NSW DEPARTMENT OF
PRIMARY INDUSTRIES

Growing lemons in Australia- a production manual - Readers' Note

This document is part of a larger publication. The remaining parts and full version of the publication can be found at:

http://www.dpi.nsw.gov.au/agriculture/horticulture/citrus/lemon-manual

Updated versions of this document can also be found at the above web address.

9. Crop Management

INTRODUCTION

The best economic returns are achieved for fresh fruit and it is important to manage trees to produce good quality fruit. Market specifications should always be the main determinant of crop management so that the fruit produced are the right size and quality.

CROP DEVELOPMENT

In tropical and subtropical regions with mild winter temperatures lemons tend to be everflowering and can bear multiple crops throughout the year (Northern Territory, Queensland, Western Australia, northern and coastal NSW). However the main crop is produced in late autumn - winter. This tendency to produce multiple crops extends the supply season providing market opportunities, but it also increases production and management costs. Fruit growth and development in warmer areas is faster taking between 6-7 months to reach maturity.

In the southern growing areas of New South Wales, Victoria and South Australia with hot summers and cold winters one crop is normally produced from the spring flowering and harvested in late autumn- winter. Fruit growth and development in these areas is slower taking between 8-9 months to reach maturity.

Citrus trees go through a sequence of growth phases throughout the year. In districts where there is only one crop of lemons produced the timing of these growth phases would be fairly typical. However in regions where multiple crops are produced different phases of growth would be occuring simultaneously. The typical sequence is as follows:

Bud formation and flower initiation (mid winter)
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Flowering and fruit set (early spring)
↓
Fruit growth - cell division (late spring - early summer)
↓
Fruit growth - cell expansion (mid summer - early autumn)
↓
Fruit maturation (late autumn - winter)

Flowering

Flowering in citrus occurs when there are favourable temperatures and soil water and flowering in lemons is affected by climatic factors more than with other citrus varieties. Flowering occurs 3-4 weeks earlier in warmer districts such as the Northern Territory and Queensland compared to the cooler southern regions of Australia.

Flower bud induction occurs with the cessation of vegetative growth as a result of either:

- cold temperatures (less than 25ºC for several weeks) in winter. The semi dormant state of trees in winter is more easily broken in lemons than with other citrus varieties enabling them to produce flowers and fruit throughout the year; or
- or a period of water stress longer than 30 days, especially in tropical and subtropical areas.

The buds then differentiate into flowers when warm temperatures or soil moisture relieve the stress.

Other forms of stress such as drought or a sudden flush of moisture after a dry-spell can also cause flowering. In a well-managed lemon orchard, stress is normally avoided by careful and timely application of management practices especially irrigation.

Flowering can also be affected by other management practices. For example nitrogen fertiliser has been used to stimulate flowering but this is usually only effective if levels of nitrogen in plant tissue are below optimum concentrations.Time of harvest can also have a significant effect on flowering especially if fruit are hung late.

Fruit set and growth

Lemons do not need cross pollination to set fruit and produce a crop. Lemons are also less sensitive than oranges to high temperatures in the fruit set period and good yields are obtained in hot regions.

Fruit growth rate is a function of temperature and soil moisture. The higher the mean temperature the faster the growth rate, providing there is adequate water. Fruit growth is faster in tropical and subtropical areas and slower in cooler climates. In tropical and subtropical regions the fruit grows uninterruppted if moisture is not limiting with a reduced time to reach maturity. In colder areas growth can be interrupted by cold temperatures.The optimum temperature for lemon tissue growth is 30ºC, temperatures of 25-30ºC are satisfactory and no growth occurs above 40ºC. The crop load is normally the most important determinant of final fruit size, however local climatic conditions, nutrition and irrigation also have an effect.

FRUIT QUALITY CHARACTERISTICS

There are many factors that have an affect on the the internal and external quality characteristics of fruit. Variety and rootstock selections, tree age, local climatic conditions and management practices all impact on fruit quality. For information on the fruit quality characteristics of different varieties and the effects of rootstock on fruit quality characteristics refer to the Varieties and Rootstock sections of this manual.

Internal quality

Lemons are naturally acid, being high in total acidity and low in Total Soluble Solids (TSS) compared to other citrus varieties (excepting acid limes). In lemons the organic acid content increases with fruit development whereas in oranges it decreases.

