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Registered Fungicides for citrus postharvest – What's out there?

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There is now a bewildering choice of fungicides on the market and readily accessible to citrus packers – although you should not be deceived into thinking that new products are very different to older products. Many of the active ingredients of new products are identical to those that have been available for many years. What is important is that citrus packers can identify the active ingredient and apply it appropriately. In this article, I will outline the main chemical actives used in citrus postharvest and their effectiveness against several citrus pathogens (Table 1 on page gives a summary of their effectiveness against latent infections as well as major wound pathogens).

INSIDE THIS ISSUE

Main Fungicide Groups

Group A – Benzimidazole

Active constituents include thiabendazole (TBZ), benomyl, carbendazim and thiophanate-methyl (not registered for citrus in Australia).

Trade Names

Thiabendazole: Tecto90®, Tecto 500 SC®
Benomyl: Benlate ®
Carbendazim: Bavistan®, SpinFlo®, Goldazim®

Formulations: Wettable powders, Suspension concentrates, Emulsifiable concentrates.

Thiabendazole was one of the first of a 'new batch' of chemical fungicides in the benzimidazole group whose properties were first noted in the 1960's. First used as a veterinary chemical (sheep dip) then later as an agricultural fungicide the chemical was first marketed by Merck. It is very effective against *penicillium* moulds of citrus. It useful in large tanks and bulk dips where frequent disposal is inconvenient and is compatible with a wide range of sanitisers. Resistance to thiabendazole is now common in some countries (See Packer Newsletter Vol. 75). However, Australia has good management practices that aid against resistance issues.

Continued on page 2

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Continued from page 1

Fungicidal properties of Benomyl were first reported in 1968 and the chemical first released by Dupont in 1969. It has a wide activity range and is used on a variety of fruits and vegetables. Used widely by the citrus industry for many years some instances of resistance have been noted. The product was withdrawn from the market in 2001 due to fears that it caused phototoxicity and health problems. The chemical is now no longer used on citrus postharvest. An update can be found the Australian Pesticides and Veterinary Medical Authority website: (www.apvma.gov.au/gazette/gazette0404p15.shtml).

Fungicidal activity of carbendazim was first reported by Hampel and Löcher in 1973 (Tomlin, 1995) and introduced by BASF (now AgrEvo) and Dupont in 1974. The product is widely used by the citrus industry and is effective against *Penicillium* moulds and some stem end rots. Carbendazim is a break down product of both benomyl and thiophanate-methyl and MRL testing by importing countries can mistake carbendazim for these products.

Benzimidazole fungicides can be unstable in highly alkaline environments so may not be suitable when mixing with wax, although in other countries such as South Africa TBZ is mixed with wax but usually in the presence of another fungicide.

Group C – DMI – Imidazole

Active constituents include imazalil and prochloraz (not registered for use on citrus in Australia).

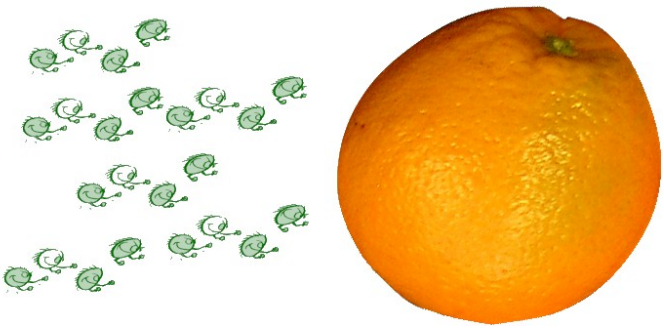
Trade Names

Imazalil: Fungiflor®, Magnate®, Deccozil®, Fungazil®, Imazagard®.

Formulations: Wettable powders, Emulsifiable concentrates.

The active imazalil in commercial form has been around since the late 1970's, and was first reported to have fungicidal properties against pathogens of citrus at the 1977 citriculture conference by Laville et al (Tomlin, 1995).

Imazalil is generally used in line as a flood or CDA (control droplet application). It is very stable at higher pH's, which can make some formulations compatible with wax (refer to the label of particular fungicide formulation to verify this application method). Imazalil gives good protection against *Penicillium* sp. It is especially good at inhibiting the formation of spores. One of the main advantages of Imazalil use in Australia is that it is likely to control mould strains resistant to TBZ and carbendazim (Packer Newsletter Vol. 55). Some formulations of imazalil are not compatible with other fungicides such as those containing TBZ (Packer Newsletter Vol 52). Studies in the USA have shown that when imazalil is heated it can provide increased efficacy against some *penicillium* moulds (Smilinick et al, 1997).



Group X: unspecified – Guanidine

Active constituent: Guazatine

Trade Names

Panoctine® liquid fungicide (Aventis), Nufarm Panoctine®, Campbell's Zanoctine®

Formulations: Water-soluble liquid.

