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.

14. Pest and Disease Control

An oscillating boom sprayer in operation

INTRODUCTION

In most Australian citrus orchards an integrated approach to pest and disease control is well established. Integrated Pest Management (IPM) relies on using a range of control options to keep pests below economically damaging levels. These control options include biological, cultural and chemical control strategies. Successful management of pests and disease in your orchard involves:

- ☑ correct identification of the pest or disease organism;
- ☑ an understanding of the lifecycle and conditions favouring the pest or disease;
- ☑ regular monitoring of trees for pests and disease;
- ☑ choosing the right control; and
- ☑ correct application and timing of the control.

In citrus orchards horticultural or agricultural mineral oils are the most common product used to control a range of pests. For disease control protectant copper sprays are the most common product used.

For more information on using pesticides safely refer to the Spray Sense Series available on the NSW Agriculture website at www.agric.nsw.gov.au/reader/spray-sense

ALWAYS READ THE LABEL
Users of agricultural chemical products *must always* read the label and any Permit before using the product, and strictly comply with the directions on the label and the conditions of any Permit. Users are not absolved from compliance with the directions on the label or the conditions of the permit by reason of any statement made or not made in this publication.

Parts of the chemical use pattern quoted in this publication are approved under Permit(s) issued by the National Registration Authority and in force at the time the publication was prepared. Persons wishing to use a chemical in the manner approved under Permit should obtain a copy of the relevant permit from the APVMA and *must* read all the details, conditions and limitations relevant to that Permit, and must comply with the details, conditions and limitations prior to use.

INTEGRATED PEST MANAGEMENT

Integrated pest management (IPM) is the use of a variety of control measures (including biological, cultural, varietal and chemical controls) in a harmonious combination to contain or manage pests below their economic injury levels and to avoid harmful effects to the environment. IPM maximises the use of biological control measures and uses other controls in a supportive rather than disruptive role. It involves regular checking of pest levels and the strategic use of pesticides where necessary.

Releasing ladybirds to control white louse scale

Many pests are controlled by natural enemies such as parasites, predators and pathogens. Careless use of chemicals particularly broad spectrum types often disrupts or kills these natural enemies.

What it Involves
There are four major components of an IPM system. These include:

- *Identification of pests and their natural enemies:*
  The correct identification of any pest is required before an effective control strategy can be determined and implemented. The location in the tree, lifecycle and feeding habit of the pest is also critical to achieve control.

- *An efficient monitoring system:*
  Pest populations need to be regularly monitored at critical times to ensure control is carried out at the right time. Monitoring involves checking a sample of trees in a block. Plant parts sampled are defined and can include flowers, fruit, leaves, twigs, branches and trunks. Various insect traps are also used for this purpose.

- *The use of action levels:*
  Action levels refer to the level of pest infestation in the orchard and the likely crop damage. This information is collected when monitoring of trees is carried out. Experienced entomologists or pests scouts use information about each pest to determine the infestation level at which some control action is necessary.

- *Choice of the correct control measure:*
  The choice of control measures to use is dependent on the pest population in the orchard. For example the use of natural enemies is often used when pest numbers are still relatively low. Chemical controls are often used when pest populations are very high.

For more information on IPM in citrus refer to the book "Citrus pests and their natural enemies".

AUSTRALIAN SUPPLIERS OF BENEFICIAL ORGANISMS

Beneficial Bug Co
PO Box 436
Richmond NSW 2753
Telepohone: (02) 4570 1331
www.beneficialbugs.com.au

Bio Protection Pty Ltd
PO Box 384
Kilmore Vic 3764
Telephone: (03) 5781 0033

Biological Services
PO Box 501
Loxton SA 5333
Telephone: (08) 8584 6977

BioResources Pty Ltd
PO Box 578
Samford Qld 4520
Telephone: (07) 3289 4919
www.bioresources.com.au

Bugs for Bugs
Bowen Street
Mundubbera Qld 4626
Telephone: (07) 4165 4663
www.bugsforbugs.com.au

EcoGrow Australia Pty Ltd
Unit 12, 5-11 Hollywood Ave
Bondi Junction NSW 2022
Telephone: (02) 9389 0888
www.ecogrow.com.au

Horticultural Crop Monitoring
PO Box 3725
Caloundra Qld 4551
Telephone: (07) 5491 4662

Pisces Enterprises Pty Ltd
PO Box 200
Kenmore Qld 4069

Source: The Good bug Book. Edited by R. Llewellyn. 2nd edition 2002.

BENEFICIAL ORGANISMS AVAILABLE IN AUSTRALIA

Beneficial organism	Type	Target Pest
Aphytis lingnanensis *Aphytis melinus*	wasp	Red scale
Chilocorus baileyi *Chilocorus circumdatus*	blue ladybird orange ladybird	Hard scales (oriental and oleander scales) Hard scales (while louse, oriental, oleander and red)
Cryptolaemus montrouzieri	ladybird	Mealybug
Encarcia formosa	wasp	greenhouse, tobacco, cotton and poinsettia whitefly
Euseius victoriensis	mite	citrus rust, bud, broad and flat mite
Leptomastrix dactylopii	wasp	citrus mealybug
Mallada signata	lacewing	aphids, caterpillars, thrips, mealybugs, whitefly
Metaphycus sp	wasp	Soft brown, black and citricola scale
Phytoseilus persimilis	mite	Two spotted mite
Pristhesancus plagipennis (Assassin bug)	bug	caterpillars and some bugs
Stratiolaelaps mites	mite	thrips pupae
Trichogramma pretiosum *Trichogramma carverae*	wasp wasp	moth eggs - light brown apple moth
Typhlodromus occidentalis *Typhlodromips montdorensis*	mite mite	two spotted mite thrips; broad, russet and spider mites

Source: The Good Bug Book. Edited by R. Llewellyn. 2nd edition 2002.

