Is copper copper? Limitations in the control of foliar bacterial diseases in capsicum, chilli and tomato

How does copper protect plants from bacterial infections?

Bacterial populations such as *Xanthomonas* spp. causing bacterial leaf spot in tomato and capsicum and *Pseudomonas syringae* pv. *tomato* causing bacterial speck in tomato, often develop copper tolerance. This means they can tolerate higher concentrations of copper than sensitive populations. It doesn't mean the bacteria are resistant and that copper has no effect.

The availability of free cupric ions (Cu^{2+}) is the important component of products to protect against bacterial infections. The concentration of Cu^{2+} on plant surfaces depends on the equilibrium established with the complexed and soluble forms of copper and the chemical reactions releasing the free Cu^{2+} from the soluble forms. There is no strong correlation between the total amount of copper applied and the concentration of Cu^{2+} on leaf or fruit surfaces.

Rainfall or presence of other free water (e.g dew), wind and leaf abrasion, compounds released by the plant and the pH of the leaf surface will affect the amount of soluble copper present. Free water interacts directly with the copper deposits, and indirectly by releasing exudates from the leaf itself, which also interact with the copper. Wind and leaf abrasion can physically remove the copper deposits and/or also release leaf exudates. The spread of the copper on the leaf surface also affects these interactions and this is influenced significantly by the particle size of the product.

As a general rule the half-life of total copper on the leaf surface is about one-month. This is well in excess of the typical application rates of 5 to 10 days. This means more frequent applications will not improve Cu^{2+} availability. Application every 7-10 days is recommended with additional applications if heavy rainfall has occurred. Studies on bean indicate that Cu^{2+} concentrations on leaves of about 50 ppb is enough to control copper sensitive populations of *P. syringae* but 10% or more of bacterial cells within copper tolerant populations could survive concentrations of up to 100 ppb Cu^{2+}.

Increasing the total amount of copper applied to the leaves will only give a very minor improvement to the amount of soluble copper present, if any at all. Generally, the amount of total copper is often in excess of soluble copper, thus adding more won't provide additional disease control. Total copper is not a good indicator for the amount of soluble copper present. It is the interaction of the copper product with the plant surfaces that drives solubility of the copper. Furthermore, the amount of free Cu^{2+} present on plant surfaces is only a small fraction of the soluble copper present. In studies on bean, free Cu^{2+} was estimated to be as low as 1% of the soluble copper present. Free Cu^{2+} typically increases with increased amounts of soluble copper.

Application techniques and product type significantly affect the efficacy of copper to protect plants from bacterial infection.

What copper products are commonly used in tomato and capsicum crops?

Products registered for use against bacterial diseases include Bordeaux mixture, cupric and cuprous hydroxide, cuprous oxide, copper oxychloride, copper salts of fatty acids, copper ammonia acetate complexes, tribasic copper sulphate and mixtures of cupric hydroxide and ethylene bis-dithiocarbamates (EBDC, e.g mancozeb).

The product information usually lists the active ingredient in percent metallic copper which is a measure of the insoluble copper salts and not a measure of free Cu^{2+}.

Tank mixes including fungicides such as EBDC (e.g mancozeb) or heavy metals including zinc or iron were shown to improve disease control by increasing the amount of Cu^{2+} in solution. On the other hand, mixing copper products with organic compounds is highly likely to have the reverse affect and reduce availability of Cu^{2+}.

The amount of available Cu^{2+} in a product is a good indicator for efficacy against bacterial pathogens. Commercial products range significantly, from 0.04 to 22.0 µg/ml Cu^{2+}. The concentration of Cu^{2+}, however, is typically not listed on product labels and requires specific measurement. The metallic copper amount listed on the label is not a good predictor of Cu^{2+} concentration. Products with a Cu^{2+} concentration of 1.5 µg/ml or more were most effective against some bacterial species. In comparing products ask for information on the predicted availability of Cu^{2+}.

Copper plus manganese-zinc ethylene bisdithiocarbamate (mancozeb) is consistently better than other copper only products in field studies of a range of bacterial diseases, including bacterial spot and speck of tomato. This is attributed to the ability of the bisdithiocarbamate anion to chelate copper and transport the Cu^{2+} into the bacteria.

Ferric chloride combined with cupric hydroxide improved bacterial disease control in walnut. The ferric chloride increased the sensitivity of the bacterium to the copper. It also increased availability of Cu^{2+} on leaf surfaces by lowering the pH and cation exchange between Cu^{2+} and Fe^{3+}. However, lowering the pH with hydrochloric acid or adding a range of other metal ions ($MnSO_4$, $MgCl_2$, $MgSO_4$, $CaCl_2$, NaCl and KCl) did not increase availability of Cu^{2+}.

Zinc used instead of or in combination with copper is effective in disease control in walnut. However, further work is needed as again different combinations of product give very different results. Research into alternative chemicals for disease control in capsicum and tomato is underway; however, no products are yet available.

Suggested spray program

What can be mixed with what in the spray tank?

A tank mix of copper plus an EBDC (ethylene bis-dithiocarbamates, e.g mancozeb) will give the best disease control compared to copper alone. Additionally, avoid mixing the copper with other products that will complex the copper reducing its solubility and ultimately the availability of Cu^{2+}.

What products are likely to perform best and how often/when to use?

There are various different forms of copper registered for use. These include Bordeaux mixture, cupric and cuprous hydroxide, copper salts of fatty acids, copper ammonia acetate complexes, tribasic copper sulphate and mixtures of cupric hydroxide and ethylene bis-dithiocarbamates (EBDC). There are no strict rules as to which form of copper works best.

Several studies have reported the combination of copper and EBDC (ethylene bis-dithiocarbamates, e.g mancozeb) work best to control bacterial speck of tomato and bacterial spot of capsicum. It is recommended to use this combination early, before harvest as mancozeb has a withholding period of 7 days for tomato and 14 days for capsicum. During harvest, other copper products or alternative control methods should be used.

Products come as wettable powders, wettable granules, liquid flowable suspensions or aqueous liquids. The particular formulation will affect coverage of the product which is an important factor to consider. The formulation may affect solubility of the copper and availability of Cu^{2+}. Additivities to products could also potentially affect solubility and/or Cu^{2+} availability. Consult your local supplier for more information about the solubility and Cu^{2+} availability of specific products

A typical application rate of 7 to 10 days should be adequate as the average half-life of total copper on leaf surfaces is one-month. Applications more frequently are unlikely to improve Cu^{2+} availability and thus disease control. However, in fast growing crops, additional applications might be required to ensure newly developed foliage is protected.

What else needs to be studied to improve disease management?

Improvement in management of bacterial diseases such as bacterial speck and leaf spot of tomato and capsicums will be through improved understanding of disease life-cycles, pathogen diversity and development of novel control products. These products could include formulations which directly interfere with bacterial survivability and/or promote defence responses within the crop plants. Additionally, further plant breeding efforts could identify resistance or tolerance within tomato and capsicum germplasm that could be used instead of or in combination with chemical control methods. Improved understanding of pathogen diversity in Australia will assist with plant breeding efforts and in the development of novel control products.

Consideration of other crop management practices is also important for control of any pest or disease. Development of a holistic strategy to control foliar diseases which considers fungal and bacterial pathogens in addition to pests and nutrient requirements would be highly beneficial.

Further information

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