioning of the roots.

Leaf analysis is an objective test of the nutrient status of the tree, including trace elements, which can be compared with levels known to be satisfactory for citrus. It is essential that the right type of leaves are sampled to get a consistent measurement from season to season and which are directly comparable to the standard levels. In citrus, the sample is taken from first mature leaves on non-fruiting terminals, in the period February - March. A significant sample of at least 24 leaves (and preferably considerably more) should be taken from a random sample of trees throughout the block, sampling four to six leaves per tree.

The standard nutrient levels generally accepted for citrus are set out in the following table.

Table 3.2.2 Leaf analysis values for citrus

Nutrient		Deficient (Less than)	Low	Normal (Optimum)	High	Excess (More than)
Major nutrients %						
Nitrogen	(N)	2.2	2.2-2.3	2.4-2.6	2.7-2.8	2.8
Phosphorus	(P)	0.09	0.09-0.11	0.12-0.16	0.17-0.29	0.30
Potassium	(K)	0.4	0.4-0.69	0.7-1.09*	1.1-2.0	2.3
Calcium	(Ca)	1.6	1.6-2.9	3.0-5.5	5.6-6.9	7.0
Magnesium	(Mg)	0.16	0.16-0.25	0.26-0.6	0.7-1.1	1.2
Chloride	(Cl)	—	0.3	—	0.4-0.6	0.7
Sodium	(Na)	—	0.16	—	0.17-0.24	0.25
Trace nutrients ppm						
Manganese	(Mn)	16	16-24	25-200	300-500	?
Zinc	(ZN)	16	16-24	25-100	110-200	?
Copper	(Cu)	3.6	3.6-4.9	5-16	17-200	?
Iron	(Fe)	35	36-49	50-120	121-200	201
Boron	(B)	21	21-30	31-100	101-260	260
Molybdenum	(Mo)	.05	.06-.09	0.1-1.0	1.1-50	51

**The optimum potassium range for standard lemons is 1.2-1.8%*

Ideally, a nutritional programme should be decided upon by utilising the results of leaf analysis, soil analysis, visual symptoms, as well as records and knowledge of tree performance.

Crop removal

Some fruit analysis data on New Zealand grown citrus can be extrapolated to show what quantities of nutrient are removed from the orchard in the fruit per tonne of crop. These Figures are shown below.

Table 3.2.3 Quantities of nutrient removed from the orchard

Fruit type	Crop removal (kg)											
	1 t			15 t			30 t			45 t		
	N	Ca	K	N	Ca	K	N	Ca	K	N	Ca	K
Navel oranges	1.2	0.6	1.9	18	9	29	36	18	57	54	27	89
Seminole tangelos	1.3	0.7	1.6	20	11	24	39	21	48	59	32	72
Satsuma mandarins	1.7	0.8	2.0	26	12	30	51	24	60	77	36	90
Villafranca lemons	1.3	1.4	2.6	20	21	39	39	42	78	59	63	117
Encore mandarins	1.8	0.4	1.8	27	62	7	54	12	54	81	18	81

Nutritional programmes

Before planting

When starting an orchard, the first requirement is to have a soil analysis and correct any nutrient deficiencies prior to planting, as well as raising the pH as necessary. The young trees are then planted into soil of the right nutritional status (see the chapter on Planting a New Block).

Young trees

Young trees are often planted with a mild organic starter fertiliser well mixed into the soil at each planting site. Local experience with starter fertilisers should be taken into account in each district.

The young trees are then normally fed on the little and often principle, at least as regards nitrogenous fertiliser, starting about six weeks after planting and coinciding with the commencement of each growth flush.

The approximate requirements of young trees are shown in the following table, but if soil analysis shows any nutrient to be in particularly good supply, it is not necessary to apply it on a routine basis. Alternatively, an element of greater importance (such as potassium for lemons) could be increased.

Table 3.2.4 Nitrogen, Phosphorous and Magnesium for young trees in grams per tree

Age (years)	N	Nitrogen Urea equiv.	Phosphorus Magnesium P/Mg	Serpentine Super equiv.	Potassium	Potassium Muriate of Potash equiv.
1	60	4 x 30*	30/13	430	25	50
2	120	4 x 60*	60/26	860	50	100
3	180	4 x 90*	90/39	1290	75	150

** Application in September and then at three approximately equal intervals until February, provided the soil is moist.*

Once the trees are 3 years old, an annual leaf analysis should be undertaken to determine which fertiliser is necessary.

Other important points in applying fertiliser to young trees are:

- Do not apply fertiliser against the base of the trunk as this may cause damage.

- Do not apply fertiliser when soil is dry or root burn followed by leaf scorch and leaf drop may occur. This is especially important when using urea as a source of nitrogen.
- Citrus is a magnesium sensitive crop and it pays to bring the magnesium levels up before planting and also apply some annually, unless a soil test shows this to be unnecessary. Magnesium can be applied as serpentine superphosphate, calcined magnesite, dolomite or kieserite.
- Poultry manure applied to trees individually can be valuable in building up nutrients and organic matter as well as acting as a mulch. It should be applied in spring after the soil has started to warm up (initiating root growth) but whilst the soil is still moist from spring rains. Leave a circle approximately 250 mm in diameter free around the base of the tree.
- Remember weeds compete strongly with young trees for nutrients and moisture-good weed control can mean more fertiliser available to the trees.
- If for some reason the young trees stop growing, regular foliar feeding can be of value in many circumstances.
- Nutrition of young trees is important, but trees suffering from lack of shelter, poor drainage, root or other diseases, or growing in soils without good structure and good physical condition will not respond fully to fertiliser.

Cropping orchards

Once orchards have settled down into the cropping phase, fertiliser is usually broadcast. The results of soil and leaf analyses are then usually used to determine what fertiliser to apply. Assuming the nutrient status of the soil is satisfactory, with no excess of any particular nutrient, the annual maintenance dressings could be as set out in Table 3.2.5. Any other suitable fertilisers can be substituted for those used in Table 3.2.5 at a rate which would give the same quantity of the element concerned.

Table 3.2.5 Maintenance fertiliser dressings applied annually

Dessert citrus and New Zealand grapefruit		
Nitrogen	Urea Equivalent	Timing
115 kg	250 kg	Autumn
Phosphorus	Serpentine Superphosphate Equiv	Timing
68 kg	1.0 t	Late winter-spring
Potassium*	Muriate of Potash Equiv	Timing
45 kg	100 kg	Spring
Lemons		
Nitrogen	Urea Equivalent	Timing
170 kg	375 kg	125 kg September, November and February
Phosphorus	Serpentine Superphosphate Equiv	Timing
68 kg	1.0 t	Late winter-spring
Potassium	Muriate of Potash Equiv	Timing
90 kg	200 kg	Spring

** It is important not to get the potassium level too high in dessert citrus or the acidity of the juice will increase having an adverse effect on eating quality.*

Foliar feeding

Foliar feeding in citrus can be approached from two angles either through the use of all purpose plant tonics, or through the use of specific recipes designed to address specific problems. Citrus is susceptible to a number of deficiencies that are most suitably corrected by specific nutrient sprays. The two most common seen deficiencies are Magnesium deficiency and Manganese and Zinc deficiency.

Magnesium deficiency can be corrected by suitable soil applications, but in severe cases, where an immediate response is required, the following spray mixture can be applied:

Magnesium sulphate 1 kg

Calcium nitrate 1 kg

Water 100 litres

This combines in the tank to form magnesium nitrate, which is taken up by the plant.

Manganese and Zinc deficiency both occur in New Zealand grown citrus and can be corrected together or singly. The combined recipe is:

Manganese sulphate l00 g

Zinc sulphate l00 g

Low biuret urea 750 g

Water 100 litres

Wetting agent (as indicated on label)

The urea assists in manganese and zinc uptake and gives a little extra nitrogen to the leaves at the same time.

Both the above nutrient spray mixes should be applied on their own without the addition of insecticides or fungicides, and the magnesium recipe should not be mixed with the manganese and zinc recipe. They should be applied at a time when there is plenty of young foliage on the tree as this absorbs the nutrients better than old leaves. Late spring, about November, or the equivalent stage in autumn when the autumn growth flush is about two-thirds expanded is ideal.

There is also a wide range of proprietary products available to supply individual major and trace elements. It is important that these are used at label rates according to the manufacturers instructions.

The safest time to apply foliar nutrients is when there is no fruit on the trees. For Satsuma and Clementine mandarins this is in the spring after harvest and before fruit set. For lemons and other varieties that carry fruit all through the year, application should be timed to coincide with the peak of the spring or autumn growth flushes.

Iron products applied as foliar feeds mark the fruit. To reduce the risk iron could be soil applied, ideally through a fertigation system.

There are a range of all-purpose foliar feeds available which contain small amounts of a wide range of nutrients. These are no substitute for a good fertiliser programme, but can on occasion be very useful. If the trees are under stress from drought, or if trees are recovering from a severe attack of citrus red mite or gummosis of the trunk, or if other similar stresses occur, the regular use of these materials can act as a very beneficial plant tonic.

Unlike the specific recipes, most of these can be applied with insecticides and fungicides, but before this is done it is always wise to check the label of the product concerned.

Foliar feeds are best applied in a significant quantity of water, under conditions of moderate temperature. This means that in the height of summer, spraying in the evening or early morning is recommended, as at this time the leaves are able to absorb the nutrients most easily. However, it is important that the spray is fully dry before nightfall to minimise the risk of fruit marking.

Fertilisers

There are a number of fertilisers suitable for citrus in New Zealand, and these include:

Urea. Contains 46% nitrogen. This is the cheapest form of nitrogen and is widely used. Like all nitrogenous fertilisers, it is ideally applied to moist soil when rain may be expected to take the nutrient into the soil.

Sulphate of ammonia. Contains 21% nitrogen. More bulky and slightly more costly than urea per unit of nitrogen. It tends to acidify the soil, and where constantly used, a watch should be kept that the pH does not drop too low. Conversely, it is useful in reducing soil pH where that is necessary, as well as supplying nitrogen. Citrus trees on *Poncirus trifoliata* rootstock do not do well in alkaline soils of pH 7.0 or more.

Calcium ammonium nitrate. Contains 26-28% nitrogen. This is a pelleted fertiliser that is easy to apply. The pellet breaks down over a period giving a supply of nitrogen to the plant. It has the advantage of having both nitrate and ammonium nitrogen for quick and delayed response. It also supplies some calcium and is neutral and so does not depress the pH.

Blood and Bone. Contains 7% nitrogen, 7% *Phosphorous*. This material tends to vary in analysis depending on its source. It is a mild organic fertiliser suitable for use with young trees at planting time, releasing nutrients over a period of time. It has virtually priced itself off the market for large-scale use.

Superphosphate. Contains 9% phosphorus. A readily available, reasonably cheap phosphate fertiliser, with phosphorus largely in the soluble form which makes it readily available to plants but also prone to be locked up in a form unavailable to plants in soils with a high phosphorus fixation property. It also contains significant amounts of calcium and sulphur.

Serpentine superphosphate. Contains 7% phosphorus, 3%magnesium. The addition of serpentine gives the magnesium content but a lower phosphorus content. The phosphorus in this material is less soluble than in straight superphosphate and as such is less likely to be 'locked up' in phosphorus fixing soils. This is a useful material to use as a routine maintenance dressing in citrus orchards as it ensures a regular addition of magnesium.

15% potassic serpentine superphosphate. Contains 6% phosphorus, 8%potassium, 3% magnesium. This is a useful material in the cheaper range to supply these three nutrients. The potassium is in the muriate form.

30% potassic serpentine superphosphate. Contains 5% phosphorus, 15% potassium, 3% magnesium. The higher potassium content makes this less suitable for regular use in dessert citrus as excess potassium can adversely affect fruit quality. As for the 15%, the potassium is in the muriate form.

Sulphate of potash. Contains 39% potassium. This is the preferred form of potassium for soils where a salt problem is likely to occur.

Muriate of potash. Contains 48% potassium. This is the chloride form of potassium, and as such is usually avoided where chloride is likely to accumulate in the soil. In most citrus growing areas of New Zealand, muriate of potash can be used without danger. It is cheaper than sulphate of potash per unit of potassium.

Kieserite. Contains 15% magnesium and 20% sulphur. It is a form of magnesium sulphate that is 100% water soluble and the magnesium is very readily available to plants.

Compound fertilisers are available with a wide range of N:P:K ratios and some with magnesium or trace elements added. The 15:7:5 with added magnesium is a good general balance for use in citrus orchards. Rates and timing are usually decided upon by the nitrogen requirement.

Animal manures. These are not available in sufficient quantity for widespread use. However, the use of poultry manure as a dressing for young trees individually has merit as it supplies mulch and humus as well as the plant nutrients. The pelleted sheep and poultry manure products are also suitable for use around young trees or in the holes at planting time, and are usually cheaper than Blood and Bone.

Figure 3.2.1 Typical magnesium deficiency symptoms showing a yellowing of the older leaves with an inverted V shaped area remaining dark green at the base.

Figure 3.2.2 Interveinal chlorosis of manganese deficiency in lemon trees.

3.3 Organic management practices

David Skinner

Introduction

All horticultural and agricultural practices to a greater or lesser extent interfere with the natural environment, and some are more harmful than others. In order to foster and sustain the ecosystem that supports us all, organic growers attempt to limit interference to the minimum compatible with reasonable food production. Biological husbandry is a management system and does not consist of simply doing nothing. There is also no reason why organic managers should not make use of all the advantages that modern science can offer by having regular soil and leaf analyses, residue tests (if necessary), and by taking note of published evapotranspiration figures and other technical information.

This chapter deals only with certified organic production. In New Zealand there are three certifying bodies: the Bio-Dynamic Farming and Gardening Association which owns the Demeter trademark, certenz and the New Zealand Biological Producers and Consumers Council Inc. which owns the Bio-Gro trademark and trades as Bio-Gro New Zealand (addresses at end of chapter). Both organisations are affiliated to the International Federation of Organic Agricultural Movements which, as the name implies, is the governing international body.

The Biodynamic approach

The bio-dynamic approach is based on the work of Rudolph Steiner who gave a course of lectures in 1924 to a group of landowners in Germany. These lectures have been published as 'The Agricultural Course' which has been the basis for much further research and study. Whereas the groups advocate what might be termed 'good husbandry practices', bio-dynamic practitioners take the matter further by focusing on the beneficial forces, both above and below ground, which act on plants and form their growth patterns. This is achieved mainly by the use and application of a range of herbal preparations, but the subject is too large to be dealt with in detail in this manual and interested persons can obtain help and information from the Association.

Conversion

One of the greatest difficulties facing people who wish to convert to organic management is to appreciate that a completely different mental approach is needed. Trees under organic management will show a more variegated appearance, having older yellowing leaves, pale young leaves, and glossy dark green mature leaves, unlike the more uniform green of the conventional orchard. This does not mean the trees are unhealthy. This is how trees look naturally.

It is an holistic system where everything is interconnected. There are no written prescriptions, no recommended spray programmes, no quick-fix solutions. It is important that this different approach is understood from the start as, if the only motivation to convert to an organic system is an extra dollar, then the attempt usually ends in failure. Some degree of dedication and philosophical motivation is necessary. The standards put out by the three certifying bodies give some specific directions and 'do's and don'ts', but mostly they are declarations of intent, general directions to explore, and pitfalls to be avoided.

To convert from a conventional system to a certified organic or bio-dynamic one requires an annual inspection by the certifying body and a period in transition before full certification is reached.

The length of this transition period varies, depending on previous practices and the state of the soil, but the absolute minimum in an ideal situation would be two years to full Bio-Gro or three years to Demeter. By the same token, a soil that has been heavily abused, e.g., with Dieldrin sprays, may never achieve full certification.

Many of the operations on an organic orchard are the same as for a conventional orchard. Pruning and shaping of fruit trees, picking and thinning of fruit, provision of adequate drainage, and the principles of good shelter, with knowledge of wind flows and direction, are all the same. This chapter will therefore concentrate on the main differences.

Fertility

The first and most important difference is in the treatment of the soil. It is no exaggeration to say that organic growers 'grow' the soil, which in turn produces healthy trees. If the soil is sufficiently lively, dynamic, and vibrant, the trees and other plants will be in a healthy balance and will therefore resist pests and diseases and produce tasty, long-keeping fruit.

To achieve this, two broad principle's apply.

- First, any fertiliser used on the ground must be worked on by the soil's micro-organisms, or by the composting process, before the nutrients become plant-assimilable.
- Secondly, the soil needs to be covered, in order to protect the humus from being burned up by strong sunlight or from being eroded by wind and water.

The first of these principles precludes the use of soluble synthetic fertilisers, such as urea or Muriate of Potash. The latter, being a crushed rock, is often thought of as organic, but is actually a very soluble form of potash and, because it has a very bad effect on soil balance and structure, is prohibited. Thus it is not only the origin but also the effect of the material that is important. These types of soluble salts which are taken up by the plant from the ground moisture lead to imbalances in the plant, unhealthy plant tissue, and increased risk of insect attack. They also find their way into the groundwater, polluting streams and other natural and artificial watercourses, and, in heavy concentrations, can make the soil toxic.

Instead, organic growers use lime and dolomite, gypsum and greensand, and reactive phosphate rock, provided it is not contaminated with heavy metals. These may be termed the 'dead' minerals and are used in addition to the more lively composts and natural mulches that add vitality and organic matter to the soil. Extensive use is made of foliar feeds based on fish or seaweed for nitrogen and the trace elements.

The second of these general principles show why most organic properties have a sward of mixed ground cover under the trees. Although the sward competes to some extent with the trees, the benefits far outweigh the disadvantages. Not only does it protect the precious humus from direct sunlight; but it also insulates the soil from extremes of temperature, fixes nitrogen, brings up minerals from the subsoil and assists drainage. The composition of the sward can tell the thoughtful orchardist a good deal about the condition of the soil from the variety, or the lack of variety, and type of plants, and provides a suitable environment in the topsoil for earthworms. Weeds by their very nature try to correct soil deficiencies with the nutrients they accumulate.

Insects

Insects are an essential part of the biosphere. If there were no insects, humankind would not survive. Like the weeds, they improve the fragile environment on which we all depend. Insects pollinate flowers, destroy unhealthy plant tissue, form symbiotic relationships with plants, aerate the soil, destroy carrion, and provide vital links in the food chain.

Unfortunately it is in their role as destroyers of unhealthy plant tissue that they most frequently attract the unfavourable attention of orchardists. If the plants are in reasonable balance, and therefore healthy, they will tend to defend themselves against insect attack, just as healthy animals resist disease. Pests and predators will be in balance too, so that insect damage to fruit will not be a serious economic problem. After all, nobody grows fruit with no rejects at all.

If, however, interference is necessary, some specifics can be used, such as the Bt sprays for caterpillars, and natural pyrethrum as a knock-down, but non-systemic, insecticide. There are also general sprays such as mineral oils, that can reduce populations by a smothering action, as is the case for some scale insects, or by 'sticking' them down, as for thrips. It is, however, important to avoid the pitfall of trying to substitute an 'organic' insecticide for a 'chemical' one, as that equally interferes with the natural balance of predators and parasites. It is part of the mental readjustment required for organic management that sometimes the grower just has to wait for a predator population to build up when pests are seen on the plants.

Specific remedies should be used to control particular problems and not on a prophylactic or timed basis. No 'just in case ...' or 'I always spray this in February ...' applications are allowed. This is an important point and, together with the preferred and prohibited materials, is spelled out in the Standards by the certifying bodies.

Diseases

These can be more difficult to control, and when planting new blocks it is as well to be aware which are susceptible varieties. Disease should not be a major problem if the trees are kept open and well pruned; if the ventilation in the blocks is good, with enough shelter to ensure a minimum of wind damage but not so sheltered that the blocks are damp and shaded; and if the rows are planted as near as possible North-South with sufficient spacing to allow good sunlight all around the tree.

If problems do arise, the limited use of copper hydroxide or lime sulphur are the main weapons for disease control, with a heavy emphasis on usage limits. The Bio-Dynamic Association permits a maximum 3 kg/ha per year of wettable copper on permanent crops. A build-up of copper in the soil is bad not only for the trees but also for earthworms and other soil fauna and flora. For this reason, monitoring of accumulation in the soil may be required. There has been some success with the use of 2% sodium silicate sprays to reduce oleocellosis and to make fruit rind more able to withstand damage during picking and packing. The bio-dynamic growers use a silica-based material, preparation 501, which helps in this area and complements their preparation 500 for the soil.

Weed control

As has been mentioned earlier, most weeds have positive functions and do not need to be eliminated, only controlled. This is usually done by mowing with an offset or swing-arm mower, which may necessitate first lifting the irrigation lines clear off the ground. The sward should be kept at about 100 mm to 200 mm which, in addition to the benefits already mentioned, provides a degree of insulation to the soil against extremes of temperature.

Mulches, either of natural materials or weed matting, can also help in this area, but plastic mulches should be able to be picked up again or the tattered remains will clog the soil and haunt the orchard for many years. It is important that natural mulching material brought on to the orchard should not be contaminated as can happen with straw mulches which have been heavily sprayed for rust control.

In certain areas weeds may have to be eliminated and in such places thermal weeding usually suffices. Gas and kerosene flame weeders are available, both hand-held and tractor mounted, though the latter are used mainly in market gardens. Development work is being done on steam weeding systems, which should be more effective as they achieve a better heat transference to the target plant. Cultivation by rotary hoe is not usually a preferred option because of damage to soil structure.

Irrigation and shelter

Bio-diversity is an important aspect of the natural balance of an orchard, hence the importance of weed control rather than weed elimination. In this area, the shelter can play a significant role and, although on an orchard there is seldom space for the 'cropping' shelter of more extensive agriculture, nonetheless a mixed shelter belt containing some bee forage and maybe firewood varieties can help. The wide variety of insect predators necessary for good pest control need the nectar and nesting sites that a touch of wildness can provide. Most orchards are too neat and tidy with carefully mown grass and straight rows of identical trees.

Irrigation is probably less vital than for conventional orchards due to the better water retention of the soil. This may be arguable, as the grass sward respires during hot weather and thus removes moisture. However, it has been demonstrated that organically managed soils are more friable, and one effect of this is that the plants tend to be deeper rooting. This is particularly apparent on organic farms, where the grass shows more resistance to floods and drought through the deeper root systems. As citrus has a comparatively shallow root zone, it is preferable to wet a larger surface area, which can be achieved by the use of sprinklers or mini-sprinklers rather than drippers.

Post-harvest treatments

The care of the fruit starts in the field, with clean smooth bins and gentle handling during picking. The oil cells in the skin of citrus are quite fragile and when ruptured can lead to unsightly staining of fruit. The wearing of gloves is a good practice, and driving full bins slowly to the shed also minimises damage. The cleanliness of the shed and grading equipment is vital to avoid the blue and green moulds, but this is the case for all fruit, whatever system it is grown by.

Fruit should be washed in clean water, although some chlorine may be used if it is rinsed off afterwards. Carnauba is the most acceptable surface coating, but other waxes may be permitted, depending on which emulsifier is used, but no fungicides or other materials prohibited by the standards may be added.

The main use of waxes is to 'reseal' the fruit in case any oil cells have been damaged during washing or grading rather than to give the fruit a cosmetic shine. The main purpose of packaging is to protect the fruit in transit and carry the certification status and necessary information rather than only for appearance and advertising.