USING PETROLEUM BASED OIL SPRAYS IN CITRUS

Oil Sprays have a Name change

Following an international conference on Spray Oils in Sydney in 1999, new names were recommended to replace such terms as summer oils, superior oils, petroleum spray oils and narrow-range and broad-range oils. This new classification is based on the degree of refinement of the oil and recommends three new categories:

- Mineral oil (MO)
- Agricultural mineral oil (AMO)
- Horticultural mineral oil (HMO)

HMOs and AMOs come from the lubricating fraction of petroleum oils. These high quality oils should be refined from virgin distillates and not from recycled products. Only HMOs and AMOs are applied to plants. They are used to suffocate (ie. drown) or alter the behaviour of susceptible pests and pathogens.

Oil sprays have been used for over a century to control insect pests. During this time there have been significant changes in the way oils are formulated, in their quality and in the emulsifiers used.

Benefits of HMOs and AMOs

- they are as effective or more effective than broad-spectrum synthetic pesticides for a wide range of pests and diseases;
- many pests can be controlled simultaneously;
- they have less harmful effects on the natural enemies of citrus pests;
- they do not stimulate other pest outbreaks;
- pests are not known to develop resistance to them;
- the oil deposits are broken down within weeks to form simple, harmless molecules;
- when using oils only minimum protective clothing needs to be worn;
- they are suitable (depending on the emulsifiers and additives used to formulate products) for use in organic farming;
- they are not toxic to humans or other animals.

Standards for HMOs and AMOs

There are a number of standards recommended for spray oils. Unfortunately this type of information is not usually on the registered label. You need to contact the manufacturer for these details.

- **They must be virgin paraffinic oils (Cp $\geq$ 60%).** This means that they must not be recycled oils and that more than 60% of the carbon-hydrogen molecules must be in chains rather than rings.
- **The concentration of unsaturated molecules must be 8% or less.** The unsaturated molecules are the ones that oxidise and produce acids which can burn plant tissue.
- **The unsulfonated residue (UR) should be 92% or higher.** The higher the UR the lower the risk of phytotoxicitity (damage) to the plant.

- **The *n*-paraffin carbon number (*n*C*y*) of HMOs are mostly *n*C21 and *n*C23 as well as *n*C24. The *n*-paraffin carbon number of AMOs are mostly *n*C24 or *n*C25**. This number relates to the weight of the oil, the lower the carbon number the lighter the oil. For example a *n*C21 oil is lighter than a *n*C24 oil.

Controlling Pests Using Oil Sprays

Oil sprays control pests either by suffocation or by altering their behaviour (eg. reduced egg laying). Diagram 1 shows what happens to the oil droplet when it is applied to the plant. Diagram 2 shows how insect pests are suffocated by oils.

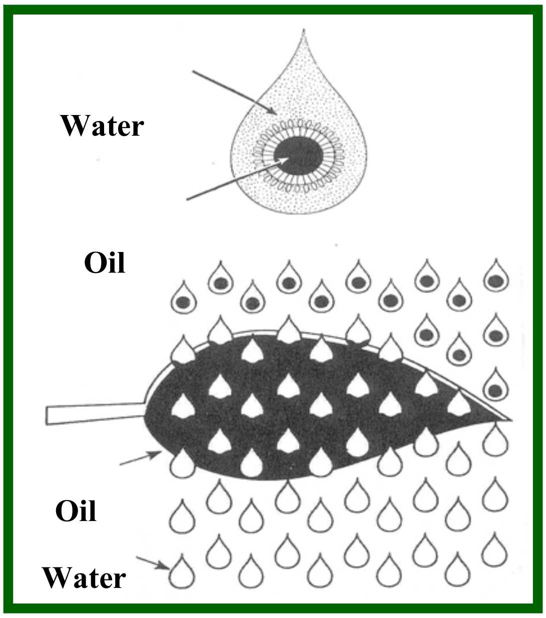

Diagram by A. Beattie

Diagram 1: Oil remains on the leaf surface or moves into the leaf and most water and emulsifier run off

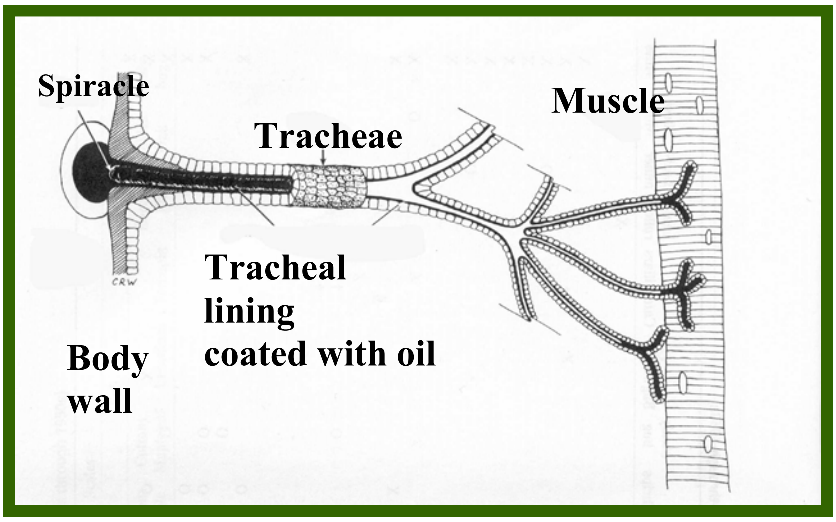

Diagram by A. Beattie

Diagram 2: Anoxia (suffocation) results from oil movement into the tracheae (breathing tube) of the pest

Soft Scales and Mealybugs
These can be more difficult to control than hard scales. White wax, pink wax and hard (Chinese) wax scales are the easiest of the soft scales to control. They have one annual generation in southern states and two generations in northern NSW and QLD.

Control should be achieved with a 1% oil as long as you apply the spray thoroughly to all infested plant surfaces. Timing of the oil spray is critical and needs to coincide with the presence of the young recently hatched stages (crawlers) which generally occur on the upper leaf surfaces.

