

Using copper sprays to control diseases in citrus

Sandra Hardy

Industry Leader, Citrus
NSW DPI, Gosford Horticultural Institute

Keith Fallow

Nipro

Patricia Barkley

Former Citrus Pathologist, NSW DPI

Warm humid conditions favour a range of citrus fungal diseases. In Australia most disease control programs rely on copper sprays to protect the foliage and fruit from infection. Successful disease control depends on both an even distribution and good retention of the copper over all of the plant surfaces.



How copper works

Copper sprays are protectant fungicides that must be applied evenly to the plant or fruit surface before the disease develops to prevent infection. Copper is not a systemic chemical and cannot be carried internally through the plant to kill the pathogen. Once the copper is applied it sticks only

where it hits and does not spread to a large extent across the fruit or leaf surface.

It's no coincidence that copper is most effective on those diseases that need free water present to develop. On the plant surface, when there is water present (from rain, dew or irrigation) exudates from the plant or spores form weak acids, which lower the pH of this surface water. The solubility of copper products increases as the pH drops, slowly dissolving to release a small and constant supply of cupric ions (Cu^{+2}) as long as the water remains. Only one copper formulation (cuprous oxide) also releases cuprous (Cu^{+1}) ions, which also have fungicidal and bactericidal activity.⁸ These copper ions are picked up by spores or bacteria that come in contact with this surface water — travelling through the cell walls to eventually disrupt cellular enzyme activity.

Over time the coverage of copper over the plant or fruit surface deteriorates due to fruit growth, and the action of rain and wind. The surface area of fruit can increase substantially from fruit set to harvest (about 14 times for lemons⁵) whereas the surface area of fully expanded leaves only increases slightly. In areas of high rainfall or wet conditions copper fungicides would tend to offer a shorter period of protection than if conditions were dry. Depending on the retention characteristics of the copper formulation re-application of the protective copper layer may be needed in certain areas, such as those on the Central and North coast areas of NSW or where overhead irrigation is used.

Copper formulations

There are five basic types of copper compounds: copper oxychloride, copper hydroxide, tribasic copper sulphate (green and blue coppers), copper



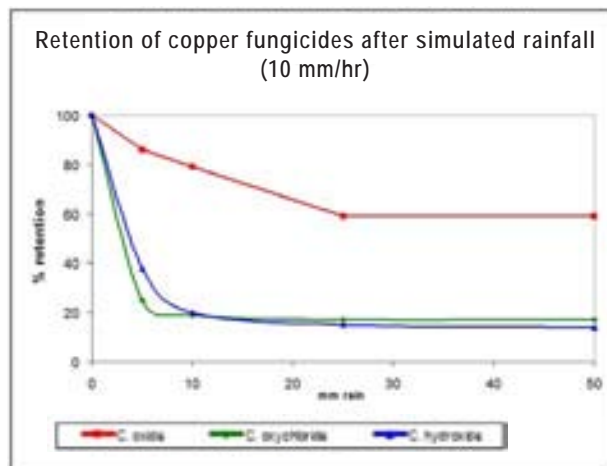
ammonium complexes (dark blue aqueous complex of copper and ammonia) and cuprous oxide (red copper). In the past most copper products were wettable powders and contained around 50% copper as the active ingredient (a.i.). However, today's formulations contain from 8% to 75% copper and application rates vary accordingly. Products are formulated as either wettable powders, wettable granules, liquid flowable suspensions or aqueous liquids. Copper products may also contain small amounts of impurities (lead, cadmium etc.) and some cheaper products may contain higher levels.

Particle size and retention

Research has demonstrated that the efficacy of a copper fungicide can be considerably improved by reducing the particle size⁸. The smaller the particle size the greater the number of particles per gram and therefore the greater the fungicidal or bacterial activity. With smaller particles coverage is improved and there is significantly more surface area available per gram of product to release copper ions when moisture is present (Figure 1).



Figure 1. Better coverage with smaller particle sizes.



Graph 1. Retention after simulated rainfall for 3 copper formulations (Centrilab, Holland).

Graph 1 illustrates the superior retention characteristics of smaller particle sizes. The median particle size of the copper oxychloride and copper hydroxide product was around 3 microns and for the cuprous oxide product around 1 micron. The main factors influencing product retention on plants are:

- rainfall (from direct rainfall dislodgement or from rain solubilisation)
- wind events (particles over 3–4 microns can be blown off plant surfaces)
- physical dislodgement of the copper particles due to plant surface growth underneath the deposits (e.g. fruit expansion).

Smaller particles resist dislodgement better as they are lighter and have a larger surface area relative to their weight (hence a greater area of contact with the plant surface) and this results in an increase in the total force of adhesion. The high initial losses experienced from weathering arise from a rapid and

Table 1. Some Australian copper formulations and particle sizes. (This information has been taken from company technical brochures.)

Product name	Active ingredient	g cu/kg	Distributor	Median particle size (microns)
Kocide WP	Copper hydroxide	500	Dupont	3.1
Kocide Blue	Copper hydroxide	350	Dupont	2.5
Kocide Blue Liquid*	Copper hydroxide	360	Dupont	2.5
Blue Shield	Copper hydroxide	500	Bayer Cropscience	2.5
Oxydul	Copper oxychloride	520	Nufarm	3.1
Coppox	Copper oxychloride	500	Melpat International	1.8
Cuprofix	Tribasic copper sulphate	200	Nufarm	3.0
Tribase Blue*	Tribasic copper sulphate	190	Nufarm	0.7
Norshield WG	Cuprous oxide	750	Nipro	1.0
Liqui-cop**	Copper ammonium acetate	80	Lefroy Valley	N/A

* Liquid flowable suspensions
**Aqueous liquid

complete loss of large particles, while the remaining residue consists of small particles⁸. Formulations with smaller particles produce improvements in disease control through better coverage, rain-fastness, and longevity of the product and release of copper ions on the plant surface.