Off-orchard practices

There is no great difference in the transport and marketing or organic fruit except in the fidelity of the product. If there is any likelihood of the fruit being confused or, worse still, fumigated, then it must be sold as conventional fruit. This may involve the removal of certifying labels or stickers from the fruit and from the packaging. The standards of the certifying bodies have recommendations on all aspects of fruit-handling, including the packaging, which should be frugal with scarce resources. The European Union has recently enacted tough legislation on the subject of wasteful packaging materials.

Conclusion

It is difficult in a few words to stress the advantages of biological husbandry. There are advantages to the orchardist, advantages to the environment and advantages to generations yet unborn. It is an agreeable way to grow food, and an agreeable living and working environment. There is a trend towards the production of less pesticide contaminated food by both consumers and producers.

Addresses

Demeter Trademark
Bio-Dynamic Farming and Gardening Association
PO Box 306
Napier

Bio-Gro Trademark
NZ Biological Producers and Consumers Council Inc
PO Box 36-170
Northcote
Auckland 9

Certenz
PO Box 307
Pukekohe

3.4 Training, pruning, and tree size control

Noel Brown

Tree training and pruning are modifications to the tree's growth. Training is controlling the shape, size, and direction of plant growth, pruning is removal of plant parts. Training and pruning may be used to: reduce tree size, allow light penetration into the tree, improve yield, improve fruit size and fruit quality, overcome alternate bearing, assist fruit harvest, and assist pest and disease control.

Traditionally, New Zealand citrus growing techniques have involved little pruning and training. However, suitable tree training and pruning can be used to encourage uniform and increased fruit size and fruit quality, and may also allow better pest and disease control.

Those cultivars that particularly need to be pruned and trained to maintain fruit size and peel and juice quality are lemons and both Clementine and Satsuma mandarins. Navel and Valencia oranges will respond to pruning with improved fruit size when tree crowding is occurring.

Citrus trees allowed to grow without any training will develop into the typical bushy, rounded shape we associate with citrus trees, although the final shape will be influenced by the variety. Most varieties become dense with age and low levels of light reach the centre and lower parts of the tree.

Most flowers occur on a citrus tree where there are good levels of light. On large, older, unpruned trees there is a 'shell' of fruit on the outer and upper parts of the tree where the light levels are good, with fewer or no fruit on the inside or shaded lower branches. Those fruit that do set on the inside and lower parts of the tree are generally smaller and may be of poorer quality.

Appropriate tree training and pruning will keep the tree open to enable light to enter throughout it. This will allow flowering and fruit set to occur and maintain satisfactory fruit size and quality throughout the tree. There is less reason to train or prune varieties that naturally have good fruit size and quality, although pest and disease control is generally easier on open trees.

The traditional pruning of a citrus tree was as a vase shape (see Figure. 3.4.1) with four to six permanent scaffold branches, as commonly used on summer fruit in New Zealand. Citrus trees may also be trained as variants of centre leader training systems (Figure. 3.4.2), as used on apples and pears and more recently on summer fruit. Whichever the training method used, the aim is to develop the tree into a series of branches with 'windows' to let in light.

The system of tree training chosen for young trees will influence decisions on tree spacing and whether to head newly planted trees. Trees should be trained early in their lives and growth in the wrong places should be rubbed off. Apart from the initial decision on whether to head young trees, the aim should be to manage without secateurs until the tree is cropping.

Some varieties have naturally upright growth habits. Encore mandarin often has branches that grow out of the trunk at an acute angel, so early training on this variety is particularly important for getting good branch angles.

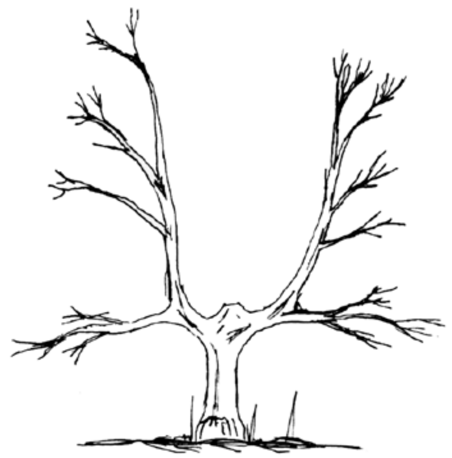

Figure. 3.4.1 Vase type tree training.

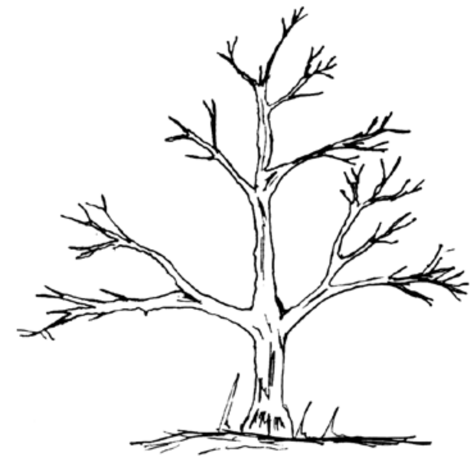

Figure. 3.4.2 Centre leader tree training.

Vase training for lemons and clementine mandarins

Varieties such as lemons and Clementine mandarins will need an intensive training and pruning regime throughout their lives to maintain good fruit size and quality.

Tree shaping for these varieties should begin from planting. The aim is to develop four to six permanent scaffold branches with good strong branch angles. Head young trees when planted to about 700 mm height if they are any taller than that. Remove any shoots lower than 400 mm, but do not remove leaves from the trunk as they assist tree growth. During the first growing season, remove any young shoots growing in the wrong place while they are still small. Toothpicks are an aid in training young shoots to a good angle when used as props between the trunk and the young shoots.

During the next two to three years the main emphasis is on developing the scaffold branches. Regularly rub off sprouts (young vertical shoots) not required for tree development. Do this about three times each year when the shoots are still young and soft, and thus easy to remove. Sprouting becomes less of a problem as trees age, and rubbing will be needed less often.

As the trees grow taller, form a first tier of fruiting branches on each scaffold branch at 1 m and a second at 2 m on the outer side of the scaffold branches. These tiers of fruiting branches will bear fruit on the many small shoots that extend outwards and downwards from the fruiting branch. Do not allow branches to develop towards the centre of the tree that will shade the inside and lower parts of the tree, and do not let the top tier dominate the lower.

After harvest each year, thin the canopy by removing the small shoots that carried the crop that season. Cut back to the new shoots that grew in the previous spring and early summer, as these will have fruitful buds. A guide to how dense the tree should be after pruning is that it should be possible to see through from one row to the next.

The centre of the tree should be quite open. The final tree size should be about 2.5-3 m tall, depending on row and tree spacing.

Centre leader training

Varieties such as Navel or Valencia oranges need only minor early training to encourage good lower tier branch angles on a single, upright central shoot. This is a good basis for future growth and productivity.

The aim is to first develop a tier of branches at about 0.7-1 m from the ground and later another tier of branches at about 1.5-2 m. Later hedging operations or hand pruning may be used to keep it to a desired size and to maintain fruit size.

Any branches lower than 400 mm, and any at an acute angle to the trunk, should be removed from the young tree at planting. Do not remove leaves from the trunk as they assist tree growth. During the two first growing seasons, rub off any young shoots growing in the wrong places but encourage one shoot to grow upwards as the future trunk.

Before the second growing season begins, remove any remaining unwanted shoots. Shorten any long growths that have bent over, or may bend, to strengthen them.

Bottom branches should be high enough to ensure fruit, leaves, and branches remain clear of the ground as the weight of fruit increases during the season. They also need to be clear of orchard operations such as mowing and weed spraying. Low fruit are prone to soil splashing on to them from the ground during rain, causing brown rot infection. Branches touching the ground allow Fullers rose weevil easy access into the tree to lay eggs. As with most trees, branches that grow at an acute or narrow angle from the trunk are weaker than branches coming out horizontally. The narrow angle often traps bark at the trunk-branch junction as the trunk and branch grow, making a weak joint. When an upright branch sets a large crop, the branch may bend and will often break.

To improve branch angles, rub or cut out bad-angle branches. If necessary, it is possible to train branches early on to a good angle with small props (e.g., strong toothpicks) when the new and soft shoots are about 150-200 mm long.

If the tree sets fruit in the second year, remove this fruit to encourage tree growth. This will also reduce any excessive bending or drooping of branches required for the tree's structure.

Tree training in the following two to three years should encourage branches where they are required and remove unwanted weak shoots near the trunk and any branches or parts of branches too close to the ground.

Navel orange, Harwood Late and Seminole tangelo

With Navel Orange, Harwood Late, and Seminole Tangelo, fruit quality is usually satisfactory without an intensive training and pruning programme. After the first two years of centre leader training and crop removal, there should not be much requirement for further tree training and crop thinning in the subsequent early cropping years. Some skirting of lower branches and removal of large branches high in the tree that shade areas may be all that is required.

As the trees age and begin to crowd each other, a pruning programme to maintain fruit size in the orchard may be useful. Often trees are planted close in the row to give high production early in the life of the orchard, but as trees crowd and shade one another, fruit size is reduced. Removal of alternate trees down the row at this stage improves fruit size.

To prepare for tree removal, trim back each second tree in the row after harvest to leave the adjacent untrimmed trees about a 600 mm space to grow into. The following year, after harvest, the trimmed tree can be removed with little or no loss of yield in the orchard. Figure. 3.4.3 shows the trimming cut.

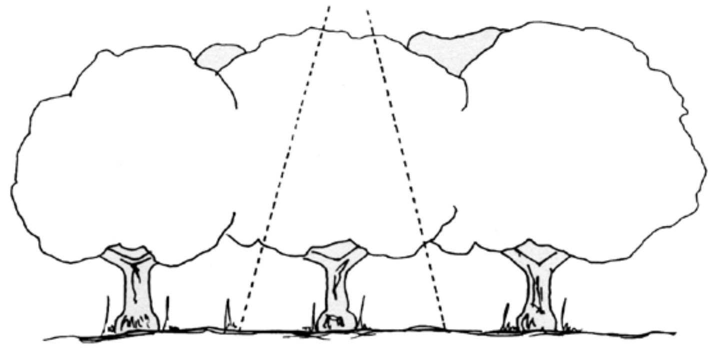

Figure. 3.4.3 Alternate tree removal in the row.

Trees continue to grow as they age, and unless widely spaced, they will eventually shade adjacent trees in the row, and even trees in adjacent rows. Trees often become alternate-bearing as they age.

Work at the Manutuke Research Station showed it was possible to mechanically hedge Navel orange trees and maintain yields and fruit size for a number of years as the orchard aged. The best time to hedge trees was shortly after a heavy flowering. Hedging only one side of the row in a season of heavy flowering reduced alternate bearing. The crop on the unhedged side of the row also reduced the vigour of the new growth on the hedged side. Provided the hedging was before the middle of December, the new shoots coming from the pruned side of the tree flowered and the following year set a crop.

Provided the initial hedging on one side of the row was before the trees were too large, the hedging of the other side could be left until two years later. Hedging alternate sides every two years could maintain tree size and fruit yield.

The shape and height to hedge the trees to depends on the row spacing and other management considerations. Hedging the trees with a sloping cut maintained Navel orange fruit yields at 35-45 tonnes per hectare and improved average fruit size. The triangular cross section (looking along the row) after hedging was 2.5-3 m tall at the apex or top, and 1.5-2 m wide at the base. The triangular shape was completed after the second hedging (see Figure. 3.4.4).

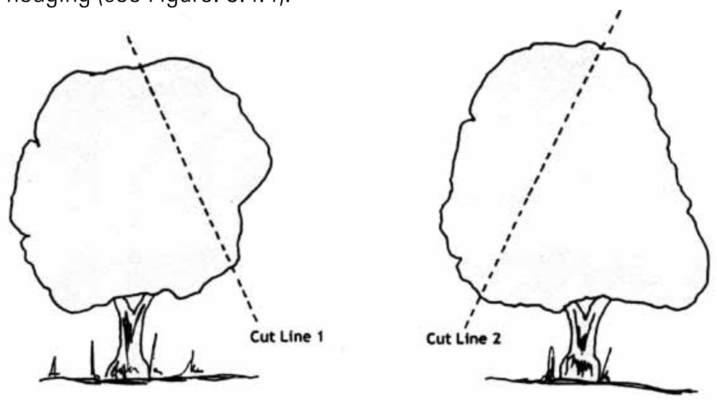

Figure. 3.4.4 Diagram of tree hedging to maintain or reduce tree size.

After a citrus branch has been cut, regrowth usually occurs near the cut, and the larger the branch cut, the more vigorous will be the regrowth from that cut. Hedging, then, should begin before the cuts have to be made through large branches to avoid very vigorous regrowth. If there is a choice of a cut, cutting off lower and downward pointing branches will regenerate less regrowth than if the branches were sloping upwards.

It is also better to hedge before the interior of the tree has become severely shaded, otherwise the tree and yields are slower to recover if hedged back to where leaves have been dropped due to lack of light.

With Navel oranges and Seminole tangelos, individual branch removal can take place from harvest until shortly after flowering. With Harwood Late, harvest is usually after flowering, and pruning should be soon after harvest.

Mandarins and lemons

On mandarins, where the harvest is usually before flowering, it is best to prune after harvest but before flowering. An early pruning allows healthy and fruitful shoots to develop at the time of the spring growth flush. These will flower well in the following spring a year later. This pruning will also reduce the amount of hand thinning otherwise required to thin the crop after flowering.

Prune lemons at or after harvest in the winter-spring period.

Other considerations

Note that the lemon tree borer will attack most citrus cultivars. The preferred site for egg laying is on fresh wounds so pruning wounds may be ideal egg laying sites. Most egg laying takes place from October to January. An insecticide applied after pruning at this time may have merit, as may painting large cuts. Remove other hosts for borer in the locality. Note that shelter fallen but not burned or otherwise disposed of may contain large numbers of larvae. At Manutuke, however, the level of borer damage was not obviously worse on the trees hedged in November than on unhedged trees.

Citrus trees will recover from very hard pruning and crop again about two years later. Note that if trees are cut back to major scaffold branches exposed to the sun, these should be protected from sunburn with a whitewash paint.

Keeping the inside of the tree canopy free of dead wood has been shown to dramatically decrease the amount of disease blemish on fruit rinds. This is especially so for large grapefruit and orange trees that are badly infected with melanose (see the chapter on Pest and Disease Programmes).

Further reading

Pauline A. Mooney and Andrew R. Harty, 1992. Pruning of Clementine mandarins for better fruit quality. Citrus Research Seminar '*Citrus Postharvest Practices*' HortResearch.

R. E. (Ted) Crawford. *Citrus Pruning*. Turners and Growers Exports Ltd.

3.5 Fruit thinning

Andrew Harty and Peter Sutton

Regulating crop loads

Many citrus cultivars are not able to regulate the amount of fruit they carry from season to season, and have a cropping pattern referred to as alternate bearing. The trees carry heavy crops of many small fruit in one season (the 'on' year), and very light crops in the alternate season (the 'off' year). Shoot growth is virtually nil in the 'on' years, but is the main growth process in the 'off' years.

The ratio of 'on' trees to 'off' trees varies between orchards. In some cases, almost all the trees are synchronised, so that production from the orchard in an 'off' year is extremely low. In other cases, the ratio may alternate between 60%:40% and 40%:60%, for example, and annual yields for the orchard overall appear to be relatively stable. This yield stability is, however, hiding the fact that many of the trees are not cropping to full potential. Also, because most of the crop comes from heavily laden 'on' year trees, the overall fruit size is very small.

Good orchard management (nutrition, irrigation, pruning, pest and disease control) can reduce alternate bearing. However, the only real solution to this problem is for the grower to regulate the crop load on trees through fruit thinning.

To promote vegetative growth on young trees, complete crop removal is recommended for at least the first two seasons of orchard life. This is especially important on non-vigorous cultivars like Satsuma mandarins. Once a suitable canopy has been established, it is necessary to begin cropping the trees in a regulated fashion. This requires removal of fruitlets after fruit set, either by hand or through application of chemical thinning agents. An alternative approach is to chemically inhibit the formation of excess flowers. Selective pruning of vigorous cultivars such as clementine mandarins can also assist in balancing the crop load.

The crop load left on the tree should allow production of fruit of desirable market size and quality, while allowing for some shoot growth to carry the following season's crop. There is a limit to which increased fruit size will compensate for fruit numbers removed, so excessive thinning will decrease total yields. Also, very large fruit may have poor fruit quality. Insufficient thinning results in small fruit size, poor tree growth and low return crops.

The optimal crop load is that which gives the highest sustainable return to the grower, and its sustainability must be proven over a number of cropping seasons. The return to the grower will be determined by (a) the minimum fruit size acceptable to the market, and (b) any premiums paid by the market for larger grades. Therefore, the optimal crop load may change as market requirements change. Also, the optimal crop load will not necessarily be the same for all cultivars.

Most of the information available in New Zealand on citrus fruit thinning relates to the early or wase Satsuma mandarin cultivars. This group of cultivars suffers very severely from alternate bearing, and because of the interest in exporting Satsumas, most research has been directed to correcting this problem. The following thinning guide and description of gibberellic acid (GA_3) use refer specifically to Satsumas. However, almost all citrus cultivars will benefit from fruit thinning in an 'on' year. In research trials, thinned mature Silverhill Satsuma trees will produce 75% more yield of marketable fruit over two seasons than unthinned trees.

Why do we need to thin fruit?

- To allow shoot growth and canopy development on young trees
- To provide large fruit sizes (50-60 mm plus for the local market, 55-70 mm for the export market)
- To stop alternate bearing and provide heavy, regular crops

How should young trees be thinned?

- Satsuma trees should be completely stripped of their first two crops to allow strong tree growth
- Flowers can be stripped off young trees, but this approach takes more time
- Trees can carry their first crop in the third season from planting

How should bearing trees be thinned?

- A crop load of 25 leaves for each fruit should be aimed for in the cultivars Miyagawa, Miho and Okitsu. This will give the heaviest, regular yields of export-size fruit
- A leaf-to-fruit ratio of 20:1 is more suitable for Silverhill trees

When should thinning take place?

- From mid-December (when the trees have completed their natural fruitlet drop) to mid-January
- Later thinning, up till mid-February, will result in smaller fruit and should be done only if the market requires small fruit

Which fruit should be taken off?

- First remove all smaller, damaged fruit
- Remove the largest fruit on the end of the shoot
- Remove all other fruit except two to three per shoot until the desired crop load ratio is achieved
- Allow enough space between the fruit you leave to ensure they will not touch at harvest

How many fruit should be left?

- Count the leaves on a small branch, and divide by either 20 (Silverhill) or 25 (Japanese cultivars)
- Select the correct number of fruit, and remove all others as suggested above
- Fruit should be left in groups of two or three fruit per shoot. On trees with a heavy fruit set, this will mean that some shoots need to be stripped completely to give the correct leaf:fruit ratio
- Example: the branch has 137 leaves which divided by 20 is 6.8 and divided by 25 is 5.4. Therefore leave seven fruit on a Silverhill (one shoot with three fruit and two shoots with two fruit), but only five on Japanese cultivars (one shoot with three fruit and one shoot with two fruit)

How many leaves should be counted?

- Only count leaves and remove fruit carefully on a few small trees, or on a portion of a large tree
- Use these carefully thinned canopies as a reference until you have your 'eye in'
- To be commercially acceptable, thinning must be done quickly
- You can quality control orchard workers by regularly checking leaf and fruit numbers on trees they have thinned

Common thinning errors

- Not removing enough fruit. Be confident. Too many fruit results in a smaller size and a smaller crop next year and is false economy
- Leaving hidden bunches unthinned (look under the canopy after thinning)
- Leaving fruit on young trees. Check again in late January for any missed fruit: it takes one or two to stunt a newly planted tree

Gibberellic acid

Gibberellic acid or (GA_3) assists thinning of Satsuma mandarins. It is one of a group of plant growth regulators called gibberellins. The gibberellins have many useful effects on citrus crops. They are used commercially to strengthen and delay colouring of rinds. On many citrus varieties they reduce flower bud formation.

This flower-inhibiting can be used by applying winter sprays of GA_3 to varieties that produce too much blossom, such as Satsuma mandarins. When new growth begins in the following spring, there are fewer flowers, and therefore fewer fruitlets, that need to be hand- thinned. On newly planted trees that would be weakened by early cropping, higher rates of GA_3 can be used to prevent flowering.

New Zealand trials have been only on wase Satsuma mandarins (Miyagawa, Miho and Okitsu). However, many reports from overseas show that GA_3 will inhibit flowering on almost all citrus cultivars. It is likely that rates for each cultivar will vary, and some experimentation should be carried out to determine the ideal rate.

How does GA3 work?

Citrus trees begin to form flower buds in late autumn. A cool temperature is the trigger for buds to change from shoots to flowers. This process takes place from May through to July, and apparently occurs because levels of natural gibberellins fall very low in the tree. This is the time that the flower-inhibiting effect of GA_3 can be put to good use. In several trials at HortResearch, a spray of GA_3 in mid-June has been the most effective in reducing blossom the following spring.

A brand of GA_3 called Grocel GA is stocked by Fruitfed Supplies. Other brands may be registered soon. HortResearch recommends two rates of usage for Satsuma mandarins as outlined in Table 3.5.1. The first for one and two year-old trees to prevent cropping, the second for flower reduction in trees three years and older.

Table 3.5.1. Recommended rates of gibberellic acid

	Active ingredient GA_3	Grocel GA / 100 litres water
Non-cropping trees	50 ppm	5 tablets
Cropping trees	25 ppm	2.5 tablets

The spray should thoroughly wet each bud. This means that high volume sprays need to be applied. Hand gun applications are very effective on young trees. In a trial on four year old Okitsu Satsuma trees, we had fewer flowers and fruit to remove when we increased the spray rate from 1,950 litres per hectare to 2550 litres per hectare.

Wetters definitely assist with GA_3 uptake. In our trials, Citowett proved satisfactory at the recommended label rate. The makers of Grocel (ICI Cropcare) recommend the wetting agent Contact. Organosilicone surfactants such as Pulse are possibly too effective, and there is a risk of too much flower inhibition when only thinning is required. These surfactants are useful when complete flower inhibition is required on young trees.

Unfortunately, GA_3 is not the perfect thinning spray. Some hand thinning will always be needed to get accurate crop loading. However, far fewer fruitlets need to be removed when GA_3 is used.

Trees that have just carried a heavy crop should not be sprayed. They will have an 'off ' year because of the heavy fruit load, and will produce very few flowers in the following spring. GA_3 sprays would only make this worse.

Some growers have reported rind spotting on fruit still on the tree at the time of GA_3 spraying. This has been erratic from season to season, but may be related to the wetting agent used.

Use tank mixes the same day they are made up. GA_3 solutions cannot be stored overnight. GA_3 is not a toxic chemical, but normal spraying precautions should be taken.

3.6 Growth regulators

Noel Brown

Hormones are organic substances produced in one part of a plant and translocated to another part where, at very low concentrations, they affect growth and development. Plants produce hormones in young growing shoots, fruits, leaves, buds, seeds and roots. The term 'growth regulator' refers to both naturally occurring hormones and those synthetically copied or created.