The other soft scales such as black and soft brown scales are more difficult to control because they have many overlapping generations.

To achieve the best control, time your oil spray to coincide with the greatest number of young stages. Spot spraying heavily infested trees rather than whole blocks is also an option for these scales.

**NB. Ants protect soft scales and mealybugs and must also be controlled. Controlling soft scale infestations is pointless if you do not also control the ants.*

Armoured (Hard) Scales
Light infestations of armoured scales such as red and purple scale are easily controlled using oil sprays. Moderate to heavy infestations are more difficult to control largely as a result of the very large numbers of scale insects present.

A 1% oil spray applied at high volumes should be used. Good coverage of all the above ground parts of the tree is necessary. Manipulate your sprayer to direct more spray into the tops of trees so that the spray drips down inside the canopy. Good coverage of the inside of trees is essential and high volume sprays are necessary.

Mites
Mite infestations can be controlled using multiple low concentration (0.25-0.5%) oil sprays. The oils suffocate the mobile stages and the oil deposits on the plant surface can reduce feeding and egg laying behaviour. Citrus red mite (only present in the Gosford and Sydney areas) appears to be more susceptible to oil sprays than Two-spotted mite.

Citrus Leafminer (CLM)
In most of southern and eastern Australia CLM infestations occur from mid-summer until mid-autumn. Adult moths lay eggs on immature leaves when they are less than 4cm long. The peak egg laying period occurs between mid-February and mid-March.

The oil sprays don’t kill CLM but instead affect the behaviour of the female moth. The moth tends to lay fewer eggs on the oil sprayed leaves and the oil deposits also affect the movement of moths between and within trees. This then results in reduced populations of CLM.

Control of CLM is usually only necessary in nursery situations and in young trees. Multiple (every 5-14 days) low concentration (0.25%) oil sprays are applied to the susceptible new growth as soon as the summer flush commences in mid to late January. Good coverage of leaf surfaces is essential and trees should be sprayed to the point where the spray just starts to drip off the leaves.

It is difficult for the moth to establish large populations if you commence spraying early in the summer flush cycle (January) when the flush is first observed.

Spray volumes

HMO's and AMO'S need to be applied at high volumes so that the oil forms an effective film over the plant or fruit surfaces. Thorough coverage to the tops and insides of trees is important. Oils are not poisons and have limited residual activity, however the benefits of a single effective spray can last more than one season.

Some sprayers are better at applying high volumes of spray than others. The best high volume sprayer is the oscillating boom with a horizontal outrigger. If you are using an airblast sprayer then a tower is recommended in trees higher than 2m.

The volume of oil sprays needed depends on the type of pest; the level of infestation; tree height; canopy density and planting density. The following recommended volumes are for 4m high orange trees. However, for young trees and lemons (which usually have a sparser canopy than oranges) the volumes may be reduced.

Oil sprays applied in November-December and February-March will commonly kill a range of citrus pests.

Pest	Timing	Volumes (L)/ha* *For 4m high orange trees	Concentration of Oil
Red Scale and other Hard scales	Young stages	10-14,000	1%
Mealy bugs	Young stages and before young fruits touch	10-14,000	1%
Thrips	Young stages and before fruits touch	10-14,000	1%
Soft Scales	Young stages	8-10,000	1%
Mites	Young stages	5-8,000	0.7-1% Single spray or 0.25-0.5% Multiple low concentration sprays
Citrus leaf miner	Young new growth (<4cm long) in summer/autumn	4,000	0.25-0.5% multiple low concentration sprays

Plant Damage from Oil Sprays

Oil sprays can sometimes damage plants - this is referred to as phytotoxicity. Instances of phytotoxicity are less common these days than in the past, largely due to the availability of better quality high grade products.

Damage to plants can occur if the oil sprays are not applied correctly or under the right conditions. Damage can include leaf burning and oil soaking (of leaves and fruit), and in severe cases leaf drop and reduced yields.

Oil soaking may be evident on fruit surfaces and on leaves (typically along the leaf midrib) up to a few weeks after application (this is common). See Photo 1.

Photo by Andrew Beattie
Oil soaking on leaves is common

The extent of soaking depends on the concentration of oil applied, the frequency of application, the citrus variety (Meyer lemon fruit appear more sensitive than Eureka lemon), and the climatic conditions. The oil soaking disappears over time, as the oil evaporates from the plant, and moves within the plant. The loss of oil from the plant is more rapid in tropical and subtropical climates than in temperate regions. This is largely related to daily temperatures, the higher the temperature the more rapidly the oil disappears.

Leaf burn is largely caused by the acids, which are formed when the unsaturated oil molecules in the product are exposed to air and sunlight. This is why it is recommended that HMOs and AMOs have less than 8% unsaturated molecules, because it is these molecules which are responsible for the burning. Burning is more likely to occur in slow drying conditions, when trees are moisture stressed, in high temperatures, with high concentrations of oil, and with heavier oil products (oil with carbon values of *n*C24 and *n*C25).

Things to know when using HMOs and AMOs

- You need to apply oils so that you achieve a thin even coating of oil over the plant or fruit surface.
- It is better to apply a higher volume of spray mix than to use a higher concentration of oil in the mix.
- In situations (tropical and subtropical regions) where you are using multiple low concentration (<0.5%) oil sprays annually, apply sprays just to the point of runoff (spray on leaves just starts to drip).
- In situations (subtropical and temperate regions) where only one or two applications of a higher concentration (1%) oil spray are used annually, apply at volumes which exceed the point of runoff (spray on leaves is continuously dripping).
- Timing of oil sprays is critical, apply them when the target pest numbers are highest and they are at their most susceptible stage.
- For most pests you need to thoroughly coat all plant surfaces - the upper and lower leaf surfaces, fruit, twigs, branches, insides and outsides of trees.
- The residual activity (how long they last) of oils is less under hotter tropical conditions than in the cooler temperate climates. This is largely because the oil molecules evaporate and move within the plant more quickly in warmer climates.

