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Estimating Copper, Manganese and Zinc Micronutrients in Fungicide Applications[1]

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Micronutrients such as boron (B), chlorine (Cl), copper (Cu), iron (Fe), manganese (Mn), molybdenum (Mo) and zinc (Zn) are essential for plant growth. "Essential" means that when micronutrient supply is insufficient, plants may develop deficiency symptoms and yields may be reduced.

Because micronutrients are needed in relatively small quantities (a few pounds per acre compared to several tens or hundreds pounds per acre for macronutrients) and because excessive micronutrient applications may result in toxicity, all micronutrient applications should be taken into account when developing fertilizer programs for vegetable crops.

The University of Florida/Institute of Food and Agricultural Sciences (UF/IFAS) recommendations for micronutrient application are based on the results of pre-season soil tests (Table 1). In addition, plant nutritional status in micronutrients may be determined during the growing season with leaf analysis (Simonne and Hochmuth 2009, Hochmuth *et al.*, 2004).

When soil test or tissue analysis indicate that micronutrients are needed, sources that are commonly used include boric acid for B, copper sulfate or copper chloride for Cu, iron sulfate or chelates for Fe, manganese sulfate or manganese chloride for Mn, molybdic acid or molybdenum oxide for Mo, and zinc sulfate or zinc chloride for Zn. However, because micronutrients such as Cu, Mn and Zn are also present in several fungicides, vegetable growers may wonder whether they still need to apply Cu, Mn or Zn when these fungicides are used.

Using tomato as an example, this document lists the common sources of micronutrients in common fungicides, estimates micronutrient applications for an entire crop, and discusses the availability of these micronutrients. This document does not encourage the use of fungicides for the purpose of micronutrient applications to crops, but indicates that contributions

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of micronutrients from fungicides should not be ignored.

Unit of Expression Used for Micronutrients

The amount of metal in the fungicide is stated in fungicide labels, often expressed as "percent metallic equivalent" for copper and sometimes as elemental copper. For manganese and zinc, the percent metallic equivalent is used in *maneb* and *ziram*, respectively. However, in *mancozeb*, the amounts are expressed as percentages of Mn++ and Zn++.

When the label states that the product contains 50% metallic copper equivalent, it means that there are 50 lbs Cu/100 lbs fungicide. Similarly, a fungicide with 16% Mn++ means that 100 lbs of the fungicide contain 16 lbs of Mn++.

Micronutrients Found in Common Metal-based Fungicides

Many copper fungicides such as *Kocide* and *Champ* are formulated using copper hydroxide as the active ingredient and may contain as much as 50% metallic copper equivalent. Manganese-containing fungicides with the active ingredient maneb include *Maneb 80WP* and contain 16.5% Mn equivalent. The most common Mn-containing fungicides are those made with *mancozeb* as the active ingredient. These fungicides, such as. *Dithane* or *Manzate*, may contain up to 16% Mn++ and 2% Zn++. Newer products available for commercial use may contain all three elements. For example, *ManKocide* 61.1 DF contains 30% Cu, 3% Mn and 0.4% Zn.

Quantities of Micronutrients Added through Fungicide Applications

Metal-based fungicides are usually protectant fungicides that need to be applied onto plant surfaces prior to pathogen infection in order to reduce the incidence of the infection. In a standard preventive fungicide program, metal-based products could be applied several times during a growing season, typically at application intervals of 7-10 days.

Depending on the types of fungicides used, plant micronutrient needs may be met through fungicide applications (Table 2). For example, in a tomato crop, as much as 12 lbs per acre of Cu are applied per season through the use of Kocide 101, which far exceeds the UF/IFAS recommended micronutrient application rate of 1.25 lbs Cu per acre. However, if liquid copper is used, it may be necessary to supplement with foliar fertilizer to correct any Cu deficiency noted in testing. When *Bonide Liquid Copper* is used (and it often is used for home vegetable gardens), the maximum amount of Cu added per season is only 1.8 lbs per acre.

Similarly, high amounts of Mn are supplied through fungicide applications if *maneb* (*Maneb 80WP*) or *mancozeb* (*Dithane M45*) are used at the maximum rates during the season. However, Zn contribution from *mancozeb*-based fungicide applications is low as the Zn content of such fungicides is low. By contrast, substantial amounts of Zn are applied through the use of high-Zn fungicides such as *Ziram 76DF* (16.3% Zn).

Micronutrient Availability

The discussion above focused on calculating the total quantities of Cu, Mn or Zn applied under several disease-control programs. However, a basic principle of plant nutrition is that the presence of a nutrient does not equate with plant-availability. This principle applies regardless of whether the nutrient is derived from fertilizer or fungicide.