A large number of growth regulators have been defined. The five basic groups are: auxins, gibberellins, cytokinins, inhibitors, and ethylene and ethylene generators.

Some examples of uses of growth regulators in citrus production are:

- prevention of fruit drop before harvest (e.g., auxin 2,4-D)
- flower and/or fruit thinning (e.g., gibberellin GA_3, ethylene generator ethephon, auxin NAA)
- retention of the button on fruit after harvest (e.g., auxin 2,4-D)
- degreening of the fruit (e.g., ethylene); delaying rind maturation of the fruit on the tree (e.g., GA_3)
- rooting of cutting grown citrus (e.g., auxins IBA and IAA)
- control of sprouting on pruning cuts (e.g., auxin NAA)

Growth regulators do not act independently in the plant. Their many functions and complex interactions are not fully understood. Be cautious when using growth regulators, and try to gather experience in their use on a few plants only. Read labels carefully about their use and compatibility with other pesticides, wetting agents, etc. Various wetting agents, surfactants, spreaders, adjuvants, etc., can have major effects on growth regulators. Always read the labels of the growth regulator for instructions on its use.

Prevention of fruit drop

Fruit drop occurs over several periods from flowering through to harvest. The first period is from flowering to shortly after flowering. Citrus varieties generally flower profusely, set only a very small percentage of flowers and shed many young fruitlets when they are about 3-15 mm in diameter. Fruit drop occurs in the December - February period for most cultivars. This drop can be increased significantly by stress on the trees such as severe pest or disease outbreaks, incorrect nutrition or climatic extremes. However, fruit thinning is usually required and growth regulators are more likely to be used to thin young fruit or reduce the numbers of flowers than to retain fruit on the tree (see Fruit and Flower thinning section below).

Another period of fruit drop on some varieties is before harvest. Navel oranges and New Zealand grapefruit can drop a significant percentage of their crop around May in some years, when the fruit is colouring. Fruit drop can continue through the harvest period. Research in the USA showed clearly the role of the auxin 2,4-D in preventing fruit drop on some citrus varieties in this period.

Before fruit drop an abscission layer of weak corky cells forms under the button on the fruit and the fruit eventually drops. Inspection of fallen fruit will show the button is not on the fruit; it can be found still on the tree. The auxin 2,4-D, at a low rate of 16-20 ppm, may stop the formation of this abscission layer.

The site of action of this 'cling spray' is at the junction of the button and fruit. The cling spray is poorly translocated in the tree, so to be effective the 2,4-D must be applied to the area of the button on the fruit. To do this, the cling spray should be applied in high volumes of water to wet all fruit thoroughly. Correct calibration of the sprayer is important to apply the spray where required. The addition of a suitable non ionic wetting agent will assist coverage and penetration.

When using 2,4-D always follow the manufacturers' recommendations regarding the addition of wetting agents, surfactants, and other additives, as these may significantly alter the effectiveness of 2,4-D. Never mix 2,4-D with oil sprays or Bordeaux as these both increase the uptake into the tree. Also avoid applying either oil sprays or Bordeaux these within 7-10 days of 2,4-D application. Check spray water for hardness and pH, as these can also affect the effectiveness of 2,4-D.

Fruit drop can occur at other times of the year for various reasons, such as cold, pest attack and disease. It is unlikely that 2,4-D applications at these times will be successful in preventing fruit drop.

2,4-D is a weed killer. Even at these low rates, when used as a cling spray it may cause damage to growing shoots on citrus and serious damage to sensitive crops. Clean the sprayer before using on other crops and avoid drift to sensitive crops. In New Zealand, the cling spray usually used is the amine salt of 2,4-D at 20 ppm. The most common brand available is supplied by Fruitfed Supplies as Stop Drop. The butyl ester form of 2,4-D is more volatile, is more likely to cause damage to other crops through drift, and is likely to be more active. It is used in some countries, but at a lower rate of 16 ppm.

Use of a cling spray

Navel oranges

Apply a cling spray at the end of April or in May after autumn growth has hardened off. To prevent fruit drop occurring, the cling spray must be applied before the development of the abscission layer. Applying it when fruit drop is first observed is too late to stop that cycle of fruit drop, as the abscission layer has already been formed. Often growers make two applications, the first at the end of April to mid-May and the next mid to late July.

Preventing the formation of the abscission layer by 2,4-D lasts about three months. This means that an application at the end of July should reduce fruit drop until about the end of October.

Only apply 2,4-D when the autumn growth on the citrus trees has hardened and before spring growth has begun. Distortion of the spring growth foliage is a symptom of hormone damage from late application. While spectacular, the tree will usually grow out of the damage. Take care, particularly with late applications, that there is no chance of drift on to crops sensitive to hormone damage.

Grapefruit

To prevent fruit drop at the time of colour change, apply 2,4-D in late April to early May.

For delayed harvest of grapefruit, make two applications of 2,4-D. The first should be as above and the second in late July to early August, but before spring growth begins. This second application will reduce fruit drop for three months or more.

Fruit and flower thinning

Many of the Satsuma mandarin cultivars flower profusely and set excessive crops. Thinning of the flowers and/or young fruit is a common practice to prevent overcropping. Leaving too many fruit on the tree will cause harvested fruit to be small and biennial cropping to begin. In addition, overcropped Satsuma mandarin trees do not grow and may, in extreme cases, die.

Growth regulators can be used to assist in thinning. The most successful technique to date has been to reduce the number of flowers by the use of GA_3 in the winter months.

GA_3 should be applied in high water rates per hectare to thoroughly wet the trees. Oil sprays should not be used with GA_3 or for one month before its use. A buffering agent to maintain a pH of 4 to 4.5 will increase GA_3 effectiveness.

Preventing or reducing flowering with growth regulators to encourage young tree growth on young Satsuma mandarin trees is a useful management tool. GA_3 applied in June at 50 ppm will reduce flowering considerably, with a hand thin follow-up. Other less precocious citrus varieties can be thinned by hand.

With cropping Satsuma mandarin trees, GA_3 applied in June at 25 ppm has been effective in reducing flowering. Experience to date shows that trees need to have been thinned the previous year so that they are in good health and 'balance' before using GA_3. Hand-thinning can then follow on trees that still have an excessive crop.

The future of fresh market Navel oranges may depend on good fruit size. A suitable chemical or growth regulator fruit thinning regime is needed to improve fruit size in years of a heavy fruit set, as hand thinning is unlikely to be economic.

Ethrel® (ethephon) has been tried but is too variable with both oranges and mandarins.

Trial work with Navel oranges has shown GA_3 applied at 10 ppm may have a useful role in fruit thinning if applied in April or early May. The subsequent flowering was much reduced but the crop had a similar harvested yield with a larger average fruit size. When used at this time it considerably delayed colour development of the rind and improved the rind firmness for late harvest of fruit.

Post-harvest uses

The addition of 2,4-D to post-harvest wax applications aids the retention of the stem button on lemons. Using ethylene for curing lemons can cause an increase in the percentage of stem button drop. Bagging the fruit in polyethylene liners during curing increased stem button drop, and this may be due to ethylene accumulation in the bags. In local trials, no stem button drop occurred where 2,4-D at 500 ppm was added to the wax.

Rind strengthening

GA_3 has been registered in a number of countries for improving rind quality of late-harvested Navel oranges and for increasing resistance to rots. To achieve the maximum delay in harvesting, GA_3 should be sprayed on the trees just before or at early colour break. Navel orange fruit treated at this time will not achieve a marketable colour for about four months. More research work is needed to assess suitable rates and timing.

The following are tentative recommendations.

Apply GA_3 at 10 ppm in enough water and with a suitable wetting agent to thoroughly wet all fruit at early colour break. 2,4-D (as Stop Drop) is necessary to prevent excess fruit drop, and it is suggested this be applied separately. Applications of GA_3 in mid and late May have caused excessive flower thinning in the return crop, so to avoid this period make the application late April to early May.

Root formation on cuttings

The majority of citrus are propagated on seedling rootstocks. Meyer lemons grow well on their own roots, and the use of IBA will help root development.

Sprouting inhibition

Excessive shoot development after pruning is time consuming and sometimes difficult to control. In lemons this growth has been controlled by the use of NAA at rates of 1%. NAA may be applied either in a paint or as a spray with a dormant oil plus wetting agent. The oil plus wetting agents aid the uptake of the NAA. This may be successful on other cultivars, but be cautious and try it only on a few trees first. On young trees it can cause some die-back.

Growing Citrus in New Zealand
A practical guide

Section 4.
Harvest and Post-harvest

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New Zealand Citrus Growers Inc

4.1 Maturity testing

Andrew Harty

Fresh New Zealand citrus can be the finest-tasting in the world, but the picking and selling of immature fruit will ruin this reputation. The industry must adhere to fruit internal quality standards to prevent the marketing of an unacceptably sour product.

What makes a dessert citrus fruit acceptable to the human palate? Many organic compounds impart unique fragrances and flavours to fruit of different citrus varieties. However, the two components in citrus juice that have the most influence on human taste perception are sugar levels (sweetness) and acid levels (sourness). These two factors combine to give an overall perception that most people refer to either as sourness or sweetness, depending on whether sugar or acid is dominant. Although individual palates differ slightly, taste-panel tests show that most people prefer citrus fruit to have a sugar:acid balance that falls into a fairly narrow range.

The Brix:acid ratio concept

The balance, or ratio, of sugar to acid is measured in terms of total soluble solids (mostly sugars) and total titratable acidity (mostly citric acid). Total soluble solids (TSS) is measured either with a hydrometer or a refractometer, and recorded as degrees Brix. Total titratable acidity is measured by neutralising a juice sample with sodium hydroxide, and is recorded as % acid. The Brix:acid ratio is then calculated simply by dividing TSS by titratable acidity (see The Citrus Internal-Maturity Test below for details). The test is fast, simple, and requires relatively unsophisticated equipment.

It has been found that dessert citrus fruit with a Brix:acid ratio below about 7:1 is unacceptably sour to most people.

Maturity standards

Most overseas citrus producing regions have legally enforceable minimum Brix:acid ratios that must be achieved for each cultivar before sale. Typically, fruit consignments are tested in the market place by government inspectors, and are rejected if immature.

Table 4.1.1 Recommended minimum Brix:acid ratios for New Zealand citrus

	Local market	Export market
Satsuma mandarins	7:1	10:1
Oranges, tangelos other mandarins	7.5:1	-

The citrus internal-maturity test

1. Pick a 20-fruit sample from the orchard block that you want to harvest. Make sure the sample is representative of the fruit to be harvested - sample fruit from throughout the block, from all sides of the tree, and do not include damaged or atypically small fruit. If testing Satsumas that are not fully coloured, make sure that the fruit in the sample is of the colour you intend to pick.
2. Juice the fruit using an electric citrus juicer, and strain the juice through a sieve with 12 meshes to the centimetre.
3. Total soluble solids:read the degrees Brix on a hand-held or digital refractometer (or use a hydrometer).
4. Total titratable acidity:pipette a 10 ml sample of juice into a glass flask, and add 2-3 drops of phenolphthalein indicator. While gently shaking the flask to mix the solutions, dribble 0.1 N sodium hydroxide* from a burette into the flask until a faint pink colour appears and persists.

5. Calculate the % acid by multiplying the ml of sodium hydroxide added by 0.064.
6. To calculate the Brix:acid ratio, divide the Brix value by the % acid.

*0.1 N sodium hydroxide is obtained by dissolving 4.00 grams of pure sodium hydroxide in 1,000 ml distilled water; alternatively, ampoules are commercially available for dissolving in 1,000 ml distilled water.

Older citrus orchardists will remember the days of the Citrus Marketing Authority (CMA), when oranges were accepted for packing only when a sample had passed a maturity test and the fruit was determined to be legally ripe. Minimum internal quality standards were set by legislation, which prevented unripe citrus from being marketed. Not only did this protect consumers against poor-quality fruit, but it also ensured that New Zealand grown citrus was always palatable. The CMA was assuring the quality of the fruit it marketed.

After the abolition of the CMA in 1980 and the repeal of laws governing citrus marketing, an insidious situation developed. As with most fresh produce, the first consignments of a citrus variety to reach the market-place each season usually command a premium. With the removal of controls on ripeness, citrus has been harvested and marketed earlier each season in an attempt to capture this premium. Inevitably, consumers who have purchased sour fruit at the start of the season no longer buy that particular variety for the entire duration of the season. This consumer backlash against immature citrus fruit has severely affected the economics of tangelo production, and there is an equal danger that it will harm our Navel orange and Satsuma mandarin industries.

It is unlikely in today's political climate that legal maturity standards could again be imposed. It is therefore up to the industry, in its own interests, to control the internal quality of local market citrus.

Internal changes as fruit ripen

As citrus fruit approach maturity, the most dramatic change internally is a drop in acidity, accompanied by a slower increase in TSS as fruit is hung longer on the tree.

Decreasing acid levels and increasing sugar levels result in an increasing Brix:acid ratio, and sweeter tasting fruit. Harvesting too early means that high acid, low sugar fruit is picked.

Because of the *Poncirus trifoliata* (or 'trifoliata') rootstock used on dessert citrus cultivars, and the cool climate, New Zealand grown citrus develops high TSS and acid levels compared with those in imported fruit. Provided that our fruit is hung on the tree until the acid level declines, it can be the richest flavoured of any citrus in the world. However, if the fruit is picked early in the season, high acid levels for each cultivar will result in unacceptable sourness.

All dessert citrus (oranges, mandarins, tangelos, grapefruit) should be tested for internal maturity. Unfortunately, external colour is usually not a good indicator of internal maturity, and this explains why tangelos (which are superbly coloured but highly acidic in June) have suffered most to date from premature marketing. Rind colour also complicates the situation for Satsuma mandarins because, in some cases, partially green-rinded fruit can be internally mature. The fact that some cultivars are termed 'early' does not mean their fruit will be the first to mature internally under all conditions. Differences between districts, topography, tree age and management practices will all influence the time of internal maturity. There is only one objective way to assess ripeness of your fruit, and that is by testing the internal maturity.

Testing facilities

To assist orchardists with determining the maturity of their fruit before picking, Fruitfed Supplies offices in each of the main citrus districts will carry out Brix:acid tests. Growers need to submit 20-fruit samples of the fruit they intend picking, following the guidelines listed above. Results are provided on an official form, and depending on the result, the grower is advised either to proceed with picking or to delay harvesting and resubmit another sample at a later date. There is no compulsion to comply with this recommendation, and all results are kept confidential. In addition, many larger packhouses now have their own fruit-testing facilities, and insist that grower members supplying fruit have it pass the Brix:acid ratio before accepting it for packing. Brokers and merchants also take notice of fruit testing results, and most will not accept fruit without documented evidence that the fruit has reached acceptable maturity.

Ultimately, should the concept of internal quality assurance gain widespread industry support, it is possible that a total quality assurance scheme could be introduced, in which standards would also be applied to external fruit appearance. There is a registered Citrus Quality Mark held by the Fruitgrowers Federation that could be used to label and distinguish high quality New Zealand citrus from imported brands.

Summary

All dessert citrus fruit should reach a minimum Brix:acid level before being picked and sold. An internal maturity test is the only accurate way of assessing whether a particular orchard block is ready for picking. Maturity testing facilities are available in the major citrus districts at Fruitfed Supplies offices or at some packhouses.

Further Reading

A detailed description of the internal-quality test for citrus is given in the manual *Citrus Maturity Testing* by P.G. Sutton & T. Machin: HortResearch Client Report No. 93/175.

4.2 Picking and post-harvest practices

Stephen Lawes

The quality of packed citrus fruit relates to fruit composition (flavour, texture), appearance (size, colour, blemish), consistency, and price. Fruit must be fit for its intended purpose e.g., process or export, marketing in Japan or Wellington, storage or immediate sale. Market requirements change. The benefits of matching fruit characteristics to customer needs include return sales, increased market share, and higher profit.

Quality is built into a fruit, starting with the purchase of a tree. If picking and post-harvest operations are to result in quality fruit, the culture and environment must first have produced good fruit. Post-harvest practices can then make or mar good citrus. Fruit within a line or box should be consistent. Post-harvest handling complements culture: it is not a substitute for it. Guidelines for market grades and controlling factors are as follows:

Table 4.2.1 Size

Required by market	Determined by:
Export	
Mandarin:	Culture
55-80 mm diam. (55-150 g)	Cropload
in steps of up to 5 mm (or 15 g)	Cultivar
Lemon:	Rootstock
mean 100-180 g,	Grade standard
prefer 120-150 g	Quality control
Local	
Lemon: 55-75 mm diam.	
Mandarin: 45-80 mm	
Grapefruit: > 80 mm	
Orange: 60-80 mm	
Tangelo: > 55 mm	
(usually in 5 mm steps)	

Table 4.2.2 Packs

Export
Lemon: 17 kg
Satsuma mandarin: 5 or 10 kg net (allow for 3-5% weight loss).
Loosefill. Pattern pack large Satsuma
Local
18 kg plastic crate or 16-20 kg cardboard carton.

Table 4.2.3 Composition

Required by market	Determined by:
Dessert citrus	Culture
Export (mandarin)	Environment
TSS/Acid 10:1, Acid (citric) < 1.1%	Maturity
	Quality control
Local	
TSS/Acid ≥ 7.5:1	
No off-flavour	
No dryness	
Juice %: lemon (20); other (30)	

Table 4.2.4 Colour

Required by market	Determined by:
Lemon:	Cool autumn reduces green colour
silver-green (export), yellow-green (local)	
Mandarin:	Degreen e.g., 1-10 ppm ethylene
orange (some Satsuma with partial light green)	
Orange:	21°C 90% RH, for up to two days
full orange (slightly green in Valencia)	
Tangelo:	Standard set for harvesting
orange with blush	
Grapefruit:	
full colour (dessert)	

Table 4.2.5 Shape etc

Required by market	Determined by:
Uniform. Typical of cultivar	Environment
Stem flush with button	Strain and cultivar
Nil buttons missing	Picking method
Dessert citrus: no 'nipple'	

Table 4.2.6 Blemish

Required by market	Determined by:
No pests, rots, cuts, deposits	Culture e.g., pest control
Peel thin, non-puffy, smooth	Environment e.g., wind, frost
No dark brown discolouration	Post-harvest e.g., handling,
Blemish allowances:	temperature, grading, chemicals
Export	
Mandarin: < 1 cm^2/fruit, other < 5 cm^2 (On minority of fruit in line)	
Local	
May allow more blemished fruit, or darker blemish	

Table 4.2.7 Storage Life

Required by market	Determined by:
No decay	Gentle handling
Weight loss , < 4%	Hygiene
Hold 3-6 weeks	Fungicide
	Surface coating
	Temperature

Table 4.2.8 Picking and packing effects on quality (summary)

Operation	Affects	Desired action
Plan picking and handling	Packout Shelf-life	Organise: methods equipment training
Determine harvest date	Palatability Fruit size Storage life	Maturity tests
Harvesting	Fruit quality	Respond to: weather market crop characteristics Also supervise staff
Grading and packing	Presentation Acceptibility Storage life	Attend to: grade standards handling methods pack type equipment stamping, labelling quality control
Storage	Decay Blemish Weight loss Acid loss	Optimise and monitor: conditions storage time
Transport	Quality Weight loss	Protective methods No delays

Picking practice

All resources and procedures should be directed at selecting marketable fruit, preventing injury, and maximising post-harvest life. The correct fruit (i.e., mature, good quality) are selected, and detached in a satisfactory way under the right conditions.

The following factors are important:

People

- Provide prior training in procedures and specifications, and ensure there is an awareness of their significance.
- Give ongoing field supervision and assistance.
- Have a field quality controller monitor standards/defects in the orchard.
- Give pickers feedback from the packhouse on fruit quality.
- Ensure staff have correct clothing and equipment and know how to use it safely. (Clipping may cause sore wrists; picking aprons may cause backache).

Conditions

- Moist, turgid fruit readily develops a visible brown blemish (olecellosis) of dead peel tissue (within five days) if pressed too firmly. If fruit must be picked under marginal conditions, take extra care.
- Do not pick if trees or fruit are wet from rain or dew, such as in the early morning. Pick at least one day after rain if possible.
- Picking fruit in cold temperatures (e.g., below 8ºC), especially if the fruit is also wet, increases the risk of peel browning (oleocellosis). In cool, damp conditions, delay picking until the weather improves. Alternatively, start later in the day in the driest, highest parts of the orchard.
- After winter frosts fruit wastage may be high. Before picking, cut a fruit sample to determine internal condition (dryness).

(Australian fruit injury-risk test: Place absorbent paper on fruit; apply a pressure tester with 10 mm head until oil is released; if it took less than 2.75 kg force take extra care if picking).

Procedures

Adequate planning and control of the harvesting process is critical to a successful outcome.

- Satsuma mandarin with puffy skin, oranges of advanced maturity, wet fruit, and bright yellow lemons are more susceptible to handling injury and wastage. They require extra care at all times.
- Especially at the start of the harvest, fruit maturity varies over a tree and within a block. Commence with select picks using criteria of colour and size, and taking fruit from the outer top of the canopy. Fruit on weak shoots inside a dense canopy are of inferior quality. Where marked fruit colour variation occurs (e.g., lemons, early mandarin), a harvest of uniform colour facilitates packing a consistent and attractive line.
- Pickers should wear soft cotton gloves, or keep fingernails cut short. Harvest into a bag, crate, or bucket. Pickers should not bang the picking apron or bag on the ladder, bin etc. They should carefully roll (not drop) fruit into wooden bins from the picking container.
- Pickers should not place fruit which is punctured, rotten, or off the ground in the picking container and should avoid overfilling bins and picking containers, as excessive depth causes compression injury. Bins with a maximum depth of 400 mm are better for soft citrus; 600 mm may be satisfactory for lemons and oranges.
- It is usually better to clip all citrus from the tree, but especially Satsuma, tangelo, and lemons.
- Steps should be taken to ensure no fruit stems or shoots get into bins as they damage fruit. Fruit should be taken to the packhouse slowly, over well-formed roadways, and with well-sprung equipment (e.g., air bag suspension).
- Lemons (but not mandarins) may be held in the orchard for 24 hours if cool and dry (but not in direct sun or hot weather). This will make the peel more tolerant of handling.

- Fruit should be clipped from the tree with sharp, blunt-nosed clippers, especially if they are for export or storage or are injury-susceptible fruit such as easy-peel citrus.
- Double-clipping achieves some pruning (e.g., weak, shaded wood) and assists in optimising fruit clipping. The fruit-bearing shoot should be cut off 1-2 cm from the fruit, or at a suitable main shoot, or strong leaf bud, and the fruit stem then cut flush with the button (not more than 1 mm beyond).
- Some fruit may be single-clipped at the button. This is easier on lemons.
- Care must be taken not to puncture fruit, e.g., when in bunches. Very close clipping facilitates inspection for weevil eggs.

Snap picking

Snap picking is satisfactory for oranges and grapefruit. It is not recommended for lemons, mandarin and other easy-peelers as the risk of fruit peel injury is high.

Done well, snap picking close to the button on tolerant cultivars does not result in increased injury and decay. It allows faster harvesting but increases fruit damage by poor pickers: hence good training and supervision are required.