Application tips and precautions when using HMOs and AMOs

☑ To prepare an oil spray, fill the spray tank with two-thirds of the water, then add the oil whilst agitating the tank, then top up with the remaining water.

☑ Spray the oil mix immediately after preparation.

- ☑ Oil spray mixtures need to be continuously agitated. Never leave the spray mix to stand for longer than ten minutes. If you do, then vigorously agitate or stir before recommencing application.
- ☑ Aim to have the oil spray dry on the plant within 1-2 hours of application.
- ☑ In slow drying conditions, use oil products with UR values > 99.8%.
- ☑ The effectiveness of some synthetic chemicals is enhanced when mixed with low concentrations of oil.
- ☒ Don't apply oil sprays in temperatures higher than 35^{0}C (if high temperatures are forecast, spray in the early morning or late afternoon).
- ☒ Don't apply oil sprays to moisture stressed trees.
- ☒ Do not add additional emulsifiers or surfactants to the oil spray.
- ☒ Do not mix oils with incompatible chemicals such as sulfur, captan, carbaryl, propargite, dimethoate, and foliar fertilisers with high amounts of sulfur. If oils are mixed with incompatible chemicals, the risk of phytotoxicity is increased.
- ☒ Do not apply an oil spray within one month of a sulfur spray.
- ☒ Do not use more than a 0.5% concentration of oil with a copper spray.
- ☒ To reduce the likelihood of oil "soaking" on fruit, do not apply an oil spray within four weeks of harvest (especially in cool conditions when the oil takes longer to dissipate from and within the plant).
- ☒ Excessive use of oil sprays (high doses) can reduce yields by clogging up the water and food transport systems in the plant.
- ☒ Do not use more than an annual total of 3.0% in tropical/subtropical climates, and 2.0% in temperate climates.
- ☒ Do not spray citrus with 1% or more oil spray before October or after April.
- ! Take care when applying oil sprays when the ambient shade temperature is more than 32^{0}C.

Best Practice Tips

- ☑ In most situations, the concentration of oils should not need to exceed 1%. Focus on increasing spray volumes rather than increasing the concentration of the oil.
- ☑ Oils need to be applied so that you get a good even coverage of all plant surfaces on which the target pest is located.
- ☑ Carefully follow all the application recommendations and precautions to avoid problems with phytotoxicity.
- ☑ Aim to apply oil sprays so that they dry within 1 to 2 hours after application.

USING COPPER SPRAYS TO CONTROL DISEASES IN CITRUS

Most Australian citrus disease control programs rely on copper sprays to protect the trees and fruit from infection. Fungal diseases are more of a problem in areas with warm humid conditions such as those in the tropical, sub tropical and coastal regions. The main diseases affecting lemons and spray programs are outlined in Table 1.

Table 1: Typical fungal disease control programs in Australia

Disease	**Spray Program**
Melanose	Copper at petal fall & 6-8 weeks later.
Greasy spot	Copper &/or citrus spray oil
Lemon scab	Copper at ¼ - ½ petal fall & 6 weeks later.
Brown rot	Copper in autumn before rain when fruit is maturing.
Pink disease	Copper
Septoria	Copper prior to autumn rain

How copper works

Copper sprays are protectant fungicides that must be present on the plant or fruit surface before infection by the pathogen. Copper is not a systemic chemical and cannot be carried internally through the plant to kill the pathogen. Plant exudates in the presence of moisture form weak acids which dissolve the copper products on the plant surface releasing copper ions. Any fungal spores that come into contact with these copper ions pick them up and they interfere with their enzyme system.

Once the copper is applied it sticks only where it hits and does not spread across the fruit or leaf surface. The coverage of copper over the plant or fruit surface deteriorates over time due to both fruit growth and weathering by rain and wind. Depending on conditions copper fungicides only offer about 4-8 weeks protection. Therefore reapplication of the protective copper layer may need to be made if infection is likely over longer periods.

The key to using copper fungicides effectively is to achieve the most even distribution on the plant/fruit surface as you can.

The differences between different copper formulations

There are basically three types of copper compounds: copper oxychloride and copper hydroxide (green and blue coppers) and cuprous oxide products (red copper). Today's copper fungicides are generally more effective than older products per unit area of metallic copper and can therefore be used at lower rates.

From work done on copper products by Professor Pete Timmer in Florida he found that:

- whether it is a liquid, flowable or dry product there is very little difference in the level of control per unit of metallic copper;

- there is also little difference in the effectiveness of the different formulations;
- the most important factor affecting product effectiveness is the particle size of the formulation and how well it sticks (rainfast) to the plant surface;
- products with a smaller particle size tend to have better coverage, rainfastness and longevity on the crop.

Use copper sprays on their own
In Florida they recommend that no other products be mixed with copper sprays. This includes other fungicides, insecticides or nutrient sprays. The use of low rates of petroleum spray oils (<0.5%) as a spreader is generally okay.

All good quality copper products may contain small amounts of other impurities (eg cadmium and lead), however some cheaper products may contain higher levels.

Damage from copper sprays
Copper sprays can cause necrotic (dead) spots between the oil glands giving the fruit rind or leaves a speckled appearance. These spots appear similar to those of the disease melanose, however, the spots are almost black and are often on the exposed (outward facing) surface of the fruit. Copper sprays also darken existing blemishes (ie wind blemish on the fruit).

On some soils copper levels can also increase and become toxic to citrus roots and also interfere with nutrient uptake.

The phytotoxic effects of copper are more common when:
- copper is applied with other products (especially acidic ones) in the one tank mix;
- applied at high temperatures (especially when fruit and plant surface temperatures are above the high twenties);
- humidity is low and cloud cover is close to zero;
- liquid formations are used.

Reducing copper damage
Copper damage to fruit and leaves can be reduced by:

- applying lower rates;
- not mixing copper with other products;
- applying them when fruit/leaf temperatures are lower than 25^{o}C.