Research by Professor Pete Timmer^{1,7} in Florida found that:

- whether it is a liquid, liquid flowable or dry formulation there is little difference in the level of control per unit of metallic copper;
- the most important factor affecting product effectiveness is the particle size of the formulation and how well it sticks (rain-fast) to the plant surface;
- products with a smaller particle size tend to have better coverage, rain-fastness and longevity;
- more frequent applications of copper at lower rates are more effective than the same amount of copper applied in fewer applications.

The impact of water pH

Most copper products are formulated to be almost insoluble in water at pH 7.0. As the pH of water decreases the solubility of the copper fungicides increases and more copper ions are released. If the water used is too acidic (below pH 6.0-7.0 — depending on the copper formulation) excessive amounts of copper ions could be produced which may cause damage to fruit and foliage. Formulations vary in solubility — hydroxides are more soluble than oxychlorides which are more soluble than tribasic copper sulphates and cuprous oxide. Less soluble formulations are usually more persistent.

Damage from copper sprays

Copper sprays can cause dead (necrotic) spots between the oil glands giving the fruit rind or leaves a speckled appearance (stippling). These spots



Copper damage on leaves



Copper damage on fruit

appear similar to those of the disease melanose but the spots are almost black and are often on the exposed (outward facing) surface of the fruit. Copper sprays also darken existing blemishes (e.g. wind blemish on fruit).

If too many copper ions are released at one time, damage to the fruit and foliage can result. This can happen if the spray solution is too acidic (i.e. below pH 6.0–7.0), by some aqueous liquid copper formulations^{6,7}, by copper formulations that have high amounts of soluble copper or by formulations that are very soluble and release too many copper ions.

Some copper-based fungicides may cause a small reduction in plant vigour. This reduction is caused by too many copper ions passing into the leaf and/or by other impurities in the product. Copper salts such as copper chloride (used in the production of copper hydroxide and oxychloride), if not completely oxidised during manufacturing, can remain (up to 2%) in some low quality copper formulations. This copper salt rapidly dissolves and could increase copper ions to excess levels as soon as the product is added to the spray tank. Other heavy metal impurities such as lead and cadmium have also been implicated in increased levels of blemish. This partially explains some of the crop safety differences between copper formulations — low quality copper formulations with higher levels of impurities may reduce plant growth and cause more fruit blemish.

Timing, frequency of application and the rate of copper applied is also very important, particularly with spring and summer applications. Researchers from South Africa and the US found that copper stippling is more severe the later the copper was applied in summer (December–January) and where 3–4 successive applications of copper were used at higher rates^{3, 6}.

In recent research in the drier climate of Gayndah, Queensland, using lower rates of copper (40–80 g copper/100 L water) there was no increase in blemish on navels from either 2 or 4 applications of copper hydroxide or 4 applications of either copper ammonium acetate or cuprous oxide (applied from flowering at monthly intervals). However there was a significant increase in blemish after 4 applications of copper oxychloride at 100 g copper/100 L water⁹. A similar, but not significant trend, occurred in another recent trial on Murcotts at Gin Gin (Miles, unpublished) with more blemish after 3 applications (at 3–4 week intervals) of copper oxychloride at 100 g copper/100 L water than with 3 applications of copper oxide or 2 of copper hydroxide (at 56 g and 53 g copper/100 L water respectively). In both trials the copper rates chosen were based on the amount of each product needed to control the target disease as per the manufacturer's recommendations. The researchers also found there were no significant differences in disease control between any of the copper products when applied at the above rates.

In Uruguay there was reduced copper phytotoxicity on lemons when a low number (2) of copper sprays were applied early in the crop cycle (at flowering and one month later) and when the doses applied were low. They found the phytotoxicity of copper products was strongly correlated to the total amount of copper applied per hectare – the higher the rate of active ingredient (copper) applied the greater the blemish on the fruit.⁵

In some soils copper levels can also increase and become toxic to citrus roots. High copper levels may also interfere with the uptake of other plant nutrients.

It is also generally recommended that no other products, such as fungicides, insecticides or nutrient sprays be mixed with copper sprays. The use of low rates (<0.5%) of petroleum spray oils as spreaders is generally alright.

The phytotoxic effects of copper are more common when:

- copper is applied with other products (especially acidic ones) in the one tank mix
- high rates of copper are applied mid-summer
- 3–4 successive applications of copper are used at high rates
- copper is applied to wet fruit, when the rind cells are turgid (e.g. early morning before the dew has lifted or spraying immediately after rain)
- copper is applied at high temperatures (especially when fruit and plant surface temperatures are above 25°C)

- there is cool and slow drying weather or when humidity is low and cloud cover is close to zero
- using some aqueous liquid formulations (i.e. copper and ammonia complexes)^{6,7}.

Best practice tips

- ✓ Copper sprays are protectant fungicides and need to be applied prior to disease infection.
- ✓ Apply a good even coverage of copper to plant and fruit surfaces.
- ✓ The protective layer of copper diminishes over time and only offers short-term protection under certain conditions (i.e. in wet or humid climates). If infection is likely over longer periods then re-application may be necessary.
- ✓ Smaller particle size results in better rain-fastness and retention of the copper product.
- ✓ Always apply copper sprays on their own.
- ✓ The pH of the water used to apply copper should be >6.0.
- ✓ Choose a product and rate that minimises the amount of copper.
- ✓ More frequent applications using lower rates of copper are just as effective and cause less phytotoxicity than applying high rates in fewer applications.
- ✗ Don't over-apply copper.
- ✗ Don't apply copper when fruit or leaf temperatures are high, humidity is low or the fruit is wet.

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