The damage caused by snap picking is worse with over-mature fruit, thin or loose peel, and fruit hanging in tight clusters; and shows as torn peel or plugged fruit. Any sharp stem ends may puncture other fruit.

To snap pick, gently grasp the fruit in the hand and lift it to the horizontal. With a snapping motion, move the fruit upward or downward to break the stem where it joins the button. Do not twist the fruit on its stem or pull.

Monitoring

A sample of fruit in bins from each block should be checked during picking for size, blemish, plugging, and stems. Fullers rose weevil eggs may be laid under the button, so it is useful to remove some buttons and inspect with a hand lens. (Statistically sound sampling levels are yet to be developed).

Each lot of fruit should be tested for Brix and acid level to confirm standard, especially for export fruit.

Equipment

- Clean picking bags should be used. (Wash with a solution of 1% active ingredient (a.i.) formaldehyde beforehand).
- Picking aprons, bags, and bins should be free of grit and twigs and frequently cleaned.
- Picking buckets may be an advantage by minimising fruit movement and compaction.
- Bins of smooth timber with no sharp edges or protruding nails should be used. Bins should not be too deep (a maximum of 400 mm is desirable).
- If appropriate, cushioning materials in bins, e.g., corrugated cardboard or foam rubber on the base, should be used.

Hygiene

In production and post-harvest handling, fruit may be infected or contaminated with pathogens or materials detrimental to its soundness and acceptability. Losses from fungal decay, e.g., *Penicillium*, are a major concern, and practices and an environment that emphasise cleanliness are encouraged.

- In the orchard, hand pruning to remove dead wood reduces sources of stem-end rot or melanose fungi (*Diplodia, Phomposis*) and *Alternaria.* It may also limit fruit punctures.
- Skirting trees to keep foliage off the ground may reduce fruit brown rot (*Phytophthora*) infection in autumn, *Alternaria* in tangelo, and fruit contamination in summer with Fullers rose weevil (see below).
- Collect fallen fruit from under the trees before sporulation. Either bury them, chop them finely to dry and decompose quickly, or remove them.
- Limit bracken fern and weeds near citrus as they may host passion-vine hopper and lead to sooty mould. Maintain good weed control below a tree during summer to reduce movement of Fullers rose weevil on to the tree and fruit from the soil.
- Wash picking bags before harvest starts. Remove rotten fruit from bins, and spray bins with a solution of 1% a.i. formaldehyde. No fallen fruit should be put in bins of fruit.
- In California, to monitor Fuller's rose weevil it is suggested that branches be shaken over sheets in mid to late summer, and if any beetles are collected, to sample fruit at chest height near the leaf damage by twisting off the button and inspecting for eggs.
- In the packhouse, handle fruit promptly. Delays may allow sporulation and packhouse contamination.
- Place no decayed fruit in the wash tanks. If chlorine is included, infection of other fruit is reduced.
- Manage bins of fruit to prevent soiled bases entering the water dump. Change the water in the dump when it starts to get dirty. If the fruit is dry brushed, wash the brushes daily with a solution of 1% a.i. formaldehyde to stop the build-up of Penicillium spores.
- Steam clean the packing line annually. No mouldy fruit should be allowed over the packing line.
- Provide extractor fans to draw air out of the packhouse, especially in the sorting and grading areas.
- Have a concrete packhouse floor and yard. Frequently clean the shed floor and remove fallen or mouldy fruit.
- Prevent the access of birds and rodents to the packhouse and fruit or packaging sortage areas, and remove other animals, e.g., dogs, from the area in the packing season.
- Chemicals should be labelled, stored, and controlled to prevent unnecessary fruit contact.
- Staff should wash their hands after using the toilet.

Handling in the packhouse

Do not underestimate the care needed to minimise wounding, decay, olecellosis, and weight loss. Do not stand bins of fruit in the sun.

Initial handling should minimise physical injury, avoid the spread of rot-causing spores, and protect minor wounds. Handling may remove surface deposits, e.g., spray or soil.

In the packing line, avoid poor design, overloading, and poor lighting. Apply protective materials and then cool fruit rapidly. Markets prefer minimal use of post-harvest chemicals.

Washing

Advantages

- Removes surface dust, spray residue, and sooty mould.
- Causes less physical damage than dry brushing.
- Clean fruit improves waxing efficiency.

Disadvantages

- Soaking increases injury risk to easy-peelers from water absorption.
- Wet fruit waxes poorly, with milky appearance (chalking) developing later under humid conditions.
- May spread spores and increase infection of minute peel injuries.
- Chorine compounds are corrosive to metal.

Method

- Use water, chlorinated water, or a proprietary cleanser.
- Water-rinse after any chlorine exposure.
- High pressure water sprays are effective in removing most scale from citrus fruit.
- Clean tanks of residues and rubbish frequently.
- Use soft brushes, e.g., horsehair. Rotating brushes even for less than one minute can greatly increase fruit weight loss.
- Limit length of brush line. Use lower brush speeds on easy-peelers, e.g., 70-90 rpm.
- Dry fruit with an air curtain or sponge rollers. Use high velocity air at 40ºC for two minutes or dehumidified air.

Chlorine wash dump tanks require a minimum 200 ppm of available chorine and pH 7-9. A five minute soak kills surface *Penicillium* spores (no wound penetration). Mix 1.5 kg calcium hypochloride (70% available chlorine) in 5,000 litres. Add sodium carbonate to pH 7.0. You may add 0.02% of detergent to increase effectiveness. Test pH and chlorine level at least once a day.

Wounds and decay

Causes

- *Penicillium* usually infects only injured skin. Minute skin breaks may be infected.
- Wet or turgid fruit are the most easily injured.
- Pressure (e.g., picking), and sharp objects (twigs, poorly clipped fruit, bins, old wax accumulations on rollers) cause oleocellosis or cuts.
- Curing freshly-picked fruit reduces susceptibility to later handling injury.
- Prolonged brushing or using stiff brushes injure the skin, especially of easy-peelers.
- Spores spread through the air and by brushes and dump water.
- Stem end rot may be worse with button abscission, after long or warm-temperature storage.
- Mechanical abrasion of ageing peel causes rind staining of oranges and peteca of Meyer lemons.
- Too low a storage temperature causes dead brown peel lesions or dry pulp.

Method

- Always handle fruit gently.
- Apply any fungicide within 24 hours of picking.
- Chlorine added to a water dump or spray kills spores and protects wounds.
- A 30 second dip in benomyl (e.g., Benlate 50 g/100 litres) reduces *Penicillium*. Fungal resistance is widespread in New Zealand and develops quickly, however, so this is not recommended.
- Imazalil (not for Japanese market) as spray, dip or in wax reduces *Penicillium*, and sour rot (Geotrichum). Ensure good coverage, and maintain correct concentrations over time.
- With 2,4-D at 500 ppm in long storage, buttons are retained and stay green, and decay may be reduced. Not registered for use in New Zealand.

Fungicide treatments (apply within 24 hours of picking):

- Imazalil stops sporulation by *Penicillium* infection. Dip or drench fruit 500-750 ppm with full coverage. Usually up to 1 tonne fruit/100 litre mix.

Thiabendazole to control *Diplodia, Phomposis, Penicillium* (resistance may develop), but ineffective for *Alternaria, Geotrichum*. Best applied as spray 2,000 ppm with full coverage. Keep mix well agitated and check for nozzle blockages.

Table 4.2.9 Causes of peel punctures

Picking	On tree	Transport	Shed
Fingernails	Twigs, birds	Rough bins	Stem end contact on dumping
Clipping	Insects	Compression in bins	Fingernails on raking fruit
Debris in apron	Fruit movement		Drops and sharp edges
Rolling about in apron			Wrong brushes, excess brushing
			Re-clipping
			Box/crate filling

Wounding test (for monitoring)

Soak fruit for five minutes in 0.1% indigo carmine plus a few drops of wetting agent and also 0.5% hydrochloric acid.

Peel injuries appear blue-green.

Waxing

Fruit coatings improve visual appeal and reduce weight loss in fruit.

- Natural materials, e.g., carnauba and shellac-based coatings are required by Japanese markets.
- Polythylene fruit coatings are also available. Coatings vary in cost.
- Some coatings cause off-flavours, especially in fruit held at high temperatures.
- There is less control of rot when a fungicide is combined with the wax. Chemical formulations, e.g., wettable powder, may not be compatible with wax so follow manufacturer's instructions.
- Coatings are better applied to fully dry fruit.
- Use 1.0-1.5 litre coating per tonne of fruit. (Refer to the manufacturer's instructions).
- Pulsed spray application good. (Very high pressure may destabilise formulation). Wax application by dripping on revolving brushes less satisfactory. (Wash brushes in water when finished to keep them soft).
- Wax coating may be thick (dip) or uneven (foam).
- Dry coated fruit immediately, e.g., air at 30-40°C for 2-2.5 minutes. A high air velocity is better.
- Coatings minimise the risk of high weight loss from brushing injury to fruit.

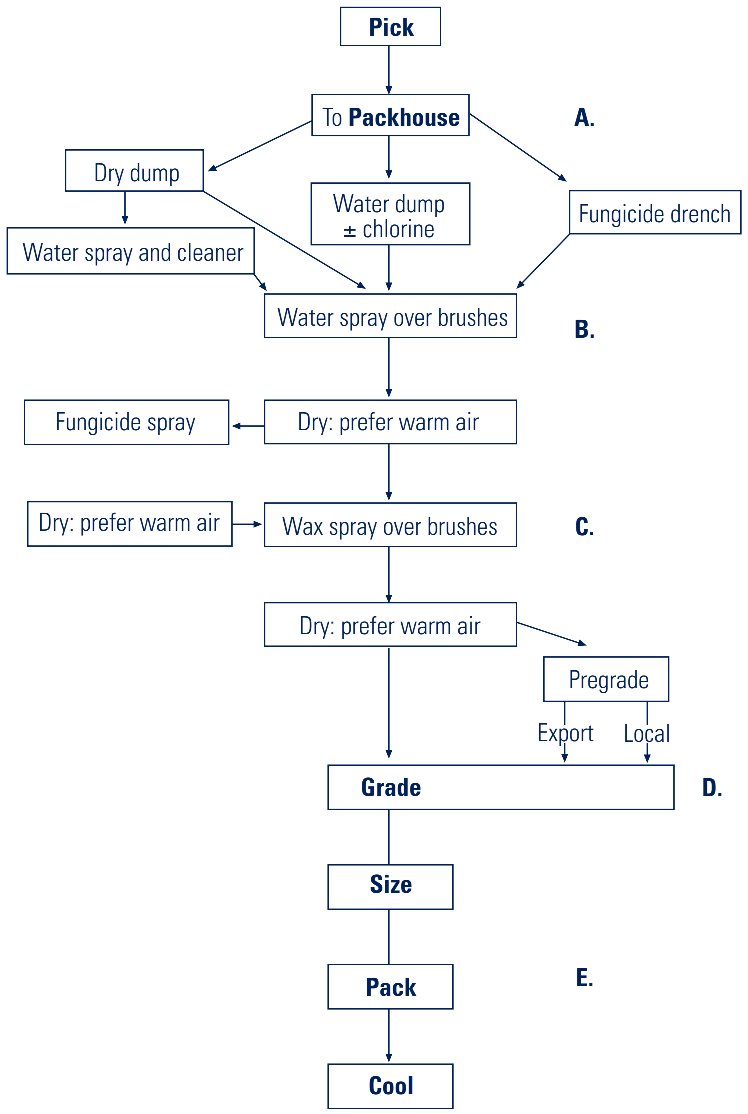

Figure 4.2.1 Post-harvest Citrus Handling System (examples)

In the flow chart, key functions to be understood, effectively staffed, controlled, and improved over time include:

A. Receipt: Pre-packing storage
Defect assessment
Assessment of risk of fruit injury
Wet dump composition

B. Washing: Fungicide application
Brushing
Drying

C. Waxing: Rates and type of coating
Fruit coverage
Drying

D. Grading: Standards
Size bands
Consistency and throughput

E. Packing: Fruit uniformity
Fruit labels
Carton weights
Stamping
Carton condition

Packing

- Lemons picked silver-green may be cured by holding at 15-20ºC, 90-95% humidity for three to six weeks. This results in thinner peel, increased juice content, and a peel that better withstands handling.
- Fruit should not be held at ambient conditions more than three days before packing and storage. Avoid cold draughts, as dehydration may cause oleocellosis.
- Pack only sound, within-grade fruit. Fruit within a container and grade must be of consistent quality. Pack type, size, and fruit diameter bands as required by the market.
- Usually loose-fill 5 or 10 kg (net) cardboard boxes (export), and 18 kg plastic crates or net stockings (local). Label the cartons and/or crates to match market requirements.
- Respond to seasonal changes in market demand in fruit quality characteristics.
- There should be no physical mishandling of packed fruit, and lower the fruit's temperature as soon as possible.
- Institute packhouse monitoring, e.g., after the grading table: sample and monitor defects and fruit size for each size band, at least once a day. After packing: sample packs across all fruit sizes frequently during the day for detailed assessment of major, minor, quarantine, and other defects in comparison with standard specifications.

Storage

- Decrease fruit temperature within two to three days of harvest especially if it is to be stored or exported sooner in warm weather.
- Optimise temperature, storage time, and handling methods to minimise fruit loss (decay, off-flavour) or downgrading (weight loss).
- Citrus boxes must be well vented and properly stacked for good air movement in storage.
- Monitor fruit storage temperature frequently to (0.5ºC), preferably with automatic temperature recording, e.g., every four hours.
- Avoid unnecessary time in storage or exposure to ethylene to avoid fruit looking tired, increased button drop, and rots, and yellowing in lemons.
- Avoid fruit warming in transit. Ideally precool, e.g., to 7ºC first.
- Fruit acid (%) falls after about four weeks cold storage, e.g., in early picked Satsuma.
- Postharvest ethylene treatment may be used with care, to reduce green peel colour, e.g., in Harward Late, mandarins, and lemons.
- Low storage temperatures cause pulp dryness and peel browning. High temperature promotes button abscission, early stem-end rot and decay, and shortens storage life.
- Typical storage conditions are:
- Lemons 12-14ºC, 85-90% humidity
- Oranges 4ºC
- Mandarin 5-6ºC
- Fruit normally store satisfactorily 5-8 weeks. Disorders increase with long storage.

Growing Citrus in New Zealand
A practical guide

Section 5.
Calendar of Operations

5.1 Calendar of operations

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5.1 Calendar of operations

Noel Brown

The following calendar shows the likely growth stages and operations in a year of citrus growing. For details of operations and key timings you should refer to relevant chapters in this manual. It is not possible to cover all situations, but the calendar is split into sections. These are: planting and caring for a new planting; nutrition; weed, pest and disease control; crop and harvest management; and husbandry topics, such as crop thinning, pruning, irrigation and frost control.

For all operations, dates will differ significantly from district to district. In drier areas, such as Gisborne, there is at present little need to monitor or spray for *Verrucosis* or *Alternaria*. In some places fruit may mature much earlier than in others, even in the same district. The calendar shows the earliest date a situation or operation may occur.

With lemons there may be two to three harvest periods, and these will vary with cultivars and market requirements.

Some operations specific to organic or sustainable growing and their timing are shown on the calendar. Refer to the chapter on organic management for the relevant information. It is suggested that all growers read that chapter to assist their understanding of the various pests and diseases on citrus.

For profitable citrus growing, trees must establish and grow rapidly to produce high yields of good quality fruit that meet market requirements.

A number of operations are critical in determining fruit quality in the market place: tree nutrition; tree and orchard management; correct harvest date; harvesting dry fruit and curing fruit where appropriate; careful handling from tree to supermarket with good hygiene, and fruit that is substantially free from pests and diseases. Dirty, bruised and marked fruit is not wanted by the markets.

Figure 5.1 Annual calendar of operations (Management operations common to all cultivars unless otherwise shown)

Month	Growth stage	Planting and caring for a new orchard	Nutrition	Weed, pest and disease control	Crop and harvest management	Other
March		Have quality trees ordered		Check for scale, mites, leafroller, mealy bug regularly over the sumer		Check soil moisture and irrigate if needed.
	Autumn growth flush	Soil test. Check drainage and install system if needed			Final thin on mandarins.	
		Control problem weeds.	Apply N fertilisers.	Spray to keep weed free under trees.		Mulch trees for weed control and fertility.*
April	Early mandarins near harvest maturity†.	Cultivate deep rip and incorporate fertilisers prior to planting if needed.	Monthly foliar sprays fish/ seaweed etc*.	Avoid glyphosphate contact with fruit as it will mark fruit.		Prune shelters.
		Create planting mounds if they will be used.	Soil test in autumn/ winter every 2 years at marked sites.	Brown rot copper sprays on lower metre of tree early winter.	Check early Satsuma mandarins for Brix and acid levels	Clean drains.
		Plan irrigation.		Watch for slugs/snails.		Stopdrop on navels and grapefruit.
	Colour break in navels.	Plant in autumn or spring. Keep bud union clear of soil.			Watch for rind puffiness.	GA_3 at colourbreak for late harvest of navels.
May			Mulch*.			Frost precautions. Cultivate, mow, irrigate.
	No root and shoot growth. Nutrient uptake by roots ceased.				Check Brix and acid levels of mid season mandarins.	
June	Mid season mandarins near harvest†.	Use residual herbicides with care.	P, K, S, Mg, Ca, Lime applications and any trace elements if needed.	Remove dead and weak shaded shoots to assist melanose control		
			Avoid excess K levels in Gisborne.		Lemon harvest at silver green.	GA_3 for flower thinning of Satsuma mandarins.
July			Spread compost, RPR, lime, gypsum, dolomite etc as required*.		Check navel Brix and acid.	Prune lemons after harvest. Open up canopy and remove dead twigs.
	Harvest navels, grapefruit & lemons†.			Apply residual herbicides		
August		Install irrigation systems.	Apply N fertilisers in 'on year' with navel and Valencia oranges to reduce biennial bearing.			Second Stopdrop for navels and grapefruit if they are to be harvested late. Prunning after harvest and before flowering.
September	Harvest Seminole tangelos† Richards Special near harvest†.	Apply fertilisers if needed taking care to avoid contact with trunk.			Check Brix and acid on tangelos and others near mature.	
	Spring growth flush.		Foliar spray monthly over spring and summer*.	Check for scale, mites, aphids	Check granulation in navels.	Check and flush irrigation system.
		Plant maize windbreaks. Maintain weed free over summer months.		Spot spray weeds		Culivate if used for the summer period.
October	Flowering begins soon.	Rub off unwanted lower shoot Check trees regularly for citrus red mite.	Foliar fetilisers applied to growth flush Consider N, P, Mn, Zn, Mg Mo, B.	Fullers rose weevil. Maintain good weed control and remove low branches		
November	Fruit set. †Harwood, Encore near harvest.			Apply trunk barriers if required. Verrucosis protection as appropriate†.		Leave headlands unmown for predator habitat. Irrigate for good moisture levels needed for fruit set
	Fruitlet drop begins.	Fertilisers. Tree training and shoot removal.		Wet weather diseases. Thrip control.		Pruning and hedging after flowering.
December				Weed control - spot spray.		
	Growth flush.	Remove any flowers & young fruit. Foliar fertilsers.		Fuller rose weevil, scale, leafroller, mealy bug, citrus red mite, rust mite.	Hand thin mandarins after fruit drop has ended	Deficit irrigation for Satsuma fruit quality.
January	Rapid fruit sizing. Regreening of Harwoods and Encore.	N fertilsers. Rubbing lower shoots. Watch for aphids and control if numbers are high.				
February		Leaf sampling for nutrient analysis.		Second had thin on mandarins.		
March	Autumn growth flush.	Foliar fertilisers if deficiency symptoms present.	Foliar fertilisers if required.	Verrucosis protecion on young autumn growth. Snails.		
		Autumn weed control.	Gound applied N fertilisers.	Autumn weed control.	Final hand thin to remove reject mandarin fruit. Plan for GA_3 in June for fruit thinning of Satsuma mandarins.	

Note: Lemons have three growth flushes and fruit sets to protect.

**Operations in organic culture*

†Test for Brix:acid

_Verrucosis, botrytis, melanose and alternaria. See chapter for details on control and susceptible cultivars.

Growing Citrus in New Zealand

A practical guide

Section 6.

Pests and Diseases

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New Zealand Citrus Growers Inc

6.1 Citrus viruses

Pauline Mooney

Many different viruses and virus-like diseases affect citrus trees. Symptoms vary from relatively harmless infections, such as citrus vein-enation virus, to rapid death of trees, as caused by severe strains of citrus tristeza virus. Although the majority of citrus viruses and viroids do not kill the trees, most are debilitating and will reduce growth. They may also have adverse effects on external and internal quality of the fruit and therefore reduce overall production of an orchard.

The virus and virus-like diseases currently known to occur in New Zealand are citrus tristeza virus (CTV), citrus vein-enation virus (CVEV), citrus psorosis complex and citrus exocortis viroid (CEV).

Citrus tristeza virus (CTV)

Citrus tristeza virus (CTV) represents the biggest threat to worldwide citrus production. It is believed to have originated in Asia, where it existed unrecognised for centuries, possibly because the commonly grown citrus cultivars were highly tolerant. CTV quick decline of trees on sour-orange rootstocks was first identified in Australia and New Zealand in 1940. The CTV had not been isolated at that time and the death of the trees was attributed to a scion:rootstocks 'incompatibility problem'.

In retrospect, this misidentification of the disease was very fortunate, as the New Zealand citrus propagators of the day had to use altemative rootstocks such as *Poncirus trifoliata* (or 'trifoliata'), citranges, and sweet orange which did not show this 'incompatibility problem'. Consequently, although we have the quick-decline strains of CTV in New Zealand, our industry has been based on rootstock varieties resistant or tolerant to CTV and we have not suffered the devastating tree losses to CTV of those counties using sour orange as their major rootstock variety.

Unfortunately, strains of CTV that create severe stem pitting can cause losses even on CTV tolerant rootstocks. Tree stunting and yield losses due to these strains of CTV are evident in New Zealand citrus orchards.

Since 1993, CTV isolates have been collected from superior clonal trees of 33 different citrus cultivars grown in the different citrus growing regions of New Zealand. Screening of CTV isolates on Madam Vinous, Eureka lemon, West Indian lime, and sour orange indicator seedlings demonstrated that severe stem pitting (Figure. 6.1.1) and seedling yellows strains of CTV were widespread throughout New Zealand. Milder forms of the disease were produced by some isolates of the virus, which either lacked both the seedling yellows and stem-pitting symptom components or lacked seedling yellows symptoms but expressed a mild form of stem pitting. Fortunately, the orange-stem pitting CTV strain recently found in Australia and Brazil has not been found in New Zealand.

CTV is spread in the field by aphid species which transmit the disease with varying degrees of efficacy. The most efficient vector of CTV is the brown citrus aphid (*Toxoptera citricida*), which is widespread in New Zealand. CTV is also readily spread in infected budwood. Consequently, we must be aware of two factors: (1) the need to stringently exclude any introduction of severe strains, and (2) the need for mild strain protection of susceptible New Zealand citrus cultivars in the future.

Strict control by quarantine must be continued in order to prevent the introduction of more severe strains, which may attack combinations other than those on sour orange or attack cultivars which are tolerant to strains already present. For growers and nurserymen, this means never ever considering illegal importation of citrus budwood.