Alternatives to copper
In Australia there are very few alternative fungicide products registered for use on citrus. In the past ten years research overseas has focused on assessing the new strobilurin fungicide group. These fungicides have the advantage of being both broad spectrum and systemic. However, resistance problems are already occurring overseas from misuse and overuse. Researchers in Queensland have recently completed a three year project (''Screening New Products for Citrus Disease Control'' Project No. CT00021) assessing this new fungicide group for the control of two diseases that affect oranges and mandarins, black spot (oranges) and brown spot (mandarins) in citrus.

The trials showed that azoxystrobin was as effective as copper and mancozeb sprays for controlling black and brown spot. There was also less rind damage with strobilurin in these trials. In Australia there are currently no product registrations for Citrus.

They also found that there were no significant differences in disease control between the different formulations of copper trialed. (The trial assessed copper ammonium acetate, copper hydroxide, copper oxychloride and cuprous oxide).

A full copy of the report is available from Horticulture Australia.

Best Practice Tips

- ☑ copper sprays are protectant fungicides and need to be applied prior to infection.
- ☑ a good even coverage of copper to plant and fruit surfaces is essential.
- ☑ the protective layer of copper diminishes over time (as a result of fruit/plant growth and rain and wind) and therefore only offers short-term protection (4-8 weeks) depending on conditions. If infection is likely over longer periods then reapplication may be necessary.
- ☑ particle size (smaller the better) and rainfastness are the most important aspects of any copper product.
- ☑ apply copper sprays on their own.
- ☑ use good quality products with low levels of impurities.
- ☒ don’t apply copper when fruit/leaf temperatures are high and humidity is low.

THE USE OF GIBERELLIC ACID (GA) IN CITRUS

Giberellic acid is used on lemons to delay rind ageing. A 10 ppm spray is usually applied 4-6 weeks prior to fruit maturity when fruit are a silver-green colour. If fruit are to be degreened postharvest then colour development is slower when GA is applied.

Best Practice Tips

- ☑ the pH of the water must be 4 to 4.5. A commercial buffer can be used to reduce the pH of water.
- ☑ use a high volume sprayer to achieve good coverage. Apply a minimum 7500L/ha to mature medium sized trees and spray to runoff.
- ☑ trees must not be under any water stress prior to and after GA application. Good irrigation management is required, trees must not be under-watered or waterlogged.
- ☑ spray during slow drying conditions. Spray either in the early morning (avoid dewy mornings) or in the late evening.
- ☒ don't spray in hot conditions.
- ☒ avoid oil & copper sprays close to GA applications. It is better to apply GA prior to an oil or copper spray. If copper or oil sprays are applied, wait 4 weeks to apply GA.
- ☒ avoid GA application if rain is forecast within 6 hours.
- ☒ avoid mixing other compounds with GA.
- ☒ avoid using GA on unhealthy trees.

Photo by Greg Moulds

Lemons can be sprayed with GA at the silver green stage to delay rind ageing

SPRAY APPLICATION

Spray application involves a number of steps. Some of the more important ones to consider include:

- ***Identify the problem:*** Only when you properly identify your pest or disease problem will you be able to select a suitable control.
- ***Choose the appropriate control:*** It may be chemicals, predators or a combination of both. If it is a chemical don't forget to read the label for specific directions of use. Check the mode of action of the chemical - this can influence how you will apply it.
- ***Select the right nozzle and pressure for the job:*** The type and size of nozzle and swirl plate determines spray coverage and droplet size. The swirl plate is just as important as the nozzle, since its spinning action controls droplet size.

Check that each nozzle is working properly. Nozzle output should not vary by more than 10-15% of the manufacturers' specifications.

A visual check of nozzle performance is easy and involves standing back and looking at the spray pattern for signs of stripping, interference or blockages.

Select the right pressure for the nozzle being used, so that the correct output is obtained. Correct nozzle pressure is recommended by the manufacturer. Be sure to obtain this information when you buy your nozzles, or better still, obtain a nozzle catalogue. If you need to change output you should modify your speed – not the operating pressure.

Filters should be used to prevent blockages in spray lines and nozzles. The size of mesh used in filters is often recommended by sprayer or nozzle manufacturers.

An example of typical mesh sizes and placement are given below:

Pre tank......................... 80
Suction line 100-120
Pressure line 120-150
Nozzle 50-60

Pressure gauges: The best type are dampered with oil inside. Use a gauge with an appropriate range. For most spraying purposes a range of 0-10 bars or 0-1000 kPa is suitable. Make sure the gauge is large enough to read.

Pressure Units: The correct unit of pressure in Australia is the Pascal. As this is a small unit it is more common to talk in KiloPascals abbreviated as kPa. Some countries use pounds per square inch (PSI) or bars.

To convert to kPa use the following formulas:

multiply psi by 6.89 to get kPa
multiply bars by 100 to get kPa

Some approximate conversions are:

15 psi = 100 KPa = 1 bar
30 psi = 200 KPa = 2 bars
45 psi = 300 Kpa = 3 bars

Pumps: The best one to use is a diaphragm pump, which has no contact between the pumping mechanism and the chemical. It should have enough capacity to drive the spray unit.

Spray safely:

- spray only if weather conditions are favourable;
- wear appropriate protective clothing and equipment;
- inform other workers to keep clear of the area where you are spraying;
- avoid spray drift onto non target areas.

Clean your equipment after use: Clean both the sprayer and the protective clothing you wore. After each day's use, flush sprayers with water inside and out to prevent chemical buildup, contamination and blockages. Choose a working area carefully to avoid contamination of water supplies and the environment.

Always wash protective clothing separately from the family wash.

Upgrade or do not spray: If your equipment is in poor condition and cannot be calibrated and used safely by the operator - then your only option is to upgrade your equipment. It may not be necessary to replace your entire spray unit - just a few of its working parts. The cost of upgrading and improving your equipment will be quickly returned by more efficient and effective spraying.

