Copper Fungicides for Disease Management in Vegetables

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Copper fungicides are important for managing diseases caused by bacteria and managing resistance developing to other fungicides being used that are at risk. There are few non-copper-based fungicides with activity for bacteria (e.g. Actigard). Most fungicides have some risk of resistance development. Chlorothalonil and manzate also have low resistance risk. Copper fungicides are also effective for fungal diseases. Copper ions kill by denaturing proteins and enzymes in cells of pathogens they contact that have not yet infected the plant. They have no post-infection activity and are non-selective, which is why phytotoxicity occurs when they get inside plants.

Copper fungicides differ in their active ingredient, use rate, re-entry interval, pre-harvest interval, and the amount of copper as well as cost. Rate also varies with crop. These differences can be important when selecting a product. Almost all copper fungicides have a fixed copper as the active ingredient, with copper hydroxide being the most common. Copper sulfate pentahydrate is different. Amount of copper is important because copper is an inorganic compound thus it does not breakdown like organic compounds and consequently copper can accumulate in soil when used intensively over many years. Plants take up some copper from soil because it is a micronutrient. Similarly, humans need a small amount of copper in their diets. Minimizing accumulation is a goal of label changes with copper re-registration. Quantity of active ingredient in a product does not indicate amount of copper. Metallic copper equivalent (MCE) is a commonly used measure of the quantity of copper in fungicides. This information is on the label in the ingredient section. For example, Basic Copper 53 has more active ingredient than Champ WG (98% vs 77%), but similar MCE (53% and 50%). Nordox 75 has the highest MCE (75%). Cueva has the lowest MCE (1.8%). To determine amount of MCE applied with an application, multiply percent MCE for the product by the use rate in lbs for dry formulations and for liquid formulations multiple lbs MCE in a gallon of product by the use rate in gal (see table). Copper sulfate is considered more toxic to native bees than other coppers.

Copper fungicides also differ in other ways. Liquid, granular and dispersible formulations dispense better in water than wettable powders and also are dust-free. There are claims that some products have particularly good ability to mix and to stick to plants, which means good rainfastness (weatherability). Products with neutral pH (e.g. Cuprofix Disperss) have lowest potential for incompatibility when tank mixed with other pesticides. On the other hand, low pH of the spray solution, which can be affected by the leaf surface, increases copper solubility and thus availability of copper

ions, which is essentially the active ingredient. Availability of copper in a product also depends on the type of copper and how formulated. With small particles there is more surface area and thus potential to release more copper ions. Properties of copper hydroxide, the active ingredient in several products, include small particle and rapid release of copper ions. Copper oxychloride is a slightly larger particle with a slower, more prolonged release of copper ions. Badge products contain both of these active ingredients with the goal of extending disease control. Some new copper formulations have highly micronized and chelated coppers. Nordox formulation is tiny hollow micro-beads.

Effectiveness of a copper application is determined by several factors. Small particle size is best because these adhere better to plant surfaces and are more difficult to dislodge by water than large particles. Additionally, spray coverage will be better due to there being more particles per unit weight. Low solubility in water of fixed copper active ingredients contributes to residual activity. Copper ions are released over time from spray deposit when water is present. In contrast, copper sulfate pentahydrate is highly soluble. Acidity (low pH) increases solubility of fixed copper, which increases effectiveness initially but shortens residual activity and thus sustained control, and also increases potential for phytotoxicity. Spray adjuvants such as LI-700, phosphorous acid fungicides in particular Aliette, and mancozeb fungicides all lower pH. Residual activity can be extended by adjuvants that function as stickers, which are typically included in a product formulation. Copper oxide has been described as the most effective form of copper. MCE can also be important, especially when other factors are similar for products, but a goal of modern product development is an effective product with low MCE. Additional factors that can greatly affect efficacy of a copper application include: when applications started relative to disease onset (best is before first infection, which occurs at least 5 days before symptoms), length of drying time afterwards before rain or overhead irrigation (check rainfastness of product), amount of water and intensity (a 2-inch downpour can remove a lot of residue), timing of application relative to rain event (before with enough time to thoroughly dry is ideal because this will provide favorable conditions for infection), occurrence of dew (water enables more copper ions to be released), coverage achieved with the sprayer (copper fungicides do not move inside plants), rate (high label rate better than low), and frequency of application. Bacterial pathogens have proven adept at developing resistance to copper, which can render copper fungicide ineffective.