The New Zealand CTV Cross Protection Programme was initiated in July 1993. Cross protection works upon the basis that if you inoculate trees with mild CTV isolate (symptomless or causing only mild symptoms) and later infect with a severe isolate, the symptoms of the severe isolate will not be expressed. This approach at present appears promising in controlling stem-pitting symptoms in trees on tolerant rootstock varieties. Once reliable mild strains have been identified, susceptible cultivars will be pre-immunised with the mild strain and budwood of these cultivars will be released through the New Zealand Citrus Budwood Scheme.

Citrus psorosis

Citrus psorosis is a disease of citrus commonly known as scaly bark. It causes a loss of vigour which is accompanied by reduced fruit quality and dramatic reduction in yield. Severe infections can result in the death of scaffold branches and occasionally the entire tree.

Psorosis is now believed to be a complex of diseases with each component caused by a different virus, and each differing widely in its effect on the trees. Based upon their symptoms, two distinct forms of the disease, Psorosis A and Psorosis B, have been identified. Psorosis A causes bark scaling lesions on the trunk and limbs of sweet orange, mandarin, and grapefruit cultivars (Figure. 6.1.2). Gum may appear on the edges of these lesions and young xylem may become impregnated with gum. Psorosis B has similar but more severe lesions and causes distinctive chlorotic flecking and streaking on young leaves (Figure. 6.1.3) and sunken regions on the rind of the fruit. Occasionally in a nursery situation, shock symptoms on new shoots of susceptible cultivars may be observed (Figure. 6.1.4). The shock symptoms are characterised by the sudden death of young shoots.

Purification of viruses from leaf and bark tissues of trees of Satsuma and tangor cultivars has identified mixed infections of two distinct virus particles: rigid and flexuous rods. Electron microscope observations of these particles suggest that these trees were infected with the citrus ringspot virus, a component of the psorosis complex. These results, coupled with observations of bark scaling and leaf flecking in field trees of Satsuma mandarin, New Zealand grapefruit, tangor and tangelo cultivars, suggest that citrus psorosis virus is reasonably widespread in New Zealand. Most citrus species are symptomless carriers of this disease complex. The psorosis virus complex can be transmitted both mechanically and in infected budwood. It can also be transmitted through seed, hence it is important to ensure a psorosis-free source of seed is confirmed before propagating rootstocks for production. At present, psorosis is the only known seed-borne citrus virus.

Citrus vein-enation virus

Citrus vein-enation virus is widespread throughout the cooler citrus growing regions of the world. It is symptomless in the majority of citrus cultivars and is not considered of major economic importance. CVEV is spread by the brown citrus aphid and in infected budwood. It is linked to the formation of wood galls on the trunks and branches of rough and Volkamer lemons. Severe infection on these rootstocks has been reported to eventually cause tree decline. Rough lemon is not a commercial rootstock in New Zealand and consequently, although widespread, this pathogen does not pose a major threat to our industry.

At Kerikeri Research Centre, graft-transmission by bark patches from field trees of citrus to sensitive indicator plants has confirmed the presence of CVEV. Symptoms of enations have been observed on the leaves of indicator plants bark-grafted with patches from a wide range of cultivars from all citrus-growing regions in New Zealand. Vein-enations appear as small galls on the veins on the underside of the leaves (Figure. 6.1.5).

Viroids

Viroids are the smallest and structurally best characterised infectious agents known at present. Unlike viruses, which have a protein coat, viroids are simply pieces of naked RNA. The two viroids of greatest significance economically are citrus exocortis viroid (CEV) and cachexia viroid (CVIIb). Citrus viroids are primarily transmitted through infected budwood. They are also readily transmitted mechanically on infected cutting and pruning tools.

Although we escaped the impact of CTV quick decline by basing our industry predominantly on trifoliata, we do have a problem with this rootstock, as it is particularly sensitive to infection by CEV. Symptoms of CEV infection in trees on trifoliata first become apparent four to eight years after planting, and include mild to severe bark cracking and scaling on the rootstock portion of the tree (Figure. 6.1.6). The bark cracking and scaling impedes the flow of both nutrients and water between the roots and canopy of the tree, resulting in reduced tree vigour, stunting, and losses in fruit quality and yield.

Citrus viroid detection and identification is based upon symptoms produced on the biological indicator Etrog citron. Graft-transmission of viroids using buds from infected field trees to Etrog citron indicator plants produces leaf symptoms indicative of viroid infection, including various degrees of leaf curling (Figure. 6.1.7). The presence of the viroid(s) is then confirmed, confirmation being based upon banding patterns of extracted viroid RNA analysed by sequential polyacrylamide gel electrophoresis. In New Zealand, CEV has been extracted and positively identified from Villafranca and Genoa lemons.

Orchard and nursery hygiene

Citrus viroids are readily spread through infected budwood, on infected cutting tools (e.g., secateurs, clippers, and budding knives) and can be spread from infected to neighbouring trees within an orchard by root grafting. Once a tree is infected with a viroid there is no way, other than pulling it out, of getting rid of the infection. Fortunately, mechanical transmission is easily prevented through the use of clean budwood and simple hygiene techniques. Hygiene is particularly important in the nursery. Sterilisation of budding knives and secateurs should be done at least between each budding batch. A sodium hypochlorite dip (e.g., commercial strength Janola) for a few seconds will effectively sterilise blades; this should be followed by a neutralising dip in a mild acid solution, such as white vinegar, to prevent blade corrosion.

Protection

There are no cures for virus or viroid infected trees. In order to keep New Zealand citrus orchards free from debilitating citrus pathogens the following must be ensured:

- Secure quarantine systems to eliminate diseases in legal budwood imports.
- Stringent border checks to stop illegal imports of infected budwood.
- Good orchard hygiene to prevent viruses and viroids spread.
- Promotion of the use of indexed budwood supplied by the New Zealand Citrus Budwood Scheme.
- Continued research into CTV mild strain selection for protection against severe strains of citrus tristeza virus.
- Processing of all commercial citrus cultivars through shoot-tip grafting in order to eliminate debilitating viruses and viroids.

Figure 6.1.1 Citrus tristeza virus stem-pitting symptoms evident under the bark on young shoot of Madame vinous sweet orange.

Figure 6.1.2 Citrus psorosis bark-scaling symtoms on Silverhill Satsuma mandarin trunk.

Figure 6.1.3 Citrus psorosis chlorotic flecking and streaking on young leaves.

Figure 6.1.4 Citrus psorosis shock symtoms on nursery plant.

Figure 6.1.5 Citrus vein-enation virus galls on underside of leaf of sour orange seedling. Insert shows close-up of galls.

Figure 6.1.6 Citrus exocortis viroid bark cracking on trifoliate rootstock.

Figure 6.1.7 Citrus exocortis viroid leaf-curling symtoms on Etrog citron (healthy plant in the right)

6.2 Citrus diseases

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Introduction

New Zealand is one of the wettest regions in the world in which commercial citrus is grown. Under these humid conditions, fungal and bacterial diseases thrive. These diseases are responsible for most of the blemishes which occur on the rind of fruit and which reduce market value. Citrus growers need to know the causes of diseases so that effective control measures can be taken.

Melanose

Melanose (Figure. 6.2.1) affects most varieties of citrus and can be particularly severe on grapefruit. Typical symptoms are small, reddish to dark-brown, flattened or raised scabs (0.5-1.0 mm in diameter) on fruit, leaves, and stems. The scabs may occur singly, or in masses which can impart a brown varnish-like coating over affected parts. Where infection is heavy, leaves and stems may be severely distorted. On fruit, symptoms can range from isolated 'fly specks' to large areas of scabbing and discoloration that sometimes resemble rust mite injury. Tear-streak and water-droplet patterns of scabs on fruit and leaves, and the rough, sandpaper-like feel of infected leaves and stems of some varieties, are characteristic features of melanose.

The disease is caused by the fungus *Diaporthe citri* (*Phomopsis citri*), which lives and reproduces in the dead wood on a tree. Spores are formed in microscopic fruiting bodies embedded within the dead tissues. During wet conditions, spores are extruded to the surface through small pores and dispersed throughout the tree by rain. Rain showers during the day, with trees remaining wet throughout the night, are ideal conditions for melanose infection. Spores being washed over the fruit leads to the characteristic streaks and tear drop patterns.

Only young, rapidly growing tissues can be infected by melanose. By the time leaves are fully expanded they are resistant. The stage at which fruit are no longer affected is not known with certainty under New Zealand conditions, but it is generally considered that when oranges are about 40 mm in diameter and grapefruit about 80 mm in diameter, they are no longer susceptible.

The early symptoms of melanose are not easily seen against the dark-green background of young fruit but become visible as the fruit changes colour. This often leads to the mistaken impression that new infections are occurring late in the season.

Melanose scabs on fruit, leaves, and twigs represent a 'resistance reaction' by the host that halts further invasion of the tissues. The fungus does not usually survive in the scabs, and does not spread from fruit to fruit or from infected leaves to fruit.

Effective control depends on reducing the spore production in the canopy by removing dead wood, combined with protecting young tissue from infection with fungicides. Ideally, dead wood should be removed annually. Weak and overgrown shoots and those growing on the underside of branches and terminal clusters should also be removed during winter pruning. This will remove a potential source of dead wood and open up the canopy, allowing better spray penetration and coverage.

Copper fungicides (copper oxychloride or cupric hydroxide products) are the mainstay of melanose control. Phaltan also has an approved label claim for melanose control in New Zealand.

Young fruit are extremely susceptible from petal fall onwards. A copper spray before blossom opening will ensure fungicide in the canopy is being redistributed on to the young fruitlets as the flowers open. A further fungicide application should be made at about one-half to two-thirds petal fall and another three to four weeks later if wet conditions occur. Copper fungicides applied after infection has occurred can accentuate the symptoms of melanose.

Brown spot (Alternaria spot)

Brown spot (*Alternaria* spot) (Figure. 6.2.2), occurs on fruit, leaves, and twigs of some types of citrus. Typical symptoms on fruit are conspicuous circular, dark-brown to black spots varying from small, dark, pin-heads to circular spots 3-5 mm in diameter. The spots may be depressed or be in the form of corky scabs raised above the rind. Spots are often light-brown or grey in the centre with a dark margin. It is common to have a range of sizes and types of spot on one fruit. Fruit affected when very young become distorted and many fall from the tree. On succulent young leaves and stems, spots may coalesce into irregular patches and will occasionally cause die-back of the shoot tips. Infected leaves age prematurely and fall from the tree before hardening off.

The disease is caused by the fungus *Alternaria citri*. The fungus is a saprophyte, living and reproducing only on dead tissues. Germinating spores produce a toxin that kills the cells below and around the position of the spore. The fungus then establishes in the dead tissues. Vegetative growth is affected only while it is tender and actively expanding. Fruit are particularly susceptible while very young but can be damaged at any time from fruit set until harvest, but early fruit infections cause the most extreme symptoms, often causing fruit drop. Later infections disfigure the fruit and lower its market value.

Dew, intermittent rain, and humid conditions promote spore formation and germination. Spores can be produced on dead tissue within 24 hours of its becoming wet, and are readily dislodged and dispersed by rain or wind. Symptoms appear within two to three days of spores germinating on the surface.

Infection sites within the canopy are the most important in perpetuating the disease. The most common sources of spores are spots on fruit, lesions on young leaves, and the abscission surfaces of buttons following fruit drop. In general, only a small proportion of spots on fruit support spore production. Lesions on young leaves are important sources of infection during growth flushes. However, they soon fall to the ground where they rapidly decompose. Any period of fruit drop will result in a large number of buttons available for colonisation and sporulation near the developing fruit.

The disease is restricted to only a few varieties of mandarin, tangelo, and tangor. In New Zealand, *Alternaria* is most severe on Seminole tangelos. It can also affect Dweet tangors.

The most appropriate long-term solution to brown spot is to grow only resistant varieties. Where susceptible varieties are grown, control is almost totally reliant on fungicides.

The programme of copper sprays used to control melanose will also protect against *Alternaria* . Champ, Rovral, and Dithane M45 have approved label claims for use against *Alternaria* . All are protective in nature, therefore regular applications will be necessary for effective control. Applications should start before spring growth and be maintained over the flowering period. Because fruit can be marked by *Alternaria* at any time, in severely affected blocks particular attention should be given to growth flushes and periods of heavy natural fruit drop, which will be providing an abundance of sporulation sites within the canopy. The long-term aim should be to reduce the amount of disease in the canopy (reducing the amount of inoculum) and to maintain it at a low level. This will greatly facilitate control from season to season.

Citrus scab (Verrucosis)

Citrus scab (verrucosis) (Figure. 6.2.3) affects the fruit, leaves, and stems of lemons and some other citrus varieties. Infections take place on juvenile tissues, leading to the typical raised, grey to light-brown, corky scabs on fruit and leaves often accompanied by conspicuous distortion of the leaf laminae and surface of the fruit. In severe cases, the petals and sepals of developing buds also become infected. Buds become hardened and open irregularly. Water held between touching leaves and fruit promotes infection, and often leads to patches of severe scabbing on fruit. As the fruit enlarge, the scab surface may break up into small, fine scabs that can resemble wind scar. The distortions caused by scab can sometimes resemble those caused by *Botrytis*. Both may be present on the same fruit and diagnosis can be difficult.

Citrus scab is caused by the fungus *Elsinoe fawcettii* (*Sphaceloma fawcettii*). The fungus lives in the corky tissues of the scabs. During wet weather, spores are produced on the scabs and are spread by wind-driven rain and rain splash. The fungus can infect citrus at almost any time that young, succulent growth is present. Leaves are most susceptible to infection just as they emerge from the bud and they become immune before reaching full size. Fruit remain susceptible to infection for about three months after petal fall.

Different cultivars vary in their susceptibility to scab. Highly susceptible cultivars commonly grown in New Zealand are Yen Ben, Villafranca, Meyer lemon, Lemonade, and Clementine and Kara mandarins. Satsuma mandarins are mildly susceptible.

Copper fungicides (copper oxychloride, cupric hydroxide products) and Phaltan have approved label claims for control of scab. Applications should be made before flowering and again at half to three-quarters petal fall. Further applications may be made at three to four week intervals if the orchard is heavily affected. A simple guideline is to respray protectant fungicides after 100 mm cumulative rainfall. In orchards where the disease is widespread, application of copper fungicide just before the spring growth flush will reduce infection on the young leaves and petals and reduce subsequent disease pressure on the highly susceptible juvenile fruit.

The disease tends to spread quite locally, leading to distinct 'hot spots' in orchard blocks. As with *Alternaria*, if the disease within the canopy can be maintained at a low level it should be relatively easy to control.

Botrytis blossom blight and fruit distortion

Botrytis blossom blight and fruit distortion (Figure. 6.2.4) are caused by the common grey mould fungus, *Botrytis cinerea*. During wet or humid weather, the fungus can establish on citrus petals and stamens as a conspicuous furry growth of grey fungal threads and powdery spores. This form of the disease can destroy individual flowers, clusters of blossom, or initiate a die-back that progresses several centimetres down the peduncle (flower stalk). Fruit distortion arises when infected petals and stamens cling to the surface of the newly formed fruitlet. The fungus causes microscopic damage to a few epidermal cells which, as the fruit expands, gives rise to unsightly distortions in the form of projections and ridges. Severe cases are grotesquely misshapen, but mild cases are difficult to distinguish from mild symptoms of citrus scab (verrucosis).

Botrytis can also cause a destructive fruit rot (grey mould) in stored citrus but is not normally a problem in New Zealand.

Botrytis can live and produce spores on all types of decaying plant material. In lemon orchards it is perpetuated in the dead petals and stamens of successive flower flushes throughout the year. Periods of wet weather lead to the production of huge numbers of spores on the dead tissues and the subsequent colonisation of new blossoms. Because the fungus thrives at cool to moderate temperatures (12-18ºC), *Botrytis* is active throughout the year.

Blossom blight and fruit distortion are most serious on standard lemon cultivars. Fruit distortion can also occur on Meyer lemons and Seminole tangelos. Cultivars of standard lemons differ in their reaction to *Botrytis*. While Yen Ben appears to be more susceptible to blossom blight than either Genoa or Villafranca, the latter varieties are more severely affected by fruit distortion.

There are no fungicides with approved label claims for control of *Botrytis* in citrus. It is probably questionable whether it would be economic to apply fungicides specifically for *Botrytis*. However, petal fall applications of fungicide for other purposes (melanose, verrucosis, *Alternaria*) will possibly exert some control over it.

Satsuma anthracnose

This disease can be very severe on Satsuma mandarins in all citrus growing areas of New Zealand. In some years it is the main cause of fruit rejection at grading. Symptoms range from diffuse brown speckling and tear-drop patterns, to brown, scald-like patches on the surface of the fruit (Figure. 6.2.5). Severely affected areas are at first firm, shiny and dark-brown with a distinct margin. With age, the skin tissue at the centres of the scalded areas tends to collapse and dry out. Superficially, the symptoms may resemble oil burn. When fruit are lightly infected, the disease seldom develops beyond the speckle or tear-drop stage and represents a primarily cosmetic disorder. Severely infected fruit may rot in storage.

The disease is caused by the fungus *Colletotrichum gloeosporioides*, which invades moribund woody tissue in the tree. The fungus forms fruiting bodies on the dead tissue and produces large numbers of spores that are spread by rain wash and splashing. The spores germinate on the surface of the young fruit and a few cells in the immediate vicinity of each infection site die. With light infection, the fruit tend to become speckled. In Satsuma mandarins, the peduncles left on the tree after thinning are a major source of spores. Fruit located directly below infected peduncles are usually severely disfigured by teardrop staining and 'scald' symptoms. Infections can occur at almost any stage of fruit development but symptoms on young fruit are not easily seen against the dark green background of the fruit. As the fruit begins to colour affected areas become obvious, often giving the mistaken impression that the disease is just occurring or is 'spreading'. In most cases infection would have taken place many weeks beforehand.

There has been no research on the details of the life cycle or control of this disease in New Zealand. Observations suggest that peduncles become infected soon after thinning and produce spores within the same season. As a result, most developing fruit are in close proximity to colonised peduncles that produce a new crop of spores each wet period. This gives particular problems for control. There are no fungicides with label claims for the control of this disease. Fungicides such as copper (copper oxychloride, cupric hydroxide products) Dithane M45 and Phaltan are likely to be active against the fungus. A more detailed knowledge of the life cycle of the fungus is required in order to recommend the most appropriate timing of applications.

Phytophthora

Phytophthora is a soil-borne fungus which can cause diseases of the trunk (collar rot, gummosis), roots (root rot), and fruit (brown rot). A number of different species of *Phytophthora* affect citrus in New Zealand. *P. citrophthora* and *P. citricola* thrive at moderate temperatures and commonly affect roots, trunks and fruit. *P. hibernalis* and *P. syringae*, also found in New Zealand, will grow only in cool conditions (less than 20ºC) and cause fruit rots during extended wet periods in the winter.

In trees with root rot, feeder roots become necrotic and tan to dark-brown in colour. The outer layer of the root sloughs off to expose the internal woody tissue giving the roots a stringy appearance. Above ground, there is yellowing of the leaves, defoliation, and twig die-back. Commonly, one branch or one side of the tree may be more seriously affected than the others.

Dark, water-soaked areas of bark extending from ground level, often accompanied by gum extrusions, are symptoms of collar rot. Under the bark there is a light-brown discoloration of tissues with a distinct margin between healthy and diseased wood. Dead bark soon becomes colonised by other fungi, dries out and breaks away from the tree. The canopy is often yellow and becomes sparse, resulting in a poor, undersized crop.

Although most of the commonly planted scion cultivars are moderately to highly susceptible to direct infection of the bark, losses of trees as a result of above ground trunk and branch cankers are not common in New Zealand.

Poncirus trifoliata (or 'trifoliata'), the most commonly used rootstock in New Zealand, is highly resistant to root and crown infection by *Phytophthora*. Because of the widespread use of trifoliata rootstock in New Zealand, root diseases caused by *Phytophthora* are not common. Troyer citrange also has a high tolerance. Sweet orange is more susceptible.

If susceptible rootstocks are used, care must be taken in nurseries to ensure that only disease free material is distributed to orchards. Nursery operations for susceptible stocks should include hot water treatment of seed (52ºC for 10 minutes), use of fumigated soil or 'new' land for planting stocks, soil drenches (Ridomil), and foliar sprays (Foli-R-Fos, Aliette) to prevent the infection of young plants.

Trees on susceptible rootstocks should only be planted in well-drained sites, and over-watering should be avoided. Trees should be budded well above the soil line and planted no deeper than they were in the nursery. Care should be taken to ensure that the bark of the trees is not damaged, that weeds around the trees are controlled, and that the tree trunk is free of mulch and litter. This will improve the air movement and reduce moisture around the trunk.

Trimming diseased bark on trunks and branches and painting the affected area with a slurry of copper oxychloride has been a common method of treating affected trees. More effective methods based on foliar sprays and trunk treatments with phosphorus acid are becoming available.

Brown rot

Brown rot is the infection of citrus fruit by *Phytophthora* that results in a dull grey-brown rot, usually on one side of the fruit (Figure. 6.2.6). The rind remains firm and leathery and there is often a darker spot in the centre of the lesion where the infection began. The rot penetrates deep into the fruit and produces a characteristic pungent odour.

Affected fruit fall readily from the tree, and in high humidity, white fungal growth may become evident on the fruit surface.

Phytophthora grows and reproduces on both living and dead tissue in almost all New Zealand soils. Because the fungus requires water for spore production and infection, root and trunk rots occur most often in sites with poor drainage and frequent waterlogging. Fruit infections are initiated during wet conditions when spores are splashed from the soil on to fruit that are touching, or near, the ground. If wet weather persists, spores produced on those fruit are splashed or blown on to fruit higher on the tree.

The disease attacks fruit of all cultivars and can be particularly serious on lemons and New Zealand grapefruit.

Brown rot can usually be controlled by a combination of cultural and chemical means. The ground should be kept free of ponded water by surface drains or contouring, and weeds and low branches should be removed to promote air circulation and to reduce contact between soil and leaves and fruit. The orchard should be managed to encourage rapid drying of fruit and foliage after rain. Shelter belts should be topped to avoid excess shading, and thinned to ensure air movement through the orchard. Overgrown trees should be pruned to encourage air movement through the canopy.

Fungicide sprays applied to the soil and the lower part of the tree before anticipated wet weather help to prevent brown rot. Copper fungicides (copper oxychloride and the cupric hydroxide range), Dithane M45 and Captan have approved label claims for the control of *Phytophthora* in citrus. Applications are normally made in autumn to provide protection into the harvest season. In very wet conditions, or in orchards with a previous history of heavy infection, a second application may be necessary in July for late harvested fruit.

Sooty mould

Sooty mould is a black, superficial fungal growth on the fruit, leaves, and stems of citrus trees that are infested with sap-sucking insects, such as scale insects, aphids, mealybugs, and whitefly. These insects excrete a sugary substance (honeydew) which provides the food base on which the fungus grows. A range of different fungi can be associated with sooty mould, the most common one in New Zealand being *Capnodium salicinum*.