The accumulation of acid is highly correlated with temperature. In hot tropical and subtropical regions, fruit tend to have higher quantities of acid per tonne of fruit. Rootstock also appears to influence fruit acidity but this can be variable depending on variety. Generally fruit grown on Rough lemon rootstock have lower acidity than those grown on *P. trifoliata*. The amount of irrigation does not appear to significantly influence internal fruit quality but the quality of irrigation water does. Generally increasing salinity results in a decrease in percent juice, acidity and TSS, however the degree of impact is also influenced by rootstock.

In the past percent juice was the only internal quality characteristic used as a marketing standard for lemons in Australia. Fruit needed to have a minimum juice content of 25% for the main winter crop and 20% for the spring and summer crops, but these marketing standards no longer apply in the Australian domestic market. California recommends a minimum juice content of 25% for lemons.

Factors impacting on fruit quality -

- ☑ Variety
- ☑ Rootstock
- ☑ Climate
- ☑ Nutrition
- ☑ Pruning
- ☑ Irrigation
- ☒ Pests
- ☒ Diseases
- ☒ Wind

Medium to long term postharvest storage of fruit can increase the juice content and acidity and reduce peel thickness of fruit. It is sometimes used to improve the quality of main crop (winter) lemons which have a tendency to become thick skinned and dry if left too long on the tree.

As fruit overmature their quality declines with decreasing percent juice, fruit firmness, total acidity and ascorbic acid content and increasing fruit diameter, weight and peel thickness.

Pests such as spined citrus bug and some nutrient deficiencies, such as boron, can also affect internal fruit quality by causing internal browning, gumming and drying of the pulp.

Fruit shape

Fruit shape is largely governed by variety choice, however shape can also change as the fruit matures or the trees get older. An example of this is the Verna lemon which has quite a prominent neck when produced from young trees, but which appears to be less pronounced as trees mature. Also if the Verna fruit are left to hang late on the tree the neck can fill out and become less prominent.

Fruit size

Fruit size is influenced by variety, rootstock, crop load and irrigation practices. Generally when there is a heavy crop or high numbers of fruit, average fruit size decreases. Some varieties such as Fino and Yen Ben tend to produce small to medium sized fruit in spite of crop load. Good irrigation management is important in achieving good fruit set and obtaining maximum fruit size. For more information on irrigation refer to the Irrigation section of this manual.

Peel quality

Peel quality and skin thickness are a result of variety choice but are significantly influenced by rootstock choice, nutrition and environmental conditions. For example fruit grown on Rough lemon rootstock tend to be more coarsely textured with thicker skins than that grown on *P. trifoliata* rootstock. Plant nutrition, in particular the balance of nitrogen, phosphorous and potassium significantly influence peel characteristics. For example excessive nitrogen and potassium levels result in fruit which are puffy and have thick peels. An excess of nitrogen can also delay peel colour development. For more information on the impacts of nutrition on fruit quality refer to the Nutrition section of this manual.

The extraction of the peel oil from lemons is an important process in some countries. The amount of peel oil in fruit is dependent on variety and tends to increase as the fruit develop and mature. Peel oil yield can also be affected by tree nutrition, with increased nitrogen tending to increase oil yield whilst increased potassium depresses oil yield.

The incidence of pests, diseases and wind can significantly reduce the external quality of fruit so good pest and disease management is essential. For more information on pests, diseases and their control refer to the Pests, Diseases and Control sections of this manual.

ACHIEVING GOOD FRUIT QUALITY

There are a number of other key management techniques that can be used to improve fruit quality. These include pruning, skirting, planting interrow sods and windbreaks.

Pruning

In general, lemons trees are usually very vigorous and require regular pruning.

Pruning also keeps production zones nearer to the ground where the costs of harvesting are lower.

Pruning opens up the tree for better light penetration and helps encourage and promote fruit throughout the entire tree canopy. Fruit are produced on strong young branches which need adequate sunlight to grow and develop. Fruit produced on the insides of trees are more protected from wind and sunburn.

Pruning also removes deadwood which is a source of disease particularly in areas of higher rainfall and humidity such as on the coast.

Hedging can be an important cultural practice especially when closer row spacings are used. It is used to shape the canopy allowing more sunlight to get to the lower parts of the canopy. Timing of hedging is important and should be undertaken at times that reduce damage to maturing fruit and to avoid sunburn of both fruit and tree limbs. For more information on hedging refer to the Canopy Management section of this manual.

Skirting trees

Skirting trees involves removing all the low hanging branches and foliage from near the ground.