Good spray technique will save you time and money. You will get better pest and disease control and you will grow a better quality product and waste less chemicals. It will also help to reduce any personal or environmental damage.

SPRAYER CALIBRATION

Preparation

Before starting your calibration, make sure that the various mechanical components of the sprayer are working properly.

Ensure the pressure gauge is working and that its range suits the pressure at which you will be operating. Worn nozzles, blocked filters, worn pumps and incorrect pressure all adversely affect sprayer output. Check that these components are in good working order before calibration.

Calibration

There are two main factors affecting spray application rate. These are:

- liquid flow rate; and
- travel speed.

Pump pressure and nozzle size determine liquid flow rate. Travel speed must be constant to ensure even application. It must be safe for the operator and also correct for the capacity of the sprayer.

Calculating sprayer output and checking nozzles

By checking individual nozzle output you can calculate total sprayer output (L/min) and also check whether nozzles are still working to the manufacturers' specifications. If the output from a nozzle varies by more than 10-15% of the output specified by the manufacturer, then replace both the nozzle and the swirl plate. To measure sprayer output:

- fill the spray tank with clean water;
- disengage the gearbox;
- place a measuring jug under each nozzle (one at a time);
- run the sprayer for one minute at the correct pressure with all nozzles operating;
- measure the output from each nozzle over a one minute period;
- compare output to manufacturers' specifications to determine if nozzles are working correctly;
- add up the output from all nozzles to get total sprayer output in Litres/ minute.

Calculating travel speed

- measure a distance of 50 or 100 metres on the ground and mark the start and finish positions with pegs;
- select the right gear and engine rpm to give 540 rpm at the PTO and achieve effective spray coverag;
- measure the time taken to travel the measured distance with the sprayer outfit attached and half full.

$$\textit{Travel speed (km/hr)} = \frac{\textbf{Distance (m) x 3.6}}{\textbf{Time (seconds)}}$$

NB. Take note of engine revolutions and gear used for later use.

Remember the slower you go the higher the application rate. A change in ground speed of 10% results in a change in application rate of 10%.

Calculating spray application rate:

$$\text{Application rate (L/ha)} = \frac{600 \times \text{Sprayer output (L/min)}}{\text{Row spacing (m)} \times \text{Travel speed (km/hr)}}$$

* NB. This formula assumes you are spraying both sides of the row with one pass. If you spray only one side then row spacing is the distance from the centre of the row to the tree line.

Calculating the amount of chemical to put in your spray tank
Read the label to determine the rate to use. Some chemical rates are given in amounts/litre of water; these usually include fungicide and insecticide sprays. However, some chemical rates are given in amounts/hectare; these are usually herbicides.When rates are in *amount/ha* use the following formula to calculate the amount of chemical to put in your tank:

$$\textit{Amount of chemical per tank} = \frac{\text{Tank volume (L)} \times \text{amount of chemical/ha*}}{\text{Sprayer application rate (L/ha)}}$$

* NB. Obtain recommended amount from the label on the chemical container.

Calculating the number of spray tanks required to do the job
By accurately calculating how many spray tanks you need to spray a known area, you reduce chemical wastage and save money.

Total spray volume required (L) =
Area to spray (ha) x spray application rate (L/ha)

$$\textit{Number of spray tanks required} = \frac{\text{Total spray volume required (L)}}{\text{Spray tank capacity (L)}}$$

PEST AND DISEASE CONTROL PRODUCT TABLES

The following tables (1-4) list the current registered chemicals for use in commercial citrus and lemon orchards in Australia.

Table 1 lists the chemicals registered for postharvest treatment. Table 2 lists the chemicals registered for improving fruit quality. Table 3 lists the chemicals registered for pest control and Table 4 lists the chemicals registered for disease control. This information has been sourced from Infopest, March 2004. For more information on purchasing Infopest phone (07) 3239 3967 or go to www.dpi.qld.gov.au/infopest

The tables are not comprehensive in that they do not list chemicals registered for general categories such as orchards or fruit trees.

These tables do not contain all the information which appears on the product label. Product registrations can also change over time. Also some products are not permitted to be used when exporting to certain countries. Before using any product always read the product label, always check the registration and use patterns and for export fruit check what is permitted by the destination country.

For more information on using pesticides safely refer to the Spray Sense Series available on the NSW Agriculture website at www.agric.nsw.gov.au/reader/spray-sense

Key to Tables

Withholding periods

NA - not applicable. NS - not stated.

Permits

Permit - refers to an Australian Pesticides and Veterinary Medicines Authority (APVMA) permit. OUP - Open Use Permit.

Chemicals under permit may only be used by the persons named on the permit in the manner specified. You must obtain a copy of the permit and read and comply with its conditions. Copies of permits are available on the APVMA website at www.nra.gov.au

States

All = All states

Q = Queensland; N = New South Wales; V = Victoria; S = South Australia; W = Western Australia; Nt = Northern Territory; T = Tasmasia.

Table 1: Registered products for postharvest treatment of citrus and lemons

Pest/Disease/Other	Active Constituent in Product	Withholding Period (WHP) days	Citrus	Lemons	States
Bactericide	iodine	NA	✓	✓	All
Blue/Green Mould	carbendazim	NA/NS	✓		QNVWS
Blue Mould	guazatine imazalil imazalil sulfate SOPP thiabendazole	NA NA NA NA NA	✓ ✓ ✓ ✓ ✓		QNVWSNt All All All QNVWS
Centre Rot	2,4-D as amine	0	✓		Q (Permit)
Colour Retention	2,4-D-dma	NA	✓		All
Fungi	iodine	NA	✓	✓	All
Green Mould	guazatine imazalil imazalil sulfate thiabendazole	NA NA NA/NS NA	✓ ✓ ✓ ✓		QNVWSNt All All QNVWS
Light Brown Apple Moth	liquid hydrocarbons	NS	✓		All
Mealybugs	liquid hydrocarbon	NS	✓		All
Melanose	thiabendazole	NA	✓		QNVWS
Qld Fruit Fly	dimethoate	Permit	✓	✓(S) ✓(QNVW)	NQ
Stem-end Rot	2, 4-D as amine	0	✓		Q
Sour Rot	guazatine SOPP	NA 0	✓ ✓		QNVWSNt Q (Permit)