Although sooty mould does not penetrate the host tissues, in severe cases it can affect tree performance by intercepting light and reducing photosynthesis. Sooty mould on the fruit makes it unsuitable for sale. Washing or brushing may remove most of the mould but enough usually remains to reduce the value of the fruit.

In general, problems with sooty mould indicate high populations of sap sucking insects, which will need to be controlled. Routine spray programmes for soft scale, whitefly, etc., will generally eliminate problems with sooty mould. Oil sprays will have a dual effect of controlling some of the pests that produce honeydew as well as loosening the mould deposits, assisting its removal by wind and rain. Routine copper spraying also helps to reduce the incidence of sooty mould.

Sooty blotch

Sooty blotch is a light-brown shading of the surface of fruit, in patches, or in extreme cases covering most of the surface. The blotches are caused by a single layer of dark-brown fungal threads spreading over the surface. Although the fungus does not penetrate the fruit, it is embedded in the cuticle and cannot be removed by washing. Several fungi are known to cause sooty blotch, the most common being *Gloeodes pomigena*.

Sooty blotch occurs in wet or humid conditions when the fruit remain moist for extended periods. It is commonly found on fruit in the centres of trees and, particularly if there are tall weeds, on the lower branches.

Pruning (to open up and allow aeration of the centres of trees) and skirting (to lift branches above the grass) will help to reduce the incidence of sooty blotch. The routine fungicide spray programmes early in the season for melanose and verrucosis, and later for brown rot (*Phytophthora*), will also protect against sooty blotch.

Green and blue mould

Green mould (Figure. 6.2.7), caused by the fungus *Penicillium digitatum*, is the most destructive post-harvest disease of citrus in New Zealand. Not only can a large proportion of the fruit become rotted, but also fruit lying adjacent to or below rotted fruit in the boxes can become contaminated and disfigured by masses of powdery spores.

The first symptoms of green mould appear two to three days after infection as a clear or slightly discoloured soft, water-soaked spot around a point of injury. The spot expands rapidly (up to 30-40 mm in diameter within 24 hours at temperatures of 21-25ºC). A white fungal growth (the mycelium) appears on the surface of the rot and continues to spread as the spot enlarges, usually remaining about 10 mm behind the expanding edge of the rot. The characteristic masses of olive-green spores are produced first at the centre with the sporulating area extending out over the rot. The whole fruit may be rotted within two to three days and become covered by a dry, dusty, olive-green spore mass. In some cases, practically the whole fruit is affected by the clear rot before surface fungal growth and sporulation occurs. This variation of green mould development is often mistaken for sour rot caused by *Geotrichum candidum*. If the relative humidity remains low, e.g., in packing sheds, the rotted fruit may form a wrinkled, dry mummy. Under moist conditions, as on the orchard floor, yeasts and other fungi also colonise the fruit and it rapidly decomposes.

The fungus is found almost everywhere in orchard soil and debris, and is common in dust and debris in and around packing sheds. The fungus sporulates prolifically and the spores are readily spread by wind and rain splash. Green mould generally requires physical injury to the skin for infection. Spores present on the surface of the fruit germinate in the wound. Even the slightest injuries can lead to infections; most of these probably originate in the field, either from natural injuries or during harvest. The incidence of rots generally increases as the season progresses, with large numbers of infected windfall fruit producing high levels of inoculum in the orchard and heavy dews or wet harvesting conditions providing ideal conditions for infection. Damage inflicted during subsequent packing provides further opportunity for infection. Because, in general, injury is necessary for infection, there is usually little spread from rotted to sound fruit during transit.

The fungus can grow over a wide range of temperatures, from around 3ºC to above 35ºC. The maximum rate of growth occurs from 25-28ºC. At normal citrus coolstore temperatures of 3-5ºC, infections establish and spread slowly. Removal to warmer conditions then leads to the rapid collapse of those fruit.

Blue mould (Figure. 6.2.8), caused by the related fungus *Penicillium italicum*, is less common than green mould but can cause considerable losses in cool-store fruit.

The early symptoms are similar to those of green mould, with a clear water-soaked spot expanding from the point of infection. Generally the rot expands more slowly than green mould and may not cover the whole fruit. The most distinguishing feature is the distinctive blue colour of the sporulating area, surrounded by a relatively narrow band of white, non-sporulating mycelium.

The life cycle of the fungus is similar to that of green mould, with spores of the fungus common both in the field and in packing areas. Blue mould differs from green mould in that it can infect fruit directly and spread from fruit to fruit in boxes.

Care during harvest operations and hygiene in and around the packing shed is essential for reducing losses from green and blue moulds. Cuts to the skin caused by clippers at harvest are the most common source of infection in Satsuma mandarins. Other incidental injuries (thorns, scratches, bruising) also afford entry sites for infection. Harvesting from wet trees (from heavy dew or rain) should be avoided, and care should be taken to prevent the contamination of harvested fruit by soil or mud.

Before the packing season, sheds and storage areas should be thoroughly cleaned and washed with, where practicable, a disinfectant. All debris and old rotted fruit should be removed, and belts and conveyors should be cleaned of accumulated wax and dirt. During the packing season, all reject fruit should be moved well away from the shed area and preferably buried in shallow trenches.

Fungicides, applied as post-harvest dips or cascades, are commonly used world-wide for controlling blue and green moulds. In New Zealand, Bavistan, Topsin M, and Fungaflor have approved label claims for post-harvest treatment of citrus for *Penicillium* rots. Strains of green mould resistant to Bavistan, and Topsin (all closely related dicarboximide fungicides) are common in New Zealand, and these fungicides are now seldom used for control. The requirements of importing countries should be determined before applying post-harvest fungicides to export fruit.

Sour rot

Sour rot (Figure. 6.2.9) is a common post-harvest rot of citrus. Initial symptoms are similar to the initial stages of green mould. A clear water-soaked spot develops around an injury site. As the spot expands it becomes flattened or slightly sunken, often with the development of a light-brown discoloration of underlying tissues. The surface of the spot is often slightly wrinkled. The rot develops more slowly than green mould but eventually causes the collapse of the whole fruit. Under moist conditions, the surface of the rotted fruit becomes covered by a thin film of white fungal growth. Rotted fruit have a characteristic sour odour.

Sour rot is caused by the fungus *Geotrichum candidum*, a common inhabitant of soil. Although spores of the fungus are readily carried by wind or rain splash, contamination of fruit by soil or dust is probably the most common source of spores. Orchard soil and infected fruit can contaminate dipping tanks, washer brushes, conveyors, and other fruit in the packing shed. Infection takes place through injuries to the rind. High moisture content of the rind and high relative humidity is necessary for the initiation of a rot. The fungus is often found as an infection mixed with green mould.

Fungaflor has an approved label claim in New Zealand for the control of sour rot, which is generally difficult to control. Most emphasis should be given to reducing the chances of infection. As with green mould, care during harvesting is necessary to prevent injuries to the rind and contamination of fruit with soil. Fruit dropped on the ground almost always succumb to sour rot. Normal shed hygiene practised for green mould control will also help reduce the incidence of sour rot. Special attention should be given to preventing the introduction of field soil and debris to dipping tanks and fruit washing equipment.

Sclerotinia

Sclerotinia, caused by the fungus *Sclerotinia sclerotiorum*, is only weakly infectious on citrus, and in New Zealand is really only of economic importance for Satsuma mandarins.

Infections, which occur in late spring and early summer under wet conditions, affect lateral growth, causing greyish lesions that often girdle the stem and cause die-back. In Florida, such infections are aptly known as ‘twig blight’.

Sclerotinia sclerotiorum is a widespread fungus that affects a wide range of crop plants and weed species. It overwinters in the ground as a hard, black fungal body known as a sclerotium. During wet periods in late spring or early summer the sclerotium produces a fruiting body, or apothecium, on or just above the soil to the surface. This in turn produces spores, which are released into the atmosphere and carried in air currents. If they land on a susceptible host in the presence of adequate moisture and the right temperature, infection can occur. In the case of Satsumas, laterals can be infected. New sclerotia (produced on the stem lesions) can fall to the soil and carry over to the next season.

Sclerotia can survive in the soil for several seasons. Growing Satsumas on land previously occupied by a susceptible crop, such as kiwifruit, tomatoes, lettuce, or beans increases the risk of infection.

The risk of damage from *Sclerotinia* can be reduced by cultural measures. Cutting out and burning infected and dead shoots prevents the sclerotia from returning to the soil to carry the infection forward to future seasons. Creating an environment in the orchard that will promote quick drying out of the trees after rain (thinning and topping of shelter belts, opening up of canopies) minimises the periods during which infection can occur.

There are no fungicides with approved label claims for the control of *Sclerotinia* in citrus.

Citrus blast

Citrus blast is a disease caused by the bacterial pathogen *Pseudomonas syringae*. The bacterium is often present on citrus leaves, but the disease manifests itself only under wet, cool conditions. It is most active at about 12ºC and rarely progresses at temperatures above 18ºC or below 8ºC. Infection is greatly facilitated by damage to the foliage from strong winds, heavy rain and hail, or other abrasions such as wind rub. Soft young shoots are more susceptible than fully mature shoots.

In New Zealand, infections occur mainly in late winter or early spring, and are often facilitated by strong north-east winds accompanied by heavy rain.

Infections usually start on the petiole or leaf stalk, appearing as water-soaked areas that soon darken to a blackish colour. These infections spread rapidly up into the leaf and down to the young stem. Sap supply to the leaf is cut off and it withers, goes brown, and eventually falls off.

The stem lesions extend above and below the point of attachment of the petiole, which becomes rusty brown in colour. In extreme cases, the stem may be girdled, causing tip die-back.

The same organism can lead to the formation of black sunken pits on the fruit of both standard lemons and Meyer lemon.

The disease can affect all citrus types under conditions favourable for infection, but in New Zealand, experience suggests that mandarins and lemons are the most susceptible. Citrus blast is rarely a problem in well-sheltered blocks.

Control of citrus blast can be achieved by:

- Providing good shelter, especially from the strong, north-easterly winds that are usually accompanied by heavy rain
- Minimising the amount of late-season growth that goes into the winter soft and unhardened
- Applying a protective copper spray in the late winter or early spring
- Tree hygiene

The other fungicides used on citrus such as Mancozeb or Phaltan will not control bacteria and are ineffective against citrus blast. Where infection occurs, prune out infected shoots and burn them.

Figure 6.2.1 Melanose on grapefruit.

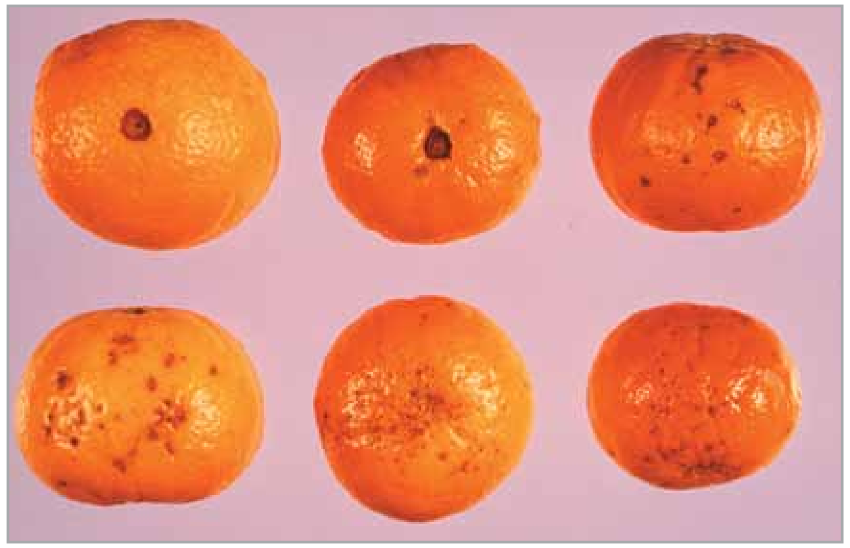

Figure 6.2.2 Brown spot (*Alternaria* spot) on tangelos.

Figure 6.2.3 Lemon scab (*verrucosis*).

Figure 6.2.4 *Botrytis* fruit distortion.

Figure 6.2.5 *Phytophthora* rot on lemon.

Figure 6.2.6 Green mould on Satsuma mandarin

Figure 6.2.7 Blue mould on Satsuma mandarin

Figure 6.2.8 Sour rot on Satsuma mandarin

6.3 Citrus pests

P.R. Sale and P.S. Stevens

In comparison to most crops, citrus has a very wide spectrum of pests. The following chapter has been divided into sections on major and minor pests.

Major pests

Thrips

Damage

Two main species of thrips are found on citrus (Kelly's Citrus Thrips and Greenhouse Thrips). Both species feed by piercing and sucking out the surface cells of leaves and fruit leading to unsightly damage from scarring. Greenhouse Thrips are found feeding on leaves and fruit whereas Kelly's Citrus Thrips are found in flowers and on fruit. Thrips feeding causes leaves to appear pale coloured or silvery. Damage caused by Kelly's Citrus Thrips generally occurs in the early part of the season and damage by Greenhouse Thrips tends to occur in late summer/autumn.

Symptoms of damage may include:

(a) A russet ring around the stalk end when attack is soon after fruit set.

(b) A silvery area often on the cheek of the fruit from mid-late season feeding.

(c) Sometimes a total russeting of the fruit, particularly lemons.

Life cycle

Both thrips species have several generations a year and are active into the winter in mild seasons. Eggs are laid into leaves and fruit. Larvae hatch out and pass through two actively feeding larval stages before pupating. Kelly's Citrus Thrips pupate in the soil beneath the trees, while Greenhouse Thrips pupate on the tree. The non-feeding pupal stages develop into adults.

Adults of both species are about 1.25 mm long, dark brown/black in colour, and narrow in shape with two pairs of feathery wings folded along the back. The wings and legs of Greenhouse Thrips are pale/white, whereas Kelly's Citrus Thrips has dark coloured wings and legs. Immature stages are smaller and paler. Immature stages of Kelly's Citrus Thrips may be an apricot colour.

Control

Good spray coverage is essential as thrips are often located in sheltered places such as between pairs of touching fruit. A petal-fall spray is important to prevent early season damage by Kelly's Citrus Thrips. Summer and autumn sprays may be needed to prevent late season damage by Greenhouse thrips, especially in mild seasons.

For a list of products with label claims for citrus see chapter 6.4. Organo-phosphorus insecticides e.g., Diazinon, Lorsban, Rogor are generally effective against Greenhouse thrips. Oil is likely to enhance control but oil is not particularly effective on its own. To gain effective control of thrips, repeat spray applications are needed as the hatching of eggs can provide new larvae to re-infest trees after a spray has been applied.

In 2000, permission to release a new biological control agent for Greenhouse thrips into New Zealand was gained. This tiny wasp, Thripobius semiluteus, lays eggs within larvae of greenhouse thrips, which ultimately results in the death of the thrips. Thripobius will not provide any control of Kelly's citrus thrips. Applications of broad-spectrum insecticides will kill Thripobius but the future introduction of more selective insecticides will permit Thripobius to reach its full potential.

Mealybug

Damage

Sucks sap, marks fruit, leads to sooty mould.

Life cycle

Three to four generations a year. All stages present throughout the year. Adults up to 3 mm long.

Control

For a list of products with label claims for citrus see chapter 6.4. Organo-phosphorus insecticides, e.g., Diazinon, Lorsban, Rogor, Orthene are options. Oil enhances control and gives reasonable control on its own if good coverage is achieved.

Mealybugs hide in cracks and crevices of the bark, in the middle of fruit clusters, in the Navel of Navel oranges and other fruit with Navels, and under the button of the fruit.

The first one or two sprays after petal fall are important to achieve control before the button closes down on the fruit. Coverage of the main branches is also helpful. Fruit thinning assists control by opening up tight clusters.

Chinese wax scale (Hard wax scale)

Damage

Sucks sap, debilitates trees in heavy infestations, leads to sooty mould.

Life cycle

Normally one generation a year with crawler release February - April. Adults are grey-white with a pinkish tinge and up to 7 x 5 x 4 mm in size. Young settled stages are star shaped and reddish brown with whitish rays.

Crawlers first settle on leaves as the immature 'stars' then a further migration takes place back to the shoots where the adults settle.

Control

Organo-phosphorus insecticides e.g., Diazinon, Lorsban, Rogor. Oil enhances control and gives good control of young stage on its own. February - April is the critical time during the crawler release. Applaud offers a 'softer' option to the normal insecticides.

Soft wax scale

Damage

Sucks sap, debilitates tree in heavy infestations, leads to sooty mould.

Life cycle

Normally one generation a year with crawler release from December - March. Adults are very white with a prolific waxy covering and approximately the same size as Chinese Wax Scale. Crawlers settle on leaves and become a white star shaped immature stage, a further migration takes place later and the adults settle mainly on shoots.

Control

Organo-phosphorus insecticides e.g., Diazinon, Lorsban, Rogor. Oil enhances control and gives reasonable control when used alone if during crawler release. Applaud offers another option. Critical time for control is December - March during crawler release.

Black scale (Olive scale)

Damage

Sucks sap, debilitates tree in heavy infestations, leads to sooty mould.

Life cycle

Normally one generation a year with crawler release December - January. Adults are dark, rounded, 3-5 mm long and with an H mark on the top. Adults settle on shoots and often on fruit stalks close to the fruit.

Control

Organo-phosphorus insecticides e.g., Diazinon, Lorsban, Rogor. Oil enhances control and is effective if used on its own in the crawler release period. Applaud offers a further and 'softer', option.

Soft brown scale

Damage

Sucks sap, debilitates tree in heavy infestations, leads to sooty mould.

Life cycle

Several generations a year, adults oval, flat light brown in colour, 2.5 mm long and usually position themselves along the midrib of a leaf.

Control

Organo-phosphorus insecticides e.g., Diazinon, Lorsban, Rogor. Oil enhances control and can give a reasonable control when used on its own if good coverage is achieved. The December - April period is perhaps the most important in which to achieve control.

Californian red scale

Damage

Sucks sap, debilitates trees in heavy infestations, infested fruit being a serious demerit in appearance, and is a quarantine issue in export consignments.

Life cycle

Several generations a year, adults small, almost circular, flat, reddish brown in colour 1.5-2 mm across. Adults infest leaves, shoots and fruit.

Control

Organo-phosphorus insecticides e.g. Diazinon, Lorsban, Rogor. Oil enhances control and gives a worthwhile result on its own if good coverage is achieved. Applaud offers an alternative and 'softer' option. Although there are several generations a year, most control is likely to be achieved in the December - March period.

Aphid

Damage

Sucks the sap of young leaves and growing tips causing leaves to roll back on themselves from the tips, also leads to sooty mould. Aphids are vectors for some citrus viruses. More a problem on young trees as they can check growth, than on mature trees in the cropping phase.

Life cycle

Aphids fly into an area during migratory flights at various times through the growing season. The Black Citrus Aphid is black with a body up to 2 mm long, which is a typical size for an aphid.

Control

Organo-phosphorus insecticides or oil will give good control. Timing to coincide with an aphid flight period is essential for satisfactory control.

Leafroller

Damage

Caterpillar feeding causes damage to leaves, particularly growing tips and fruit. Damage to fruit early in the season will heal with scar tissue causing unsightly blemishes. Late season damage is often open wounds and can readily lead to infection from brown rot or other disease organisms.

Fruit damaged by leafroller will often fall prematurely.

Small caterpillars can get under the button and pose a quarantine problem in export fruit.

Life cycle

There are several species involved with several generations a year and each generation is not precise.

The moths are small, and are an insignificant brownish colour for most species. Eggs are flat and laid in rafts of several eggs on a shiny plant surface, often the topside of a citrus leaf. Colour of caterpillers varies with the species and diet. They usually have a darker head, legs on each segment, and wriggle vigorously if disturbed. They are tiny when they emerge from the eggs but increase in size to maybe 20 mm or more before pupating.

Control

Most organo-phosphorus insecticides or Bt products. Main period for achieving control is from fruit set to harvest.

Fullers rose weevil

Damage

Causes minor damage to the edge of young foliage from adult feeding. In recent seasons, eggs laid under the button of the fruit have caused significant quarantine problems for export fruit destined for Japan or Korea.

Life cycle

Only one generation a year but can be long periods of adult activity. Adults are greyish brown and up to 8 mm long. Eggs are laid in well protected crevices such as under the button of a citrus fruit. Larvae hatch from the eggs, fall to the ground and burrow into the soil where they feed on plant roots. They pupate in the soil and adults emerge over a long period beginning in the second half of December.

Eggs laid in the early stages of adult emergence probably hatch before the end of the summer, but eggs laid from later emerging adults can go virtually through the winter. It is the later laid eggs that present the biggest quarantine risk as they are more likely to be still viable at fruit harvest.

Control

As the adult cannot fly, the primary control measures are to prevent its access to the trees by skirting up lower branches well above the ground, and maintaining good weed control under the trees. This only leaves the trunk as an access route where a physical or chemical barrier to prevent them crawling up the trunk should complete the job. A regular spray programme of Lorsban every two to three weeks from January onwards will go some way to minimising the problem if the other control measures are not employed or not fully effective.

Citrus red mite

Damage

Sucks the sap, destroys chlorophyll in the leaves, reduces colour in the fruit, increases fruit and leaf drop which leads to reduced productivity.

Life cycle

Several generations a year-the exact number of generations is temperature dependent. Active throughout most of the season including autumn and into the winter. Adults lay single eggs mainly on the underside of leaves. A lens with x10 magnification is required for careful monitoring.

Control

Oil or specific miticides such as Kelthane, Omite, Peropal, and Apollo. A monitoring system developed in Florida is as follows: Sample a minimum of 20 trees over 4 ha. (The blocks are much larger in Florida than in New Zealand). Sample five Leaves a tree from all round each tree. 15% of leaves infested is the threshold to spray.

Natural controls are present in most situations but are drastically reduced by commonly used insecticides. Minimising insecticide use or using soft options such as Bt, oil, or Applaud, gives natural controls the best chance.

Lemon tree borer

Damage

The larvae bore tunnels in the shoots and branches leading to debility, collapse, and death.

Life cycle

One generation a year with egg laying adults flying mainly from September - December, particularly in October - November. Eggs are laid in cracks, crevices, damage or pruning cuts on the wood. The emerging larvae bore into the wood and feed for up to two seasons before pupating and emerging as adults.

Control

Pruning out and destroying collapsed shoots. Injecting holes with insecticide solution, kerosene, or petrol, and plugging the hole. There is a risk of damage to the bark with petrol and kerosene, but the fumes of petrol assist the kill after holes are plugged.

Sealing all pruning cuts, particularly with an insecticidal paint, reduces the risk of infestations.

Minor pests

Citrus bud mite

Damage

Feeds in developing leaf and flower buds causing distortions. Fruits are often grossly distorted with deep divisions and puckering. Standard lemons and Navels appear to be the most susceptible.

Life cycle

Adults are up to 0.15 mm in length and not readily visible with the naked eye. The generation time is up to 30 days and is temperature dependent.

Control

A 1% all-purpose oil spray in autumn is quite effective. When necessary, a repeat application in spring can also be made.

Citrus rust mite

Damage

Feeds on and destroys the epidermal cells of the fruit turning them brown in colour and leathery in texture. Lemons may go somewhat silvery rather than brown. Damage is always seen on the exposed side of the fruit.