The benefits of skirting on fruit quality include:

- ☑ eliminates mechanical damage to fruit coming into contact with the ground;
- ☑ prevents fungal pathogens (eg. *Phytophthora* spores) from being splashed from the soil onto the fruit or foliage;
- ☑ disrupts the pathway from weeds to the tree, that ants other insects and snails use;
- ☑ makes it easier to apply herbicides without spray drift to fruit and foliage. This is important in reducing residues in fruit and herbicide damage to fruit and foliage;
- ☑ improves the uniformity of distribution of water during irrigation and also allows for easier maintenance of irrigation systems;
- ☑ prevents damage to fruit when equipment is used to spread fertilisers or mow interrow sods,
- ☑ improves air circulation in the tree canopy, which reduces the incidence of disease and speeds the drying of fruit to be harvested.

Interrow Sods

The cultivation and maintenance of a permanent vegetative cover between the tree rows is known as the interrow sod. The sod is normally a mixture of perennial grasses and legume species (such as peas, medics or clovers). The interrow sod needs water and nutrients to survive and this needs to be taken into account when irrigating and fertilising your trees. In winter the sod should be kept short to prevent the incidence of frost.

The benefits of having an interrow sod include:

- ☑ provides an important habitat for beneficial insects;
- ☑ helps keep the orchard cooler in summer and warmer in winter;

- ☑ reduces dust;
- ☑ improves soil organic matter;
- ☑ improves soil structure;
- ☑ improves and maintains soil flora and fauna populations and biodiversity;
- ☑ improves soil water and nutrient holding capacity;
- ☑ improves water penetration into the soil;
- ☑ reduces runoff and soil erosion;
- ☑ supplies extra nutrients. If legumes such as peas, medics and clovers are used they can provide a small amount of nitrogen;
- ☑ allows tree roots to remain active closer to the soil surface.The soil is cooler under the sod in summer so tree roots are able to remain active for longer. This allows the tree to continue extracting essential nutrients which are often concentrated near the surface.

Windbreaks

Windbreaks help reduce blemish on fruit and improve tree growth which affects crop yield. Surface wind scarring on fruit is one of the major reasons for fruit being downgraded or rejected at the packing line. Where possible, plant natural windbreaks well before the lemon trees are planted. Living windbreaks also need adequate irrigation and nutrition (especially when young) to enhance the rate of growth and reduce the competition of windbreak trees with the lemon trees.

The shade caused by windbreaks can have a detrimental effect on adjacent orchard trees so windbreaks may need occasional hedging to reduce their shading effects and to retain the ideal degree of permeability. Regular deep ripping of tree roots between the windbreak trees and the lemon orchard is essential.

Generally well-managed windbreaks contribute significantly to the profitability of an orchard. For more information on windbreaks see the Orchard Establisment section of this manual.

MANAGING CROP LOAD AND TIMING

Lemon crop management in Australia is largely focussed on practices that aim to produce fruit “out of season” in the late spring to early autumn period, when there is a shortage of local fruit and prices on the domestic market are highest.

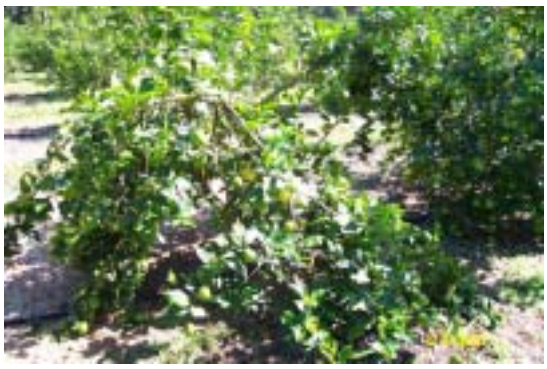
Normally lemon trees tend to flower heavily in spring producing the majority of their crop in winter. Even in those areas where trees have the ability to set several crops throughout the year between 65 - 75% of fruit is still set in spring and harvested in winter (May to August) while the remaining 25 - 35% is harvested mostly between December and April.

There are a range of management practices that have been used around the world to market fruit “out of season” and to manipulate cropping times. The most commonly used practices are documented below. The most well documented method of manipulating cropping is the use of water stress to induce flowering out of season.

Variety and Rootstock Choice

Lemon variety and rootstock selection as well as mix have been used in some orchards to extend the fruit production period. A selection of different varieties on a

range of rootstocks can be planted to expand the timing and extent of harvest. However this technique is more suited to smaller scale operations and in areas where trees have the ability to flower throughout the year.



Verna trees with very heavy crop loads and harvested late, were inclined to have significant limb breakages and some trees died as a result.