Table 2: Registered products for improving fruit quality in citrus and lemons

	Active Constituent in Product	Withholding Period (WHP) days	Lemons	States
Adhesion control	lauryl alochol ethoxylate	NS	✓	All
Rind quality maintenance	gibberellic acid	NA	✓	All

Table 3: Registered products for pest control in citrus and lemons

Pest	Active Ingredient	Withholding Period (WHP) days	Citrus	Lemons	States
Ants	Chlorpyrifos	14	✓		N (OUP 70A) QVS
Aphids	Azinphos-methyl dimethoate petroleum oil omethoate pirimicarb	14 7 1 7 2	✓ ✓ ✓ ✓ ✓	 ✓	QNVWST All All W Q
Banana Fruit Caterpillar	endosulfan	14	✓	✓	QW (Permit)
Black (Brown Olive) Scale	Azinphos-methyl petroleum oil paraffin oil	14 1 1	✓ ✓ ✓		QNVWST WT WT
Black Citrus Aphid	maldison pirimicarb parathion-methyl methidathion	3 2 14 21	✓ ✓ ✓	 ✓	NVWSTNt NVWST All QW
Blastobasid Fruitborers	methidathion	21	✓		QW
Broad Mite	abamectin sulfur dicofol	7 0 7	✓ ✓ ✓		All Q (Permit) QW
Bronze Orange Bug	dimethoate maldison endosulfan carbaryl methomyl methidathion	7 3 14 3 2 21	✓ ✓ ✓ ✓ ✓ ✓	✓ QW ✓	All NVWSNt QW (Permit) QW QVWS QW
Brown Citrus Rust Mite	abamectin sulfur wettable sulfur zineb mancozeb dicofol	7 0-1 1 7 NA 7	✓ ✓ ✓ ✓ ✓ ✓		All All QNVWS QN All QW
Budworms (Heliothis)	endosulfan methomyl	14 2	✓ ✓	✓	QW (Permit) QVWS
Bugs	dimethoate	7	✓	✓ QNVWS	All
Chinese wax scale	petroleum oil	1	✓		W
Circular black scale	petroleum oil methidathion	1 21	✓ ✓		QVWSNtT QW
Citrophilous Mealybug	buprofezin	28	✓	✓	All
Citrus Bud Mite	sulfur mancozeb wettable sulfur ferbutatin oxide zineb dicofol	0-1 NA 1 7 7 7	✓ ✓ ✓ ✓ ✓ ✓		All All QNVWST QNt (Permit) Q QW
Citrus Butterflies	maldison carbaryl	3 3	✓ ✓		NVWSNt NVWST
Citrus Flat Mite	abamectin fenbutatin oxide	7 7	✓ ✓		All Q (Permit)
Citrus Gall Wasp	methidathion	21	✓		QW
Citrus Katydid	endosulfan	14	✓	✓	QW (Permit)
Citrus Leaf-eating weevil	bifenthrin chlorpyrifos carbaryl	NA 14 3	✓ ✓ ✓		All Q VWSNt

Table 3: Registered products for pest control in citrus and lemons (continued..)

Pest	Active Ingredient	Withholding Period (WHP) days	Citrus	Lemons	States
Citrus Leafminer	diazinon permethrin petroleum oil aldicarb paraffin oil methidathion	14 NS 1 NA 1 21	✓ ✓ ✓ ✓non bearing trees only ✓ ✓		QNW N All QNVWS All QW
Citrus Mealybug	buprofexin petroleum oil chlorpyrifos	28 1 14	✓ ✓ ✓	✓	All Q (Permit) Q
Citrus Nematode	cadusafos	NA	✓		All
Citrus Plant Hopper	endosulfan	14	✓	✓	QW (Permit)
Citrus Red Mite	abamectine + clofentezine or amitiaz (Permit 4515)	NA	✓		N
Citrus Rust (Maori) Mite	abamectin lime sulfur propineb sulfur wettable sulfur zineb mancozeb fenbutatin oxide dicofol	7 NS 7 0-1 1 7 NA 7 7	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓	✓	All NVWST QNVWS All QNVWS QN All QNt QW
Citrus Rust Thrips	chlorpyrifos	14	✓		Q
Cottony Citrus Scale	petroleum oil methidathion	1 21	✓ ✓		Q (Permit) QW
Fruit Flies	fenthion maldison and yeast autolysate	7 3	✓ ✓		QWNt QNVSNt
Fruiteating Weevil	chlorpyrifos	14	✓		Q
Fruitpiercing Moth	carbaryl	3	✓		VWST
Fullers Rose Weevil	chlorpyrifos carbaryl	14 3	✓ ✓		Q NVWSNtT
Giant Northern Termit	fipronil	NA	✓		Nt (Permit)
Grasshoppers	diazinon	14	✓		QW
Hemispherical Scale	petroleum oil methidathion	1 21	✓ ✓		Q (Permit) QW
Jassids	buprofezin	28	✓	✓	All
Large Citrus Butterfly	methomyl	2	✓		QWVS
Leafhopper	endosulfan	14	✓	✓	QW (Permit)
Leafroller moths	azinphos-methyl	14	✓		QNVWST
Lemon Bud Moth	methomyl	2	✓		Q (Permit)

Table 3: Registered products for pest control in citrus and lemons (continued..)