Life cycle

Adults are up to 0.15 mm in length and are not readily visible with the naked eye. This is not a widespread pest in New Zealand as temperatures are marginal or it to thrive. When it does become a problem it is usually in the most favoured sites lying to the sun and absorbing the most heat.

Control

An application of the fungicide Dithane M45 at petal fall will usually give an adequate control. A repeat application may be necessary three weeks later.

Cottony cushion scale

Damage

Sucks the sap causing debility to the trees. This is not commonly a pest of economic importance in citrus orchards in New Zealand.

Life cycle

The adult scale is oval in shape and reddish brown in colour. The females produce a large white coloured ovisac which can contain up to 1,000 eggs and from which the pest gets its name.

There are two generations per year. Young immature stages settle on twigs and leaves, but later instars move to larger twigs and branches.

Control

Organo-phosphorus insecticides and oils as applied for other scale insects in the January - March period will give adequate control. In minimum insecticide regimes, natural biological control is likely to be satisfactory.

Guava moth

Damage

Caterpillars feed on large fleshy fruit such as citrus, feijoa and guava.

Life cycle

Little is known of the life cycle either in New Zealand or in Australia. However, in Australia the caterpillars are commonly found feeding in ripening fruit in the autumn. Currently, the distribution of guava moth in New Zealand is restricted to approximately 1000 km^2 in Northland around Ahipara, Kaitaia and Kerikeri.

Control

As guava moth has only recently arrived in New Zealand, there has been no research into effective control measures. However products used to control other types of caterpillars may be effective (see leafroller section).

Katydid

Damage

Katydids feed on foliage, twigs, and young fruit. Their large mouth parts cause significant loss of area on young foliage, and scars on the fruit. Bites are usually so large that a scarred fruit would not be export grade.

Life cycle

The adult is a large green member of the grasshopper family, up to 45 mm in length.

Control

A standard insecticide programme with applications in December and January will normally control Katydids quite adequately.

Citrus flower moth

Damage

Caterpillars feed on blossoms and young foliage. Copious webbing is usually produced. In New Zealand it has been seen more on lemons than other citrus.

Life cycle

The greyish coloured moth is up to 4.5 mm in length, and the opaque pinkish caterpillars up to 5.5 mm.

Control

A normal insecticide programme with applications timed for pre-blossom and petal fall should give an adequate control.

Passion-vine hopper

Damage

Sucks sap and leads to sooty mould.

Life cycle

One generation a year, overwintering as an egg. In late spring or early summer, tufty tailed nymphs hatch and start to feed. Adults with dark lacy wings appear from January onwards and continue to feed until April - May. Adults lay eggs mainly in dead plant tissue, bracken being a favoured host for this purpose.

Control

Destruction of alternative hosts, particularly those favoured for egg laying, in the orchard surrounds. A normal insecticide programme as applied to citrus gives a reasonable level of control.

Citrus nematode

Damage

Feeds on roots in severe cases, causing significant debility of the tree: growth slows, trees stress easily, foliage is pale, and fruit small.

Life cycle

Only females are parasitic, with populations concentrated in the upper soil layers. Life cycle is temperature dependent. Optimal temperatures are from 28-31ºC at which cycle becomes six to eight weeks so New Zealand conditions are suboptimal.

Control

Resistant rootstocks are *Poncirus trifoliata* (or 'trifoliata') or some of its hybrids.

Nursery hygiene and care not to spread soil or plants from an infested area.

Slugs and snails

Damage

Feed on foliage, fruit, and stems of young trees. Fruit damage can facilitate brown rot infection. Slug damage is usually confined to lower branches, snails can be found at the top of citrus trees.

Life cycle

Slugs and snails are active throughout the year in citrus districts, whenever conditions are wet enough.

Control

Create an unfavourable environment and minimise access to the trees. Maintain good weed control and skirting up of lower branches. Good hygiene and weed control up shelter rows as well as in the orchard. Check routinely under plastic sleeves round the trunks of young trees. Use slug and snail baits where necessary, and in extreme cases, use a spray of Bordeaux mixture to appropriate areas.

Figure 6.3.1 Varying degrees of thrip damage from nil to severe (left to right). The ring around the button is typical of early season damage.

Figure 6.3.2 Thrip damage on the cheek of a Clemetine mandarin.

Figure 6.3.3 Long-tailed Mealy bug.

Figure 6.3.4 Mealy bug and sooty mould on citrus fruit.

Figure 6.3.5 Chinese wax scale.

Figure 6.3.6 Soft wax scale – note pinhead to guage size.

Figure 6.3.7 Black scale.

Figure 6.3.8 Soft brown scale on the underside of a citrus leaf.

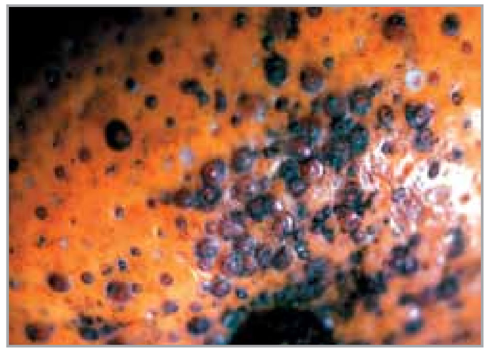

Figure 6.3.9 A heavy infestation of Californian red scale on a citrus fruit.

Figure 6.3.10 Leaves of a New Zealand grapefruit curled from the tip as a result of sap sucking by the Black citrus aphid.

Figure 6.3.11 Leafroller caterpillar – note the dark head and the legs on each segment of the body.

Figure 6.3.12 Early season leafroller damage is an obvious cosmetic defect at harvest.

Figure 6.3.13 Late season leafroller damage.

Figure 6.3.14 An adult Fullers rose weevil on fencing wire.

Figure 6.3.15 Fullers rose weevil damage to the edge of citrus leaves.

Figure 6.3.16 Fullers rose weevil eggs under the button of a citrus fruit.

Figure 6.3.17 A deep red coloured adult Citrus red mite being attacked by a smaller predator mite.

Figure 6.3.18 Citrus red mite damage to Celemintine mandarin leaves alongside dark green, unaffected leaves.

Figure 6.3.19 Citrus red mite damage to a Navel orange fruit – note the pale insipid colour.

Figure 6.3.20 A shoot collasping as a result of borer damage.

Figure 6.3.21 A major branch honeycombed and almost girdled by borer larvae.

Figure 6.3.22 Lemon fruit badly distorted as a result of Citrus bud mite.

Figure 6.3.23 Seminole tangelos and Burgess Scarlet mandarins showing symptoms of damage from Citrus rust mite.

Figure 6.3.24 Damage to Satsuma fruitlets from young katydids.

Figure 6.3.25 Damage to orange fruitlets caused by feeding of adult katydids.

Figure 6.3.26 The moth stage of the Citrus flower moth.

Figure 6.3.27 Damage to a New Zealand grapefruit by slugs and snails.

6.4 Pest and disease control programmes

Pat Sale, Keith Pyle and David Steven

Spray programmes for citrus vary by citrus type and variety, mainly due to major differences in disease susceptibility. The pest spectrum is similar across all types and varieties, but varies a little from region to region. However, different diseases assume markedly different proportions according to the type or variety. There are also regional differences that need to be taken into account, for example Northland with its warmer, wetter climate is more prone to diseases than other citrus districts. Most diseases will infect all varieties under the most stringent conditions, but the combinations to take special note of are listed in Table 6.4.1.

Table 6.4.1 Disease susceptibility

Fruit type	Disease				
	Brown rot	Scab[1]	*Botrytis*	*Melanose*	*Alternaria*
NZ grapefruit	+	-	-	+	-
Oranges	+	-	-	+Northland ?other districts	-
Tangelos	+	-	+	?	+
Satsumas	+	+Northland ?other districts	+Northland -other districts	+Northland ?other districts	-
Encore	+	-	+	?	?[2]
Clementine	+	+	-	?	?[2]
Lemons	+	+	+	?	-

+ = Highly susceptible, preventive spray applications usually required.

? = Routine spray applications only required if seen to be necessary.

- = Not usually a problem but may be under severe infection conditions.

1 = Also know as verrucosis in New Zealand.

2 = Not a problem on Clementine but can be on Encore or Dweet.

Table 6.4.2 Registered materials with approved label claims for the major pest problems on citrus (May 2001)

Aphids	Attack, Chlorpyrifos 50W,Diazinon*, Folimat, Lorsban 50W, Maldison, Oil, Orthene, Rogor.
Mealy bugs	Attack, Chlorpyrifos 50W, Diazinon*, Folimat, Lorsban 50W, Maldison, Orthene, Rogor.
Scale insects	Applaud, Attack, Chlorpyrifos 50W, Diazinon*, Folimat**, Gusathion, Lorsban 50W, Maldison, Oil, Rogor.
Thrips	Ascend 200SC***, Chlorpyrifos 50WP, Folimat, Gusathion, Lorsban 50WP, Maldison, Oil, Rogor.
Leafrollers	Attack, Bt****, Chlorpyrifos 50WP, Gusathion, Lorsban 50W, Orthene.
Citrus Red Mite	Apollo, Folimat, Kelthane, Oil, Omite, Peropal

** Includes Basudin 50WP.*

*** Red scale.*

**** Kelly's citrus thrips only.*

***** Not all Bt products have a label claim for citrus.*

Table 6.4.3 Registered materials with approved label claims for the major disease problems on citrus (May 2001)

Brown rot	Captan, Copper oxychloride, Cupric hydroxide*, Dithane M45
Scab	Benlate, Copper oxychloride, Cupric hydroxide*, Phaltan
Melanose	Benlate, Copper oxychloride, Cupric hydroxide*, Phaltan
Alternaria	Champ, Dithane M45, Rovral

** Blue Shield, Champ, Champion, Hydro-Pro and Kocide.*

NB. Always read the label to check the right product is being used for the purpose. Label claims change and the situation should always be kept under review.

It is not illegal to use a product where there is no label claim, but it is always at the user's risk. Using a product with no approved label claim for citrus could result in completely unacceptable residues.

Withholding Periods

The withholding period is the minimum time that must elapse between the last application of an agrichemical and harvest.

As different countries have difference tolerances, the withholding period can vary according to the market on which fruit is to be sold.

New Zealand Citrus Growers Inc and agrichemical companies are researching many new pest and disease control products. The goal of this research is to reduce dependency on broad spectrum insecticides, and to find effective new fungicides. Many changes to Tables 6.4.2 and 6.4.3 are expected in the next five years, check agrichemical manuals for the latest registered products with approved label claims for use on citrus. In addition, some older materials are likely to become commercially unavailable.

Table 6.4.4 Suggested withholding periods in days for export and local market fruit (May 2001)

Material	Australia	Canada	Japan	Korea	French Polynesia	Taiwan	Singapore	Malaysia	New Zealand
					Market				
Applaud	14	Not set	14[1]	Not set	Not set	Not set	14[1]	Not set	14
Apollo	21	Not set	21	21	Not set	21	21	21	21
Ascend	42	42	42[2]	42[2]	42[2]	42[2]	42[2]	42[2]	42
Attack	28	Not set	14[3]*	14	14	Not set	Not set	Not set	14
Benlate	7	7	Not set	7	7	Not set	7	7	7
Bt Products	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Captan	28	Not set	Not set	Not set	Not set	Not set	28	28	8
Carbaryl	Not set	Not set	Not set	Not set	Not set	Not set	Not set	Not set	1
Chlorpyrifos(9)	14	14	14	14	14	14	14	14	14
Copper oxychloride	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Cupric hydroxide	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Diazinon	21	21	Not set	21[4]	21[5]	Not set	21	21	14
Dithane M45	21	Not set	14(6)	14(6)	Not set	Not set	14	Not set	14
Folimat	Not set	Not set	Not set	Not set	Not set	Not set	Not set	Not set	21
Fungaflor	Dip+7	Dip+7	Dip+7[2]	Dip+7	Dip+7	Dip+7	Dip+7	Not set	Dip+4
Gusathion	21	21	Not set	Not set	Not set	21	21	21	14
Kelthane	7	7	7	28[7]	28(8)	28	7	28	7
Maldison	Not set	Not set	Not set	Not set	Not set	Not set	Not set	Not set	3
Oils	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Omite	2	2	2	2	Not set	2	2	2	2
Orthene	14	Not set	14	14	Not set	Not set	14	Not set	14
Peropal	Not set	Not set	Not set	Not set	Not set	Not set	Not set	Not set	14
Phaltan	Not set	3	Not set	Not set	Not set	Not set	Not set	Not set	3
Rogor	14	21	21	21	Not set	21	21	21	14
Rovral	14	Not set	14[9]	Not set	Not set	Not set	Not set	Not set	14[9]
StopDrop 2,4-D	7	7	7	7	7	7	7	7	7

(1) Set for oranges only; (2) Lemons: Potential risk with larger fruit from previous flowerings. Make sure all mature fruit are harvested before the first application. Do not use after the end of March for these markets; (3) Not set for Satsumas; (4) Not set for mandarins; (5) Set for oranges, grapefruit and tangelos only; (6) Set for mandarins only; (7) Set for all citrus except mandarins which are set at 7 days; (8) Not set for grapefruit or tangelos; (9) Set for tangelos only.

Not set means there is no MRL (maximum residue level) set for this product in this market, or that there is insufficient data on the rate of decay of the residue for a withholding period to be set. Where no withholding period is set, there is obviously a risk of a residue infringement if the product is used between fruit set and harvest. Nil means that product can be used up to the day of harvesting.

Specimen spray programmes

Specimen spray programmes are shown for:

New Zealand grapefruit

Navel oranges

Seminole tangelos

Satsuma mandarins

Clementine mandarins

Lemons

These programmes are a general guide and can be reduced or increased according to experience, choice or region. Always relate back to what is to be controlled and take into account pest life cycles and susceptibility and likely infection periods of the important diseases.

Substitution of acceptable materials can be made according to choice and experience, or the results of pest monitoring.

Sprays for citrus red mite are not applied routinely in citrus orchards, but on an as required basis.

Oil sprays should not be applied when the trees are under drought stress or the temperature is 30ºC or above. Always check product labels for compatibility with oils. The fungicides Captan and Phaltan and the miticide Omite are known to be particularly damaging to citrus when mixed with oil.

The rind of citrus fruits is susceptible to marking, especially if the spray applied takes a long time to dry. Allow plenty of time for sprays to dry before nightfall, particularly when oil is used. Emulsifiable concentrate (EC) formulations are more risky to use on citrus than wettable powders or flowables, as they are more likely to be the cause of fruit marking or leaf damage, especially under slow drying conditions.

Keep spray mixtures as simple as possible, take notice of the precautions on product labels, and generally beware of mixing surfactants with oils.

There is a strong trend in the industry towards integrated pest management (IPM) based on pest monitoring with the main spray programmes based around the fungicide applications, with insecticides as needed.

Control of diseases is based on maintaining a protective residue of fungicide over the critical periods when infection takes place. Generally the most vulnerable period is immediately before and after petal fall and when there is new growth on the tree. Disease control can therefore be calendar scheduled but also needs to be varied depending on climate and previous disease incidence. A protective fungicide in general will no longer be effective after an accumulated 100 mm of rain and will need to be reapplied after this if the crop is in a susceptible stage.

Pest management should follow IPM principles outlined below. In the interests of food and operator safety, the aim of the industry is to reduce the use of toxic sprays especially of organo-phosphates that are no longer recommended on a routine basis.

The most critical pest from an economic standpoint is Kelly's citrus thrips and in most cases it pays to apply a preventive spray at petal fall and follow with a regular monitoring programme especially from December through to the end of March. Other pests are sporadic in occurrence and their control is best based on a sound monitoring programme.

There are a number of organisations providing this service now but the interpretation of the results is critical and best carried out by a professional advisor.

The wax scale insects can build up over mid summer. Control needs to be synchronised with times when the emergence of young crawlers is complete. Other scales and mealy bug have more continuous generations and accurate timing is harder to predict. Aphids are generally only of economic importance on young trees. Periodic outbreaks of pests such as flower moth are localised and vary from season to season. The greenhouse thrips are the most damaging pest in the winter months on touching mature fruit, but can cause damage at other times of the year as well. Sprays for citrus red mite are sometimes needed because of the adverse effect that multiple thrips sprays and some fungicides have on their predators.

For those who are unable to move into IPM and pest monitoring, the following programmes are shown as a general guide.

Table 6.4.5 Spray programme: New Zealand grapefruit

Time	Material	Rate/100 l	Comment
Pre-blossom	Kocide DF	150 g	Melanose
(September)*	Daizinon 50W	100 g	General pest control
	Sunspray Oil	1 l	
Petal Fall (November)*	Kocide DF	150 g	Melanose
	Daizinon 50W	100 g	General pest control**
3 weeks later	Daizinon 50W	100 g	General pest control**
3 weeks later	Benlate	50 g	Melanose***
	Daizinon 50W	100 g	General pest control**
3 weeks later	Daizinon 50W	100 g	General pest control**
Repeat at 3-4 weekly intervals until March.			
April	Dithane M45	200g	Brown rot
	Sunspray Oil	1 l	General pest cleanup
May, June or July	2,4-D StopDrop	Label rate	Preharvest drop - especially late harvested fruit

Apply a further Kocide DF or alternative Brown rot fungicide in July if necessary.

**Watch the trees not the calendar.*

*** If necessary, add Sunspray Oil at 0.5-1% to enhance control of insect pests, or to control citrus red mite. A specific miticide is also an option if necessary, for citrus red mite.*

**** If conditions after petal fall are particularly wet this spray should be brought forward and further fungicide applications may be needed.*

Table 6.4.6 Spray programme: Navel oranges

Time	Material	Rate/100 l	Comment
Pre-blossom (September)*	Sunspray Oil	1 l	General pest control
Petal Fall (November)*	Daizinon 50W	100 g	General pest control**
3 weeks later	Daizinon 50W	100 g	General pest control**
Repeat at 3-4 weekly intervals until March.			
April	Dithane M45	200g	Brown rot
	Sunspray oil	1 ltr	General pest cleanup
May	2,4-D StopDrop	50 ml	Preharvest drop
	Wetting agent	Label rate	

Apply a further Kocide DF or alternative Brown rot fungicide in July if necessary.

** Watch the trees not the calendar.*

*** If necessary, add Sunspray Oil at 0.5-1% to enhance control of insect pests, or to control citrus red mite. A specific miticide is also an option if necessary, for citrus red mite.*

Table 6.4.7 Spray programme: Seminole tangelos

Time	Material	Rate/100 l	Comment
August	Dithane M45	200 g	Alternari
Pre-blossom*	Dithane M45	200 g	Alternaria
(September/October)	Daizinon 50W	100 g	General pest control
October	Dithane M45	200 g	Alternaria
Petal Fall*	Rovral Flo	200 ml	Alternaria
(November/December)	Daizinon 50W	100 g	General pest control***
3 weeks later	Dithane M45	200 g	Alternaria
	Daizinon 50W	100 g	General pest control***
Repeat at 3-4 weekly intervals until March.			
April	Kocide DF	150 g	Brown rot
	Sunspray Oil	500 ml	General pest cleanup

Apply a further Brown rot fungicide in July if necessary.

** Watch the trees not the calendar.*

*** Dithane M45 has 14 days withholding period for the New Zealand market, but it varies for different export markets. Champ, with a nil withholding period can be substituted during the harvest period if necessary.*

**** Watch for citrus red mite and if necessary apply a miticide or Sunspray Oil. Seminole tangelos are more susceptible to oil damage than other citrus, and all precautions advised should be carefully followed.*

Table 6.4.8 Spray programme: Satsuma mandarins

Time	Material	Rate/100 l	Comment
Pre-blossom	Kocide DF	150 g	General pest
(September)*	Sunspray Oil	1 l	and disease control
Petal Fall (November)*	Daizinon 50W	100 g	General pest control**
3 weeks later	Daizinon 50W	100 g	General pest control**
Repeat at 3-4 weekly intervals until April.			
June	Grocel	25 ppm	Crop regulation

** Watch the trees not the calendar.*

*** If necessary, add Sunspray Oil at 0.5-1% to enhance control of insect pests, or to control citrus red mite. A specific miticide is also an option if necessary, for citrus red mite.*

If Sclerotinia has been a problem, apply Benlate 50 g/100 l with the petal fall spray. At the present time Benlate does not have an approved label claim for this purpose, but is known to be effective.

An autumn application of a suitable fungicide for Brown rot control should be applied if it is planned to harvest late. For early harvest to be finished by the end of June, this may not be necessary.

Table 6.4.9 Spray programme: Clementine mandarins

Time	Material	Rate/100 l	Comment
Pre-blossom	Kocide DF	150 g	Scab general
(September)*	Sunspray Oil	1 l	pest control
Petal Fall	Benlate	50 g	Scab general
(November)*	Dithane M45	200g	pest control**
	Daizinon 50W	100 g	
3 weeks later	Daizinon 50W	100 g	General pest control**
Repeat at 3-4 weekly intervals until March.			
April	Kocide DF	150 g	Brown rot
	Sunspray Oil	1 l	General pest control

** Watch the trees not the calendar.*

*** If necessary, add Sunspray Oil at 0.5-1% to enhance control of insect pests, or to control citrus red mite. A specific miticide is also an option if necessary, for citrus red mite.*

Table 6.4.10 Spray programme: Lemons

Time	Material	Rate/100 l	Comment
Pre-blossom (September)*	Kocide DF	150 g	Scab
	Sunspray Oil	1 l	General pest control
Petal Fall (November)*	Benlate	50 g	Scab
	Dithane M45	200g	General pest control**
	Daizinon 50W	100 g	
3 weeks later	Daizinon 50W	100 g	General pest control**
Repeat at 3-4 weekly intervals until March.			
May	Kocide DF	150 g	Brown rot
	Sunspray Oil	1 l	General pest control

** Watch the trees not the calendar, and apply further fungicides for scab control at petal fall of later flower flushes.*

*** If necessary, add Sunspray Oil at 0.5-1% to enhance control of insect pests, or to control citrus red mite. A specific miticide is also an option if necessary, for citrus red mite.*

Spray application

In any spraying operation it is important that good coverage of the target area (fruit, foliage and maybe branches) is achieved, or inferior results may be obtained.

Good coverage will depend upon:

1. A suitable spray machine for the job.
2. The machine being well calibrated and operated at the correct pressure nozzle settings and speed.
3. The spray volume is adequate to achieve good coverage for the target pest or disease.

It is possible to check on coverage obtained by placing water sensitive papers in different parts of the canopy, and examining after a pass of the sprayer.

If necessary it is worthwhile getting the sprayer calibrated professionally.

Spray volume per canopy hectare for dilute spraying can be worked out on a Tree Row Volume (TRV) basis as described in the Spray Application Section of the New Zealand Agrichemical Manual.

$$TRV\ (1000\ m^3/ha) = \frac{\text{Tree height (m) x Tree width (m) x 10}}{\text{Row spacing (m)}}$$

As citrus trees are comparatively dense compared to deciduous trees they have a higher volume requirement per 1000 m^3 of TRV, normally 200-300 l/1000 m^3 TRV.

To calculate the spray volume required in litres per hectare, multiply the TRV (1000 m^3/ha) calculated above by the following factors depending on the target, the degree of infestation and previous experience.