Some lemon varieties such as Verna naturally mature much later than other varieties. At a trial site on the Central Coast of NSW Verna matures 2-3 months later than Eureka and Fino, in early to mid spring. However in this trial any Verna trees that had a very heavy crop load and were harvested late (October) tended to have significant limb breakages and some trees died. In the following winter the crop load was also very small with trees tending towards an alternate bearing cycle. Hanging fruit late can impact on the amount of flowering in the following spring.

Tree spacing

Tree spacing can have a major effect on orchard profitability. Normally the closer trees are planted the earlier they come into production.The higher setup costs of high-density plantings is partly offset by this early production and yield, however controlling tree size is critical in high density plantings. Assess the expected tree vigour and future pruning program in determining ideal tree spacings.

Choice of variety, rootstock and soil depth will also affect tree vigour and growth. For more information on variety and rootstock characteristics refer to these sections in the manual. The tree spacing selected should allow for easy access of equipment (eg sprayers and tractors) down each row without causing damage to fruit. Ideally tree canopies should meet within the row in around five years.Typical tree planting densities for lemons in Australia are 6 - 7m between rows and 3.5 - 4m between trees. High density plantings are 5 - 6 m between rows and 2 - 3m between trees. For more information refer to the Grower Case Studies section of this manual.

Postharvest Storage

Lemons are able to be cool stored after harvest for long periods of time and short and long term storage can be used to market fruit at times of peak market demand both in Australia and overseas. In Australia this practice is not common and is usually only used on the main winter crop. In California long term postharvest storage is common practice.

Fruit harvested when silver green are stored for around 6 weeks, light green fruit for up to 2 months and dark green fruit for 5-6 months. During storage, if fruit are internally mature when harvested, fruit quality characteristics such as peel thickness and juice content can be improved. Fruit need to be regularly monitored during storage as losses from postharvest diseases such as green and blue mould can be high. For more information on postharvest storage of lemons refer to the Postharvest Handling section of this manual.

Degreening

Lemons can also be harvested when the peel is still green and then artificially coloured using the natural ripening compound ethrel. Degreening allows fruit to be

picked to size and is most commonly used to market the main winter crop early, in May rather than June or July. Fruit that are going to be degreened should still be internally mature.

For more information on degreening lemons refer to the Postharvest Handling section of this manual.

Growth Regulators

Giberrellic acid (GA) a natural plant hormone, delays the loss of green pigment in the fruit rind thereby delaying fruit maturity. It is registered for use in lemons and can be applied 4-6 weeks prior to harvest when fruit are at the silver green stage. However if fruit are to be degreened postharvest, the application of GA will also increase the time it takes to colour fruit compared to unsprayed fruit. For more information on the use of GA refer to the Pest and Disease Control section of this manual.

Photo by Greg Moulds

Colour development of GA sprayed lemons (top) compared to unsprayed fruit.

Lemons can be sprayed with GA at the silver green stage to delay harvest.

Pruning

Pruning is being tried by a number of growers to regulate flowering and crop load, but there is no documented evidence on what procedures consistently work.

Pruning could be used to physically adjust crop load at the main spring flowering and fruit set time. Pruning is undertaken either at flowering or after fruit set in spring, reducing the crop load resulting in a smaller winter crop. It is hoped that this would result in the trees setting more flowers and fruit at other times of the year. Hedging would be the most economical method of pruning to use.

Some growers are also experimenting with using pruning at different times of the year to manipulate flowering "out of season". One approach has been to prune in autumn to reduce the number of potential flowering sites in the following spring, thereby reducing the main winter crop. Coupled with this technique has been a modified nutrition program.

Water Stress

The use of water stressing lemon trees to produce an out of season crop is common practice in Sicily. In Sicily as in the warmer parts of Australia lemon trees normally do flower in summer but the crop load is small. In Sicily summer temperatures are 24-26^{o}C and there is a pronounced dry period from June-August.

In Sicily water is withheld from lemon trees at the beginning of summer (June-July) until the trees are severely water stressed. During this time the flower buds are induced but rarely develop. Trees are then irrigated forcing ("forzatura") them to flower (usually 3-4 weeks later) in autumn. This out of season summer crop the "verdelli" is then ready for harvest the following summer.

In Australia: A number of lemon growers throughout Australia have trialled the use of water stress to manipulate the seasonality of fruit production with limited success. However it works best in areas that have a predictable and guaranteed dry season. Overall it appears that its success rate has been extremely variable and it cannot be relied upon with any certainty especially if local rainfall events are unpredictable.