Soil pH is a major factor affecting nutrient availability. A high soil pH can immobilize micronutrients, which become unavailable to plants. Current UF/IFAS standardized recommendations call for maintaining soil pH between 6.0 to 6.5, but most sandy soils in South Florida have pH as high as 8.0 due to accidental over-liming or use of alkaline irrigation water (Simonne and Hochmuth 2009). In such a case, it would be necessary to provide periodic applications of micronutrients to correct any deficiency.

In regards to plant availability of micronutrients from fungicidal sources, two other factors need to be considered, as well -- uptake interference between micronutrients and type of formulations.

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The application of copper fungicides has been found to interfere with the uptake of other micronutrients, such as Zn (Sonmez *et al* 2007). If fungicides were applied as tank-mixes, eg. Cu fungicide mixed with Mn/Zn fungicide, Cu uptake may suppress Mn and Zn uptake by the plants. It would be necessary to monitor the plants for signs of Mn or Zn deficiency after such a mixed application.

Additionally, while absorption of Cu and Mn from fungicides is well documented (Sonmez *et al* 2007, Kaplan 1999, Deckers *et al* 1997, Shu *et al* 1992, Mollenhauer and Smith 1954, Emge and Linn 1952), reports documenting Zn absorption from fungicides are mixed. It has been determined that Zn in certain formulations such as *ziram* (zinc dimethyldithiocarbamate) is not as readily absorbed (Mollenhauer and Smith 1954) compared to Zn from *zineb* (zinc ethylene bis-dithiocarbamate) (Pire 1987, Emge and Linn 1952). Care should be taken when interpreting micronutrient contributions from Zn fungicides, and a plant tissue test should be used to check for Zn sufficiency after the fungicidal spray. Similarly, for new formulations of Cu and Mn, it should not be taken for granted that they will contribute micronutrients as the nutrient may be in a form that is not absorbable by the plant.

How to Determine Micronutrient Contribution from Other Fungicides for Other Crops

For fungicides of other crops, read the label to find out how much "% metallic equivalent" of the micronutrient is present in the fungicide and the recommended amount in "lb per acre of fungicide" to be applied. Multiply the "% metallic equivalent" to the "lb per acre of fungicide" to determine the total contribution of nutrient from the fungicide.

Take note of possible factors that would affect the availability of nutrients from the fungicides -- such as soil pH, interferences from using tank mixes and type of formulations. Do not assume that once the fungicide is applied, micronutrients in the fungicide will be available to the plants. If not sure, monitor closely after the fungicidal spray, and do a plant-tissue test for the micronutrient if necessary.

Conclusion

Micronutrients Cu, Mn and Zn are supplied through metal-based fungicide applications, but only Cu and Mn are applied in sufficient quantities to meet crop needs, depending on the type of fungicide, amount of nutrient in the fungicide and the maximum rate applied per crop season.

Careful calculations of the amount of micronutrients from fungicides and consideration of possible factors affecting availability are needed to reach a meaningful decision regarding whether additional micronutrient fertilizers should be applied.

Rather than relying solely on the information provided here, growers should use the label of new products or formulations to determine the amount of micronutrients supplied by their fungicide program.

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Table 1. UF/IFAS Recommendations for Foliar Applications of Micronutrients to Vegetable Crops[z,y]

Nutrient	**Source**	**Foliar application** (lb product per acre)	**Product nutrient content** (%)	**Estimated amount of nutrient based on highest application rate** (lb per acre)
Boron	Borax Solubor	2 - 5 1 - 1.5	11 21	0.55 0.32
Copper	Copper sulfate	2 - 5	25	1.25
Iron	Ferrous sulfate Chelated iron	2 - 3 0.75 - 1	20 5 - 12	0.60 0.12
Manganese	Manganous sulfate	2 - 4	28	1.12
Molybdenum	Sodium molybdate	0.25 - 0.50	39	0.20
Zinc	Zinc sulfate Chelated zinc	2 - 4 0.75 - 1	36 6 - 14	1.44 0.14

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Table 2. List of Fungicides Containing Copper, Manganese or Zinc and Commonly Used in Tomato Production in Florida