Fungicidal activities first published in 1968 and fungicide produced by Rhone-Poulenc. Fungicides containing Guazatine are very effective in the control of infections from *penicillium* and sour rot especially when applied at least 24 hours after harvest. Guazatine is not as effective at controlling sporulating *penicillium* spores as other fungicide groups and is rapidly decomposed in highly alkaline environments. Guazatine can be used most effectively as a bulk dip when fruit first come into the Packingshed, a second in line fungicide (with different active) is then needed – preferably one with a different active, to counteract any resistance issues and to provide longer-term protection.

Ungrouped chemicals

Active constituent: Sodium Ortho-phenylphenate (SOPP)

Trade Names

Preventol®ON fungicide, Brycote®

Formulation: Wettable powder.

SOPP's fungicidal properties were first reported in 1936. Unlike the newer chemical fungicides it needs to be applied to the fruit before fungal infection has grown beyond the initial wound (Eckert and Eaks, 1989). It also needs to be maintained in its highly alkaline state for greatest effectiveness. Lower pH of SOPP has been known to adversely damage the skin of fruit. The main activity of SOPP comes from direct contact with fungal spores on fruit or in solution and as a residue on fruit surfaces. Due to its widespread antimicrobial effects (it works on a wider range of pathogens than most chemical fungicides) it has seen resurgence in the USA where resistance is a problem. However it is not widely used in the citrus industry in Australia apart from Queensland and is currently only registered as a control for blue mould (*penicillium italicum*).

Continued on page 3

Continued from page 2

Using fungicides on export fruit

We frequently get asked by citrus packers can I use fungicide X if I'm exporting to country Y? To answer this is difficult, because the MRL's (minimum residue limits) for any importing country are constantly under review. Historically each country has set up a list of MRL standards, which regulate how imported produce can be chemically treated. In recent times in an attempt to standardize MRL's throughout the world, WHO (World Health Organization) and FOA (Food and Agriculture Authority) set up the Codex Alimentarius Commission to deal with food safety issues and ensure fair practises in the food trade, (Packer Newsletter vol 70). Codex provides standards that defer to general MRL's for fungicides mentioned in this article. However, this is a voluntary standard and many countries are yet to review and change to the Codex standard. An example of this is Guazatine – through Codex an MRL has been set for fungicides containing this active. Currently the USA market has not registered any product containing Guazatine so has no standard MRL for this active. The consequence for countries importing fruit to the USA is that it cannot treat fruit with any fungicide containing Guazatine. Packers then need to ensure that they are correctly informed about the market place and on regulations for export fruit. Citrus boards, importers/exporters and government departments can all give assistance in obtaining this information. It will also pay for packers to check with more than one regulatory source to confirm that their choice of fungicide is appropriate.

Currently the Australian Citrus Growers website has a citrus export MRL listing and can be accessed at the following address: (www.austcitrus.org.au/internal.php?page_id=156)

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Table 1: effectiveness of chemical actives against stem end rots and major wound pathogens of citrus (based on tables and information found in Timmer et al (2000) and Eckert and Eaks (1989).)

Chemical active	Stem End Rots		Wound Pathogens		
			Green and Blue mould (*Penicillium* spp)		Sour rot (*Geotrichum candidum*)
	Diplodia	Alternaria	Infection	Sporulation	
Thiabendazole (TBZ)	✓✓	×	✓✓	✓✓	×
Benomyl	✓✓	×	✓✓	✓✓	×
Carbendazim	✓✓	×	✓✓	✓✓	×
Imazalil	✓	✓	✓✓	✓✓	×
Guazatine	✓	×	✓	×	✓✓

✓ Moderately to very effective
✓✓ Very effective
× Not effective

Getting the most out of your fungicide.

Nancy Cunningham
SARDI

The number of products available to packers can make the choice of fungicide difficult. However, there are some basic principles to get the most out of a fungicide - whatever your choice. It is useful sometimes when thinking about fungicide application to remember why we use fungicides in the first place. In citrus postharvest some of the main aims of fungicide application are to

1. Destroy inoculum of major citrus pathogens blue mould (*Penicillium italicum*), green mould (*Penicillium digitatum*) and sour rot (*Geotrichum candidum*) on fruit arriving in the packingshed.
2. Prevent postharvest inoculation through wounds received after harvest.
3. Provide protection from latent infections (such as slow storage rots *Alternaria*, *Diplodia* and *Phomopsis* (as well as postharvest inoculation of *Penicillium* and sour rot) when fruit is being transported or stored for any length of time.
4. Inhibit infected fruit from sporulating and spreading to otherwise healthy fruit tissue.