In the Northern Territory researchers have been having some success with using water stress to manipulate cropping in lemon and grapefruit trees growing at Katherine. In this region they typically have problems with poor and erratic flowering due to the tropical climate and absence of very cold temperatures. Their aim was for the lemon trees to produce a crop in the December-February period which has high domestic market prices. Researchers have been trialling the use of water stress since 1996 and the trees still appear to be in relatively good condition.

In the Northern Territory they have a fairly predictable dry season extending from May to September. The subtropical growing conditions mean that fruit grow quickly taking around 6-7 months to mature, compared with cooler regions where fruit take 8-9 months to reach maturity. Flowering is also concentrated into a 2-3 week period.

The current method used in the Northern Territory focuses on maintaining a dry period of around six weeks. Periods less than this (ie four weeks) have not induced flowering. After six weeks of withholding water the trees look very stressed with full leaf curl and 10-20% leaf drop. The technique has been successfully tried on Eureka lemons on a range of rootstocks (Troyer, Benton, Swingle and Cleopatra). Approximate timing is to start the water stress at the beginning of May for a period of six weeks; irrigate in mid-June; the fruit are set by late July and then ready for harvest at the end of January. When using this technique the lemon trees will only produce one crop per year.

After water stressing the trees for six weeks the trees are then irrigated and fertilised with 100% of the annual nitrogen requirement (100g/tree/year of age) plus a foliar urea spray at 1.5%. Fruitlets are set six weeks after the initial irrigation with flowering occurring during that time. So the sequence of events is six weeks of water stress, followed by irrigation and fertilisation. The next six week period consists of bud break, leaf flush, flowering and fruitset followed by a 28 week fruit development period. In total the program takes a total of 40 weeks[1].

In California[2]: The aim of using water stress is to achieve a second crop of lemons, harvested during the summer. The long term effects of using moisture stress on yield and tree vigour are unknown. The method recommended here is based on that used in Sicily. (NB.Timing is for the northern hemishere).

1. **Starting the Stress** – Turn the water off during the first two weeks of June (December in Australia). Allow trees to use up the available soil moisture and reach the "permanent wilt" level of water stress (25 to 35 bars, negative predawn xylem pressure potential). Visual symptoms include: slight defoliation, yellowing and curling of leaves, complete cessation of growth, and leaves wilted at dawn. If this level of stress is reached in less than 50 to 60

days, start a deficit irrigation (see step 2 below) before a significant number of trees reach 50% defoliation, approximately 45 bars. Excessive defoliation will weaken the tree, reduce "Verdelli" fruit set and the quality of the winter crop. If the desired stress (25 to 35 bars) is reached after 50-60 days you don't need to implement deficit irrigation. Sandy and shallow soils will usually dry before 50 days and will need the deficit irrigation.

2. **Deficit Irrigation** – If the 25 to 35 bar level is reached in less than 50 days then a deficit irrigation regime should be initiated. Apply one-fourth of the normal crop water use in weekly to three times weekly irrigations. Typical rates will be 265 to 380 litres per tree per week during the deficit irrigation regime. The amount of applied water on any one day should not be sufficient to initiate new growth, but only to keep the plant from defoliating. Plant water stress levels of 20 to 30 bars during this period appear to be optimal.

3. **Resumption of Irrigation** – The trees should be rewatered after 50 to 60 days from the start of the dry period. The first irrigation must be sufficient to refill the primary root zone (top 18 inches of soil). Sprinklers have been the most effective for rapidly bringing the trees out of stress. After the root zone has been replenished, normal irrigation should be resumed. Overhead sprinkler irrigation should be avoided during "Verdelli" bloom to minimise pollination and disease problems.

4. **Fertilisation** – Nitrogen fertiliser appears to have minimal effect on the production of bloom, but is thought to be beneficial for fruit set and growth. Soil applied nitrogen of 18 to 36 kg of N per hectare has been the traditional approach, but foliar urea, one week and three weeks after resumption of irrigation also appears effective.

5. **Pruning** – Heavy pruning should be avoided during April or May before the "Verdelli" stress, but trees pruned after two to three weeks of stress have produced a successful "Verdelli" crop.

1 *Source: Personal Communication with Mark Hoult, Horticulturist with the Northern Territory Department of Agriculture, March 2004).*

2 *Extracted from Forsyth, J.B., Report on a Citrus Study Tour to California, 1986, Miscellaneous Bulletin 21, NSW Agriculture).*

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