Fungicide[z]	Active Ingredient	Product Max Rate[y] (per acre)		Metallic Equivalent[w] (%)			Amount Applied (lb per acre)[t]					
							Cu		Mn		Zn	
		Per Applic	Per Season[x]	Cu	Mn	Zn	Per Applic	Per Season[v]	Per Applic	Per Season	Per Applic	Per Season
Kocide 101 or Champion 77 WPs	Copper hydroxide	4 lbs	NS	50			2.0	12.0 +				
Kocide 4.5 LF	Copper hydroxide	2.66 pts	NS	24.4 (or 3 lb/A)			1.0	6.0 +				
Kocide 2000 53.8 DF	Copper hydroxide	3 lbs	NS	35			1.1	6.6 +				
Champ 57.6 DP	Copper hydroxide	1.3 lbs	NS	37.5			0.5	3.0 +				
Basicop 53 WP	Tribasic copper sulfate monohydrate	4 lbs		53			2.1	12.6 +				
Kocide 61.4 DF	Copper hydroxide	4 lbs	NS	40			1.6	9.6 +				
Nu Cop 50 WP	Copper hydroxide	4 lbs	NS	50			2.0	12.0 +				
Cuprofix Disperss Ultra 40 DF	Basic copper sulfate	3 lbs	NS	40			1.2	7.2 +				
Bonide Liquid Copper[u]	Copper octanoate	2 gals	NS	1.8			0.3	1.8 -				
Ridomil Gold Copper 64.8 W	Copper hydroxide, mefenoxam	2 lbs	NS	39.1			0.8	4.8 +				
Mankocide 61.1 DF	Mancozeb, copper hydroxide	5 lbs	112 lbs	30	3	0.4	1.5	33.6 +	0.15	3.36 +	0.02	0.45 -

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							Cu		Mn		Zn	
		Per Applic	Per Season[x]	Cu	Mn	Zn	Per Applic	Per Season[v]	Per Applic	Per Season	Per Applic	Per Season
Manex 4F	Maneb	2.4 qts (0.6 gal)	16.8 qts (4.2 gal)		7.6 (or 4 lb/gal AI)				0.49	3.45 +		
Maneb 75DF	Maneb	3 lbs	22.4 lbs		16.5				0.50	3.70 +		
Maneb 80WP	Maneb	3 lbs	21 lbs		16.5				0.50	3.47 +		
Dithane, Manzate, Penncozeb 75DF	Mancozeb	3 lbs	22.4 lbs		15	1.9			0.45	3.36 +	0.06	0.43 -
Dithane F45, Manex II 4FL	Mancozeb	2.4 qts (0.6 gal)	16.8 qts (4.2 gal)		7.4 (or 4 lb/gal AI)	0.9			0.48	3.36 +	0.06	0.47 -
Dithane M45, Penncozeb 80WP, Manzate 80WP	Mancozeb	3 lbs	21 lbs		16	2.0			0.48	3.36 +	0.06	0.42 -
Ridomil MZ 68 WP	Mancozeb, mefenoxam	2.5 lbs	7.5 lbs		12.8	1.6			0.32	0.96 -	0.04	0.12 -
Gavel 75DF	Mancozeb, zoxamide	2 lbs	16 lbs		13.3	1.7			0.27	2.13 +	0.03	0.27 -
Ziram 76DF	Ziram	4 lbs	24 lbs			16.3					0.65	3.90 +

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							Cu		Mn		Zn	
		Per Applic	Per Season[x]	Cu	Mn	Zn	Per Applic	Per Season[v]	Per Applic	Per Season	Per Applic	Per Season

[z] Mention of trade names is solely for the purpose of providing specific information and does not imply a recommendation over similar products. Always read and follow the instructions on the product labels.

[y] See Olson et al., 2009 for complete disease-management recommendations for tomato grown in StateplaceFlorida

[x] NS= None Specified on the label

[w] Specimen labels of fungicides are obtained from Crop Data Management Systems, Inc. (http://www.cdms.net/LabelsMsds/LMDefault.aspx) except for those stated below:

Kocide 101, http://msds.dupont.com/msds/pdfs/EN/PEN_09004a358023d1e0.pdf

Kocide 4.5 LF, http://msds.dupont.com/msds/pdfs/EN/PEN_09004a358023c96d.pdf

Bonide liquid copper, http://www.bonideproducts.com/retail_support/new_images/index.php

Manzate 75DF, http://www.hort.wisc.edu/cran/mgt_articles/articles_pest_mgt/labels_msds/labels/manzate%2075DF.pdf

Manzate 80WP, http://aesop.rutgers.edu/~plantbiopath/links/bbcpestweb/CranberryLabels/manzate80.pdf

Manex II 4FL, http://www.hort.wisc.edu/cran/mgt_articles/articles_pest_mgt/labels_msds/labels/Manex%20II.pdf

[v] Assuming six applications in one season (unless otherwise stated) based on a 70-day growing period with fungicide sprays applied at 10-day intervals

[u] Bonide liquid copper is commonly used for home vegetable growing. The label does not indicate maximum rate of product to use per acre, and the rate used here is based on its parent product, *Cueva* fungicide. The label states a 1.8% metallic copper equivalent, which is assumed to be 1.8% w/v.

[t] "+" indicates the amounts provided by fungicides when used at maximum rates for the season are equal to or greater than those of the recommended fertilizer rate; "-" indicates lower amounts from fungicides than the recommended fertilizer rate.

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