Fungicide Application Methods

There are several methods for the application of fungicide:

- Bulk dip/drench,
- Inline flood,
- Inline CDA
- Mixed in with wax.

The protection that each of these provide will depend on several factors.

Bulk Dips/drenches

Advantages

Good for treating large amounts of fruit on arrival. Dipping or drenching with fungicide ensures that fruit is adequately coated with fungicide. Agitation of dips is generally provided through dipping method (ie whole bins of fruit) or in the case of drenches continual flooding through the drench system.

Disadvantages

The dips/holding tanks are large and frequent disposal is difficult. Monitoring and maintaining concentrations can also be difficult.

Inline flood

Advantages

Small tanks make topping up and frequent disposal easy. Monitoring and maintaining is very easy. Fruit gets excellent coverage if concentration is maintained and especially when the fungicide is applied over brushes. This is also the case if fruit is given adequate dwell time (the time fruit spends having fungicide applied).

Disadvantages

Because tanks are small there can be a quick build-up of spores and other microbes washing into solutions from fruit and brushes.

Inline CDA (controlled droplet application)

Advantages

Reduces the amount of fungicide waste.

Disadvantages

A reasonable length of line with brushes is needed to make sure that fruit gets fully covered by fungicide. Research has shown that in some instances fungicide would need to be applied at higher rates to get the same amount of protection as a flood application. (NB, In Australia fungicide labels do not indicate a specific rate for CDA application). Blocked nozzles and inadequate monitoring can also add to inadequate coverage.

Mixed in with wax

Advantages

Provides extra protection for fruit that has been treated once in line. No reduction in concentration. No build-up of spores in mixtures

Disadvantages

Not all fungicide types can be mixed in with wax. Some areas of the fruit (such as under the calyx) may not get adequate coverage. Fungicide efficacy is generally lower.

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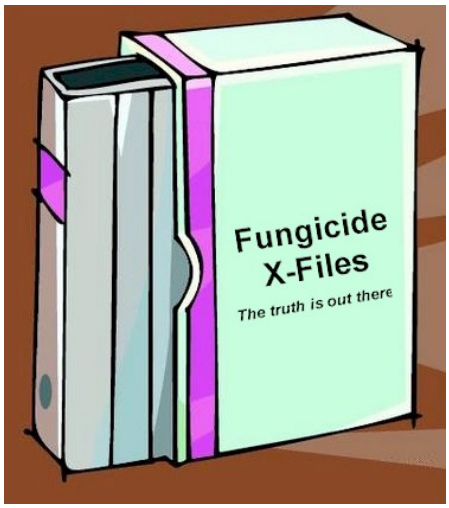

Recommendations for good decay control

- Ensure any holding tanks or surfaces are clean before mixing fungicides.
- Use clean water when mixing fungicides – or if using river water, dose with a sanitiser (remember to monitor pH and adjust if necessary if using a pH sensitive sanitiser) and leave overnight before mixing fungicide.
- Treat fruit with a fungicide as soon as possible after harvest. This is especially important if there is a delay between arrival and processing through the packingline. The usual time frame is within 24 hours of infection; otherwise mould can develop to far for fungicides to have an effect.
- When using more than one fungicide in the packingline – apply fungicides from two different activity groups (see previous article). This ensures that fruit has been adequately protected and can aid against the formation of resistant spores.
- Some packers mix fungicides with two different actives together (eg Panoctine® and Bavistan®). Some combinations are not compatible (Packer Newsletter volume 52) so if possible do not mix fungicides together.
- Ensure that when applying fungicide in dips/drenches or inline fruit has adequate coverage – either by applying over brushes (for inline) or checking that dwell time is around the 30 seconds (recommended by most manufacturers).
- Fungicide application in wax can give a reduction in decay control efficacy so ensure that fruit is adequately covered; use this as a second application of fungicide.
- Keep equipment in good condition by regular cleaning and maintenance.
- Monitor concentrations and 'top up' using double strength fungicide. This is usually adequate to maintain concentration however regular analysis is also useful in determining whether topping up procedures are working.

Detailed information on application methods and maintaining concentrations can be found in the Citrus Handling guide publication (Tugwell, 1999). *

Postharvest GA use -Fruit Quality Storage Trial

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Increased interest in Gibberellic Acid (GA) coincided with high rind breakdown in 2000. The use of Postharvest application Gibberellic Acid (GA) has also been suggested to reduce rind problems. Charlie Coggins (1992) showed that GA in wax could extend the storage life of lemons. The GA is thought to delay the maturity of green or silver lemons picked for long-term storage. The 'young' rind is less susceptible to some disorders and decay. In fact, the suppression of sour rot on GA-waxed lemon was quite significant. In overseas countries, GA is applied to many citrus cultivars, but the benefits, particularly for tree ripened citrus, is largely based on anecdotal evidence.