Pest	Active Ingredient	Withholding Period (WHP) days	Citrus	Lemons	States
Lightbrown Apple Moth	tebufenozide carbaryl methomyl	1 3 2	✓ ✓ ✓		All All NWS
Long Soft Scale	petroleum oil methidathion	1 21	✓ ✓		Q (Permit) QW
Longtailed Mealybug	parathion-methyl buprofezin methomyl	14 28 2	✓ ✓ ✓	 ✓ 	All All WS
Mealy Bugs	methidation	21	✓		WS
Mediterranean Fruit Fly	dimethoate fenthion	7 7	✓ ✓	 ✓	NVW W
Nematodes	fenamiphos	NS	✓		QN
Orange Fruit Borer	carbaryl	3	✓		QNVWS
Oriental mite	fenbutatin oxide	7	✓		Q (Permit)
Pink Wax Scale	carbaryl maldison petroleum oil paraffin oil methdathion	3 3 1 1 21	✓ ✓ ✓ ✓ ✓		QNW NVWSNtT All QNVWT QW
Purple Scale	maldison petroleum oil methidathion chlorpyrifos	3 1 21 14	✓ ✓ ✓ ✓		NVWSNtT All QW Q
Qld Fruit Fly	chlorpyrifos and yeast hydrolysate dimethoate (don't use on Meyer lemons) fenthion maldison and yeast autolysate	14 (Bait spray only) 7 7 3	✓ ✓ ✓ ✓	✓	QNW QNVWNt NVW Q (Permit)
Red Scale	azinphos methyl buprofezin chlorpyrifos maldison methidathion paraffin oil parathion-methyl petroleum oil	14 28 14 3 21 1 14 1	✓ ✓ ✓ ✓ ✓ ✓ ✓ ✓	 ✓	QNVWST All All NVWS QNVWS QNVWS All All
Rose Scale	petroleum oil	1	✓		All
Rutherglen Bug	maldison	3	✓		NVWSNtT
Scale insects	paraffin oil parathion-methyl	1 14	✓	 ✓	All NVWS
Small Citrus Butterfly	parathion-methyl methomyl	14 2	✓ ✓		All QVWS
Snails	copper complex	1	✓		All
Soft Brown Scale	azinphos-methyl maldison methidathion petroleum oil parathion-methyl	14 3 21 1 14	✓ ✓ ✓ ✓ ✓		QNVWST NVWSNtT QW All All

Table 3: Registered products for pest control in citrus and lemons (continued..)

Pest	Active Ingredient	Withholding Period (WHP) days	Citrus	Lemons	States
Sorghumhead Caterpillar	methidathion	21	✓		QW
Spider Mites	petroleum oil	1	✓		QVWSNtT
Spined Citrus Bug	carbaryl diazinon endosulfan maldison methomyl methidathion	3 14 14 3 2 21	✓ ✓ ✓ ✓ ✓ ✓	 ✓	QNVWS NW NW NVWSNt QVWS QW
Stubby Root Nematode	cadusafos	NA	✓		All
Subterranean termites	imidacloprid	NA	✓(non bearing trees only)		N
Thrips	dimethoate maldison	7 3	✓ ✓	✓	All NVWSNtT
Treehoppers	maldison	3	✓		NVWSNtT
Two-spotted mite	fenbutatin oxide dicofol	7 7	✓ ✓		Q (Permit) QW
White Flies	petroleum oil	1	✓		QVWSNtT
White Louse Scale	buprofezin lime Sulfur methidathion sulfur wettable sulfur	28 NS 21 0-1 on some products 1	✓ ✓ ✓ ✓ ✓	✓ ✓	All QNVST QW All NW
White Wax Scale	azinphos methyl carbaryl methidathion paraffin oil petroleum oil	14 3 21 1 1	✓ ✓ ✓ ✓ ✓		QNWVST QNVWST QNW QNVWT All
Wingless Grasshopper	chlorpyrifos dimethoate	14 7	✓ ✓	 ✓	QNVWST All
Yellow Peach Moth	carbaryl	3	✓		All
Yellow Scale	petroleum oil	1	✓		QNVWS

Table 4: Registered products for disease control in citrus and lemons

Disease	Active Constituent in Product	Withholding period (WHP) days	Citrus	Lemons	States
Black Spot	benomyl	NS	✓		Q (Permit)
	copper sulfate (tribasic)	1	✓		All
	copper ammonium acetate	1	✓		All
	copper hydroxide	1	✓		All
	copper oxychloride	1	✓		All
	cuprous oxide	1	✓		All
	mancozeb	0-14	✓		All
	petroleum oil	1	✓		N
	propineb	7	✓		QNVWS
	zineb	7	✓		N
	copper hydroxide + mancozeb	NA	✓		QNVWS
	paraffin oil	1	✓		N
Melanose	copper ammonium acetate	1	✓		All
	copper oxychloride	1	✓		All
	copper hydroxide	1	✓		All
	cuprous oxide	1	✓		All
	sulfur	NS/0	✓		NW
	copper sulfate (tribasic)	1	✓		All
Phytophthora Brown Rot	copper oxychloride	1	✓		All
	cuprous oxide	1	✓		QNVWS
Pink Disease	copper oxychloride	1	✓		QW
Phytopthora Collar rot	copper oxychloride	1	✓		QWN
	copper hydroxide	1	✓		All
	phosphorus acid	0/NA	✓		All
	copper sulfate	1	✓		All
Phytophthora Stem Rot	cuprous oxide	1	✓		All
Root/Collar Rot	phosphorous acid	NS	✓		All
	copper hydroxide	1	✓		QN
Scab	copper sulfate (tribasic)	1		✓	All
	copper oxychloride	1	✓		All
	cuprous oxide	1			All
	copper hydroxide	1		✓	Q
	copper ammonium acetate	1	✓		All
	zineb	7	✓		Q
Sclerotinia Rot	benomyl	NA	✓		W (Permit)
Septoria Spot	copper oxychloride	1	✓		NVWST
	cuprous oxide	1	✓		NVWS
Sooty Blotch	copper ammonium acetate	1	✓		All
	copper oxychloride	1	✓		All
	copper sulfate (tribasic)	1	✓		All
	copper hydroxide	1	✓		All
	cuprous oxide	1	✓		All