1. Full cover sprays by 300 for corrective scale control with oils and for cases where fungal diseases pose a severe challenge.
2. Medium Cover sprays by 250 for maintenance scale, red mite, fungicide and greenhouse thrip control.
3. Light Cover sprays by 200 for pests on the outer canopy such as Kellys thrip and leafroller as well as foliar nutritional sprays.

For example, in a Satsuma block with a 4 m row spacing, a tree height of 3 m and a tree width of 2 m:

TRV (1000 m^3/ha) = 3 x 2 x 10 divided by 4 = 15.

Volume required per hectare for maintenance scale control - 15 x 250 = 3750 l/ha.

Note 1: In the case of young trees which have not full their space use tree spacing instead of tree width unless using hand gun machinery.

Note 2: In all other cases use canopy hectares. Based on tree numbers, the canopy area in hectares is as follows:

Tree number divided by 10000 x row spacing (m) x tree spacing (m).

The important end point is a satisfactory biological result and to achieve this sprayers should be operated at maximum efficiency.

Integrated pest management (IPM)

IPM is the key component of systems being demanded by markets to guarantee food safety, and also those seeking to improve the environmental sustainability of production systems. IPM programmes combine a variety of control techniques in order to ensure that pests do not cause economic losses. The term 'pests' is used to cover both pests and diseases, although often the initial focus is on insect and mite pests.

IPM is an attitude rather than a proscribed set of rules. To develop and use IPM requires knowledge about the crop, the pests and their ecology.

Key elements of IPM are:

- Monitoring - to determine what is happening in the crop.
  The pests present.
  Pest abundance.
  Crop stage.
- Thresholds - the pest level at which intervention is needed to prevent losses.
- Selective controls - controls that affect the target pest and not other organisms. biological control is favoured as it is selective and natural. The use of broad - spectrum sprays must be minimised if they cannot be replaced.
- Avoidance - managing the crop to prevent pest outbreaks.

The first two points above ensure intervention is only used when needed. They also ensure optimal timing, which is critical to gaining maximum benefit.

Citrus industries overseas led the world in the development of successful IPM programmes, but this has not been the case in New Zealand. Our conditions are not typical of those in major citrus areas overseas, and the local industry has been too small and fragmented to develop the information base needed for successful IPM. However, overseas citrus industries are having to re-work their IPM systems to meet consumer concerns about food safety. Supermarkets are countering consumer concerns by requiring their suppliers to use best practices, and to be able to prove it. This is making growers and exporters instigate systems which can track produce back from supermarket shelves to the supplying orchard, and to have records to show that food safety was not compromised at any stage in the chain. Using an IPM programme which ensures harsh chemicals are only used when absolutely necessary, is expressly required by most such systems. The integrity of the system is demonstrated by having an auditable paper trail.

New Zealand citrus cannot remain isolated from these international trends, even if both the local market and key export markets in Asia are lagging behind what is happening in Europe and North America. Marketing groups, both the corporate grower-exporters and other exporters including co-operatives, are natural focus points for the development of systems that meet customer requirements. They can also pool resources to provide monitoring and technical support.

In most citrus-growing countries, governmental research has provided growers with a recommended IPM programme which outlines the sampling needed, thresholds and responses. This is frequently put into practice with modifications for local circumstance by pest scouts.

New Zealand citrus growers do not have this level of information and support. So what can they do?

1. Use overseas information, but with care.

Overseas information on IPM needs to be interpreted with care even for pests present here, since the threshold will depend on local conditions, including the intended market. For example in Florida most citrus production is for juicing and not fresh fruit sales, and so there is a far greater tolerance for blemish. Similarly most Australian citrus areas do not have citrus red mite, and so they can use pyrethroid sprays without risking mite problems.

2. Record a justification for each spray used.

This is to encourage growers to think about what each spray is intended to do, and whether it is needed.

3. Understand the enemy - the pests relevant to the citrus varieties grown and local conditions.

Necessary knowledge:

- What pests and diseases are critical for the orchard, what are less important and those that are not a real issue.
- What the pest looks like, and what damage does it do, i.e. what to look for.
- When damage is likely, i.e. when there is a need to be observant.
- How quickly problems can develop.
- Draw on local technical people and the ‘old-hands’ as well as more general information. Find out as much as possible.

4. Observe: monitor.

If a pest isn’t there, or the conditions don’t favour a disease, it is likely to be a waste of time and money spraying. Check to at least determine presence or absence, even if there are no thresholds. With experience, thresholds can be developed to suit local conditions. Several marketing and export groups are working in this way in New Zealand to develop monitoring systems for Kelly’s citrus thrips, and other pests. These groups are offering monitoring services.

5. Consider market requirements.

Fruit intended for export rather than local market face the additional problem of needing to meet quarantine requirements, although washing and waxing will remove many contaminants. For example Fuller’s rose weevil is only a quarantine problem; it has never been shown to actually damage fruit or production.

6. Choose spray products carefully.

The worst products known to cause flare-ups of secondary pests, eg those containing methidathion (Supracide, Ultracide) have been withdrawn from the market.

Where possible use selective products that kill the target pest, and don’t harm beneficial predators and parasitoids, such as Bt (Dipel, Delfin, Agree and MVP II), insect growth regulators, for example Applaud.

Avoid or minimise the use of broad-spectrum insecticides such as Attack, Orthene and chlorpyrifos products. Remember fungicide sprays can also kill or deter useful predators (see example below). Oils are useful in controlling scale at critical times in their life cycle and do not leave residues toxic to predators, and parasite.

- Check whether a product is registered before using it. If a product is used for a purpose not covered by a label claim, it is the grower’s responsibility to ensure that violative residues do not result. If a use is expressly prohibited on a label, using it in that way is illegal.

7. Apply sprays carefully and selectively.

Ensure the sprayer is calibrated regularly, at least every 2 years, and that it is being used in the way for which it was set up.

A spray only works if it reaches the target pest. Conversely, if the pest is only found in part of the tree or crop, there is no need to treat the whole crop.

Examples of selective spraying are using trunk sprays of Karate against Fuller’s rose weevil, and spot spraying to control black citrus aphids.

8. Become Growsafe accredited and keep it current.

This is useful for those making spray decisions as well as those applying sprays. It can be a specific requirement of local authorities, as well as for some supermarkets.

9. Manage the orchard to minimise pest outbreaks and to maximise the effectiveness of sprays.

Avoid varieties susceptible to pests and diseases favoured by local conditions.

Keep an open canopy. This improves drying and can help limit disease outbreaks. It also improves spray penetration, a problem especially with dense varieties such as Navels and with pests such as wax scales which are on the stems.

Rough bark and clusters of side branches can shelter mealybugs.

Clusters of fruit provide the sheltered spots favouring damage by mealybugs and greenhouse thrips.

Applying fertiliser in overly generous dollops can stimulate excessive shoot growth, encouraging citrus aphid populations, and stimulating wax scale populations.

All the above are steps towards IPM, and to meeting the food safety requirements of discerning customers.

6.5 Weed control

Gavin Loudon

Weed control is necessary in all citrus orchards is order to:

- Reduce competition for water, nutrients and light. This is particularly important in young developing orchards. In older orchards weed competition will reduce yields and fruit quality.
- Make harvesting easier. Rampant weed growth smothers trees making fruit selection and picking difficult.
- Assist in minimising the risk of frost. Weeds reduce the amount of heat absorbed by the soil during the day, and therefore increase the risk of frosts.
- Improve air movement around the trees. Good weed control together with skirting will enable fruit to dry more quickly after rainfall leading to less disease and easier harvesting.
- Improve pest control. Slugs and snails can use rampant weed growth to travel up into trees damaging fruit. In addition, Fullers Rose weevil adults can move from the ground via weeds into the trees.

Three guiding rules form the basis of good weed control in citrus orchards:

1. Identify the weeds present.
2. Use the correct type of herbicide to control the weeds.
3. Apply the herbicide at the correct rate, and at the correct weed-growth stage, under most suitable environmental conditions.

When establishing a young citrus block the primary aim is to enable trees to produce a strong branch structure as quickly as possible. This will enable trees to develop a strong framework upon which it is possible to hang fruit once the tree enters the cropping phase two to three years after planting out. It is therefore vitally important to achieve effective weed control in these early years.

Before planting

Prior to planting the block infestations of difficult-to-kill, perennial weeds, such as couch, should be brought under control. After planting, young citrus are sensitive to competition and it is important that weeds are dealt with before they affect plant growth.

Some pre-emergence herbicides can be applied around young citrus. However, some control of weeds that do emerge will be required. Light hand-hoeing will provide some control in this area. If applying herbicides, particular care must be taken that herbicides do not contact either the leaves or the trunk of young trees or serious damage could result. The use of plastic trunk guards are a good way of protecting the young citrus trees from accidental herbicide and other spray damage.

Within-row weed control for established citrus

Once you have selected the right product, check product label and read specific warnings, recommendations and dosage rates to ensure good weed control with minimum risk of plant injury.

Only use equipment designed for herbicide application and keep it for that purpose only. Between use, make sure it is flushed out properly using plenty of water. Remove bungs in tank bottoms and drain out tanks. Clean filters and flush through pumps with clean water.

Accurately measure the area that you are planning to spray. Most herbicides are applied at a specific rate 'per sprayed hectare' (1 ha = 10,000 m^2). If you want a weed-free strip along the rows, say one metre wide, the area that you are spraying is length of rows (metres) x 1 m x number of rows.

Herbicides must be applied, evenly and at the correct rate to give good control. Fixed booms with two or three nozzles to give continuous strips of treated ground are the most accurate application method. These should be used for pre-emergence herbicides in particular. With spot treatments using a handgun, it is difficult to achieve accurate dose rates on a sprayed hectare basis.

Use low pump pressures (275 kPa or 40 psi) and fan jet nozzles that give a large droplet size to reduce misting and consequent drift. Water rates per sprayed hectare can vary according to the amount of weed cover and the type of herbicides. Always read the label for recommendations before application.

Pre-emergence herbicides are particularly useful. They can prevent weed seeds from germinating for several months. In general they should be applied in the late winter/ early spring period before weed germination. The ground should be relative weed free when applying pre emergence sprays as an existing weed cover will prevent an effective dose from reaching the soil where it is required.

Existing weed growth should be first treated with a post-emergence herbicide. Residual herbicides are influenced by soil type and require adequate soil moisture for best results. Best results are obtained when the soil is moist at application or when rain falls shortly after application.

Residual herbicides are absorbed by soil colloids and the rate of application may need to be increased for heavy soils or those with higher soil organic matter levels. Always check the product label for the rates on different soil types.

Mulches can be used along the row to suppress weeds. These are particularly useful for growers wanting to produce organic citrus. Straw, untreated sawdust, or fine bark chips can be used. These mulches should be applied in the winter before the germination of weeds. They offer the additional benefits of retaining moisture and of building up soil organic matter. This is particularly useful on lighter soils.

However, as these mulches decompose some nitrogen is lost from the soil system and additional nitrogen must be provided to trees over and above their normal requirements.

With all mulches a small area at the base of the trees must be kept clear so that the tree trunk can remain dry.

Weed mats and black plastic mulches are useful methods for controlling weeds in newly established citrus.

Between-row weed control

Two methods can be used in this area - either clean cultivation or mowing the growth.

In the development stages, as has been stated young trees must be given every chance to grow as fast as possible. Where drip irrigation of plants is not available, clean cultivation between rows is often practised to control weed growth.

Cultivated ground can assist in frost minimisation. For winter harvested citrus varieties, such as Navel oranges and Satsuma mandarins, clean cultivated ground can become pugged and compacted in the wheel-track area. There is also the risk of soil erosion on sloping ground after heavy rainfall.

A mowed sward of either emergent weeds or a specially sown grass sward can also be used between the rows. This approach can have some disadvantages for young orchards with no irrigation. However a grassed surface is easier for harvest operations, particularly in the winter, and is effective in minimising soil erosion.

Table 3.2.1 Herbicides registered in New Zealand for use in citrus orchards

Product	Weed spectrum	Weed stages
Amitrole 400	Broadleaf, grasses	Post-emergent
Asulox	Docks	Post-emergent
Boundary 40/40	Broadleaf, grasses	Pre-emergent
Buster	Grasses, clover, broadleaf	Post-emergent
Caragard 500 FW	Grasses, broadleaf	Pre-emergent
Centurion 240EC	Grasses	Post-emergent
Folar	Grasses, broadleaf	Pre- and post-emergent
Gallant	Grasses	Post-emergent
Glyphosate	Grasses, broadleaf	Post-emergent
Hyvar X	Grasses, broadleaf	Pre- and post-emergent
Krovar I	Grasses, broadleaf	Pre- and post-emergent
Paraquat	Grasses, annual broadleaf	Post-emergent
Poast	Grasses	Post-emergent
Preeglone	Grasses, broadleaf	Post-emergent
Simazine	Broadleaf, grasses	Pre-emergent
Solicam DF	Grasses, some broadleaf suppression	Pre-emergent
Stomp 330E	Annual grasses, broadleaf	Pre-emergent
Stomp 400SC	Annual grasses, broadleaf	Pre-emergent
Terbogran	Grasses, broadleaf	Pre- and post-emergent
Touchdown	Grasses, broadleaf	Post-emergent
Tyllanex 500	Grasses, broadleaf	Pre- and post-emergent

Note: These herbicides are registered for use in New Zealand orchards. If citrus fruit is to be exported, growers should contact their exporter prior to using these materials.

More detailed information about each herbicide is printed on the herbicide container. Growers would be well advised to purchase a spray chemical manual. Two are currently available - they are: The New Zealand Agrichemical Manual, published by Wham Chemsafe Ltd, PO Box 11092, Wellington and Novachem Manual edited by Barney O'Connor, RD 4, Palmerston North.

Growing Citrus in New Zealand

A practical guide

Section 7.

Business Management

7.1 Citrus economics

This chapter is no longer relevant and has been removed'.

Please refer to our website for more information: http://www.citrus.co.nz/

7.2 Citrus marketing in New Zealand

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New Zealand Citrus Growers Inc

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7.2 Citrus marketing in New Zealand

Alan Thompson

Background

The New Zealand citrus industry has commenced the journey from a domestically focussed small-scale fragmented industry of the 1970's and 1980's into an export oriented niche marketer of selected varieties in the new millennium.

In the early years the marketing of New Zealand citrus was controlled by legislation and the Citrus Marketing Authority (CMA) carried out all marketing. The CMA had branches in Kerikeri, West Auckland, Tauranga and Gisborne and packing and marketing was largely undertaken by cooperatives in these areas. A few maverick Black Marketeers who purportedly included some of the industry's notable personalities, however, did continue to work behind the scenes.

Imports at this time were also regulated and managed by Fruit Distributor Limited, which was owned by wholesale markets. Dissatisfaction with the performance of this system and New Zealand's drive to deregulate the economy in the 1980's led to the demise of these systems and the local market and the import market were deregulated.

Initially, as expected chaos reigned and import volumes flooded in on top of domestic production. Prices for traditional products such as Navels, tangelos and valencias plummeted. As grower returns fell an inevitable cycle of lowered inputs led to poor quality, which reinforced the market price spiral. This focused grower's on export opportunities and the industry devised a strategic plan around the development of an easy peel mandarin and lemon export industry.

Larger corporate growers led the way in the development of these export markets, initially focusing on the development of Satsuma exports into Japan. This was then quickly followed by the development of an equally successful lemon export market.

These bigger corporates were quickly followed by grower cooperative marketing groups who's attempt to take more control of their marketing and distribution, has had mixed results.

Present situation

Today the major varieties are Satsuma mandarins, Yen Ben lemons and Navel oranges. The production base of the industry has grown dramatically in terms of Satsuma mandarins and lemons and will continue to do so as planted trees mature over the next five years.

Domestic market

The domestic market is still the largest component of the New Zealand citrus business accounting for 85% of total volumes. Three large supermarket customers who sell between 70 and 80% of the first grade product dominate the domestic market.

The supermarkets are trending towards category management of supply, which is limiting independent grower's traditional marketing channels through auction floor wholesalers.

This trend is reflective of a drive to international quality standards for product, consumer pressure on supermarkets to guarantee product integrity, quality and safety and a need to have a consistent supply.

Grower groupings are emerging to ensure these volume and quality and food safety requirements can be met efficiently and still provide economic returns.

The market for second and process grade product is diminishing, putting pressure on the supply base to be more professional in their approach to quality citrus production.

The grower base is now more aware that its competitor is internationally based for most varieties which are available for importation on a year round basis. Therefore the emphasis is on quality production and efficient distribution to head off the threat of foreign competition.

Branding of domestic citrus is in its infancy with little or no consumer recognition of brands presently and brand promotion has been limited to wholesale level and to fruit stickers, which have little effective consumer recognition.

Consumer studies carried out have found that New Zealand consumers have little knowledge of varietal differences and are put off the category because of the inconsistency of product on a seasonal basis. For example purchasers of sweet seedless easy peel mandarins available during the Satsuma season are put off repeat purchasing of mandarins in general, when exposed to seedy mandarin varieties later in the season. The same is true for Navel oranges that are sweet, juicy and without seeds being replaced on the shelves by seedy Valencias, without appropriate labelling.

Volumes of some varieties will increase rapidly over the next 5 years and pressure will come on the domestic market to absorb these volumes.

Growers will need a shift in focus from a 'grow and sell model' to a 'planned supply and demand matching model'.

This will have to be coupled with a coordinated promotional plan differentiating the attributes of each product in the consumer's mind.

Growers who cannot meet the highest quality standards will struggle to sell their product while quality producers will need to be prepared to work together promoting branded product and capturing a higher percentage of the consumer fruit spend.

There are still too many sellers in the New Zealand market compared to buyers and fragmentation of grower supply between brokers will inevitably lead to price degradation.

The Satsuma industry is such an example and is at a crossroads in terms of future profitability. It reached the point in the 2001 season where volumes presented to the local market increased by 160% from approx 3000 metric tonnes in 2000 to 5000 metric tonnes in 2001. Two factors, which exacerbated this problem, were (1) a late harvest season, and (2) poor quality product from some regions. Sales were fragmented and a downward spiral in price ensued with returns dropping below the cost of production for some sizes and grades.

As the crop is forecast to increase in volume a further 3000-5000 metric tonnes over five years it is imperative that growers focus on the critical issues.

These are:

1) Extending the supply season from the present mid April to early July to early April to the end of August

2) Reducing the peak production spike that occurs from mid May to the end of June

3) Removing the volume of poor quality fruit from the market both in cosmetic and taste terms by setting minimum grade standards.

Export market

The New Zealand export citrus industry revolves around the three main crops.

Mandarins

Satsuma mandarin export volumes increased rapidly through the mid 90's, peak shipments were in 1999 at 1290 metric tonnes but have dropped to 880 metric tonnes in 2000 and it is expected 2001 shipments will once again be down due to inclement weather conditions during the harvest season.

This reduction is due to the seasonal timing differences, the perception of mediocre internal quality of the product and Japanese consumer market conditions which require lower delivered prices to increase sales volumes.

At present the exchange rate is favourable but fungicide free New Zealand mandarins suffer from a short shelf life necessitating airfreight to the market. The high cost and limited volume of uplift available are self-limiters on the industry. Technical work to extend the product shelf life so that sea freight is an option is an area of high priority for continued research and is critical to the industry's future.

Efforts to improve this in 2001 had mixed results and the industry still does not have a clear road forward in terms of sea freight.

Lifting the volume of export in the future is the major priority for mandarin growers in order to ease pressure on the domestic market. This can only be achieved through lower pricing which can only come from lower returns to growers or successful sea freight techniques being developed.

These techniques will also be required if successful development of the US market is to be achieved after access issues are resolved.

Lemons

The New Zealand lemon industry can be competitive particularly in the post harvest chemical free niche. This is due to its short transit time to market 12 days compared with competitors up to 30 days and New Zealand's quarantine status, which means cold treatment is not required. The main markets are Japan (90%), Korea and Hong Kong. Further potential markets exist with access issues solved in the U.S. and Taiwan. The European market may also have potential surprisingly due to the deregulation of the apple industry leading to more interest in this country from European buyers.

The cost of freight to market is the major impediment to long term competitiveness and the continued growth of the New Zealand citrus export industry. The cost to freight is much higher than our major competitors due to the lack of southbound freight. This means the freight containers are returned to New Zealand empty a cost that is passed on to the exports.

The largest lemon producer in the world, Argentina is becoming aggressive and will be a major competitor in the future as it gains access to Asian markets.

Navel oranges

The New Zealand Navel crop is based on an existing tree stock of variable age and quality. Basic husbandry is improving the quality to near an international standard but more research is required to fully utilise this resource.

Market niches have been recognised and are beginning to be exploited. New Zealand growers traditionally tried to produce fruit in July and August but today are positioning the fruit later to avoid clashing with other Southern Hemisphere producers.

Demand for late season Navels for supply from October to the first half of January is increasing and further work to obtain consistent supply and quality in this period is needed as well as further plantings of Late Navels.

The Navel industry is only now emerging as a possible long-term export prospect.

A late season niche from September to November exists with the strong emphasis on the superior flavour of New Zealand Navels. This niche is impeded by a lack of volume of the right quality, which is needed to ensure the viability of a successful export programme.

The New Zealand citrus exports have been heavily reliant on the Japanese market. This is due to a number of historical factors including quarantine access, prices achievable, variety available. This situation is not viable in the longer term and efforts to expand the markets for New Zealand citrus in order to successfully market the increasing volumes of fruit will require increased investment.

Future exports

For a successful future, access to Pacific Rim nations in particular the USA, Canada, Australia, Korea, Taiwan and China are critical to growing the industry from its current levels. Attempts to ship product to Europe have proved difficult in the past but may become viable with new transport technology.

The major issues facing the growth of our export markets revolve around New Zealand competitiveness in the face of strong competition from other Southern Hemisphere producers. Our primary Southern Hemisphere competitors are South Africa, Chile and more recently Argentina. The key factors that will impact on the New Zealand industry's competitiveness in the market place are in order of importance:

1) Production volumes and cost of production.

2) Shipping and logistical costs.

3) Exchange rate relative to competitors.

From a growers perspective the second and third factors are the most variable and the least able to be controlled.

The future

The industry faces a number of challenges if it is to successfully grow and prosper in the next five years these include:

- Consumer demand for guaranteed food safety, with regard to both spray residues and bacterial contamination.
- Consumer demand for consistent high internal quality of the product. This will lead to the rapid development and adoption of NIR technologies. This in turn will increase the pressure on growers to produce uniform high quality fruit.
- Producing quality fruit in bulk in order to meet the volume and quality for offshore markets.

These pressures will increase compliance costs to growers without any corresponding lifts in the price consumers are prepared to pay. Inevitably growers will need to be larger to achieve the economies of scale or will need to form stronger selling entities with larger collective volumes in order to survive. The days of the small independent supplier to wholesaler/consolidators are probably numbered.

As an industry citrus can have a bright future with three good products of sufficient volume to form a vibrant industry.

The key to this success will be:

- Focussed research on post harvest storage and handling to meet our unique market requirements.
- Growers being prepared to work together for marketing and promotional needs to achieve a better consumer understanding of our products.
- Commercial plantings of key products in the correct growing areas to provide the volumes required for credible export programs.