Our interest is in the effects of postharvest application of GA on tree-ripened fruit. In particular, we were interested in measuring the effects on rind quality and 'button' freshness. We included 'button' freshness because GA may be a possible replacement for the increasingly problematic 2,4-D.

Navelina oranges (an early season Navel) were collected from a commercial packingshed and treated with a standard postharvest fungicide containing imazalil. One group was treated with a standard wax treatment; the second group was treated with wax+50ppm of GA. The process was repeated five times and packed into cartons, a subset of fruit in each carton were selected for weight loss monitoring before they were placed in 3ºC. The Fruit was monitored every week for weight loss and every other week for blemish, oleocellosis, change in fruit colour and button health and any possible chilling injury. After 6 weeks the fruit used for weight loss monitoring were taken out of cold storage and placed at ambient temperature for 2 weeks. The other fruit remained at 3ºC and was assessed on a weekly basis for several more weeks until fruit was over stored (14 weeks total).

GA may be a possible replacement for the increasingly problematic 2,4-D.

The main findings of the trial were:

- All fruit, both Control (wax alone) and wax + GA treated fruit, was in excellent condition throughout the trial, even after over storage at 12 weeks (Figure 1).
- There were no significant differences in oleocellosis, blemish or fruit colouring.
- Significant differences in weight loss were seen over the initial 6-week storage time with GA treated fruit having less weight loss than control treated fruit (Figure 2).

Figure 1: Fruit that was over stored for 14 weeks was still in excellent condition.

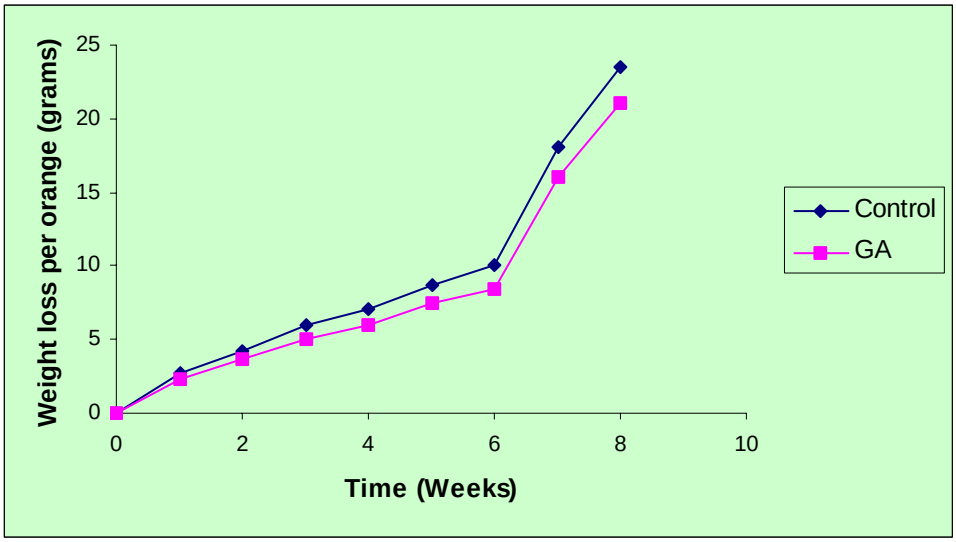

Figure 2: Significant differences in fruit weight loss were seen over the 6-week storage time.

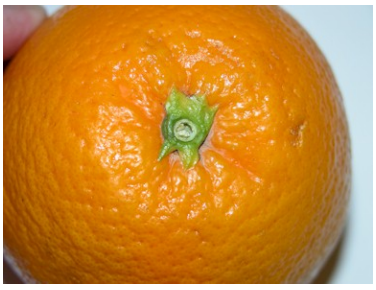

Figure 3: Buttons were also in very good condition after long storage.

- Button health was also in excellent condition for both treatments during the storage trial, however when fruit was over stored there were significantly more buttons on the wax + GA treated fruit that remained green compared with control treated fruit (Figure 3).
- Many of the storage disorders that were found did not appear until after 12 weeks of storage (Figure 4).

Figure 4: Fruit exhibiting internal storage disorders (*Diplodia or Alternaria*)

Conclusions

The fruit chosen for this trial was in excellent condition regardless of the treatments. However there was a suggestion that fruit treated with GA in wax was 'fresher' reflected in the lower weight loss achieved by this treatment. A difference of this kind may not make a practical difference in seasons where fruit is in excellent condition (such as this season) but could make a significant contribution in years where fruit quality is poor. GA may also have an influence dependant on the type of cultivar. Due to seasonal differences this trial will be followed up next season (2005) with a different cultivar. ✻