Comparative efficacy data for copper fungicides is limited. Typically when copper is included in fungicide evaluations conducted by university researchers, a single representative product is used to assess copper efficacy generally or copper is included in a fungicide program. More than one copper fungicide has been tested in some evaluations, mostly on bacterial diseases. Cueva was as effective as Kocide 3000 for black rot in cabbage in New York in 2011 and 2012 but not in 2013 when Champ and Cuprofix Ultra Disperss were also more effective than Cueva. Badge X2 was effective for black rot in collards while Basic Copper 53 was ineffective; neither were effective for Alternaria leaf spot in Massachusetts in 2013. Neither were effective for either disease in similar experiment in 2014. Kocide 3000 was more effective than Cuprofix Ultra Disperss for bacterial leaf spot in parsley in Ohio in 2012, but similarly effective for bacterial leaf spot in pepper in North Carolina in 2011 and as effective for this disease as Nordox in Georgia in 2011, whereas Cuprofix Ultra Disperss was more effective than Nordox 75 WG for bacterial leaf spot in pepper in Florida in 2010. Cueva and Badge were similarly effective for bacterial leaf spot in pepper in Florida in 2015. A two-year study conducted in New Jersey to compare copper fungicides with different active ingredients for bacterial spot in peach revealed few differences in efficacy among Kocide 3000, Cueva, Badge X2, and Nordox applied at the same rates of actual (metallic) copper per acre.

The specific directions on fungicide labels must be adhered to. They supersede these recommendations (above), if there is a conflict. Any reference to commercial products, trade or brand names is for information only; no endorsement is intended.

Updated 7/27/20

Information about some copper fungicides including their highest label rate for some vegetable crops [z].

Product	Active ingredient	Metallic copper equivalent	Maximum Labeled Rate/A (MCE in lb/A)				REI	PHI
			Broccoli	Lettuce	Squash	Tomato		
Badge SC	16.81% copper oxychloride + 15.36% copper hydroxide	20%	1.8 pt (0.51)	1.7 pt (0.48)	2.5 pt (0.71)	1.8 pt (0.51)	48 hr	0 day
Badge X2 [y]	24% copper oxychloride + 21% copper hydroxide	28%	0.75 lb (0.21)	1.75 lb (0.49)	1.25 lb (0.35)	1.75 lb (0.49)	48 hr	0 day
Basic Copper 53 [y]	98% basic copper sulfate	53%	3 lb (1.59)	3 lb (1.59)	2 lb (1.06)	4 lb (2.12)	48 hr	0 day
Champ WG [y]	77% copper hydroxide	50%	2 lb (1.0)	Not labeled	3 lb (1.5)	4 lb (2.0)	48 hr	0 day
ChampION ++ [y]	46.1% copper hydroxide	30%	0.75 lb (0.23)	1.5 lb (0.45)	1.25 lb (0.38)	1.75 lb (0.53)	48 hr	0 day
C-O-C-S WDG	73.49% copper oxychloride + 13.39% basic copper sulfate	51.25%	1 lb (0.51)	1.9 lb (0.97)	2 lb (1.03)	1 lb (0.51)	48 hr	0 day
CS 2005 [y]	19.8% copper sulfate pentahydrate	5%	25.6 oz (0.8)	Not labeled	25.6 oz (0.8)	32 oz (1.0)	48 hr	0 day
Cueva [y]	10% copper octanoate	1.8%	2 gal (0.32)	2 gal (0.32)	2 gal (0.32)	2 gal (0.32)	4 hr	0 day
Cuprofix Ultra 40 Disperss	71.1% basic copper sulfate	40%	1.25 lb (0.5)	Not labeled	2 lb (0.8)	3 lb (1.2)	48 hr	0 day
Kocide 2000-O [y]	53.8% copper hydroxide	35%	1.5 lb (0.53)	Not labeled	2.25 lb (0.79)	3 lb (1.05)	48 hr	0 day
Kocide 3000-O [y]	46.1% copper hydroxide	30%	0.75 lb (0.23)	1.5 lb (0.45)	1.25 lb (0.38)	1.75 lb (0.53)	48 hr	0 day
Nordox 75 [y]	84% cuprous oxide	75%	2 lb (1.5)	1.25 lb (0.94)	1.25 lb (0.94)	2.5 lb (1.88)	12 hr	0 day
Nu-Cop HB [y]	77% copper hydroxide	50%	1 lb (0.5)	1 lb (0.5)	1.25 lb (0.63)	2 lb (1.0)	48 hr	1 day
Phyton 27AG	21.27% copper sulfate pentahydrate	5%	20 fl oz (0.08)	20 fl oz (0.08)	25 fl oz (0.10)	40 fl oz (0.15)	48 hr	0 day

[z] MCE = Metallic copper equivalent. REI = Re-entry interval. PHI = Pre-harvest interval. Most labels do not state minimum time after an application that harvest can be done; however, the REI for Worker Protection Standard affects harvest as harvesting by workers isn't allowed as a WPS early-entry provision so harvesting during a restricted-entry interval is not allowed.

[y] Product is OMRI-listed for use in organically produced crops. Formulations of Kocide without an 'O' in the name are not OMRI-listed.