Open Questions on the Risks and Benefits of Copper Sprays on Tree Fruits

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Background on Copper Sprays

Tree fruit diseases for which copper sprays are useful:

A. Bacterial diseases

1. Fire blight (as a dormant spray)
2. Bacterial canker of cherries (at leaf drop and/or in spring)
3. Bacterial spot on peach and nectarine

B. Fungal diseases

1. Peach leaf curl
2. Cherry leaf spot on tart cherries
3. Secondary effects on apple scab and other apple fungi ?
4. Summer diseases in organic apple production

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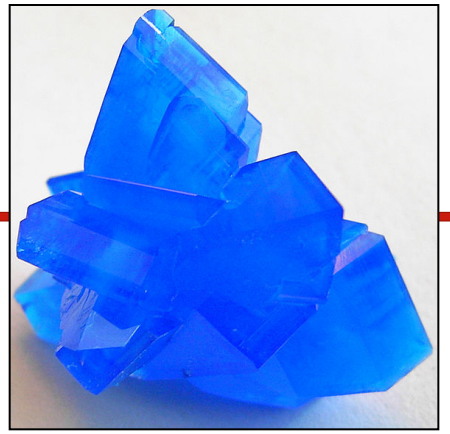
Background on Copper Sprays



Copper has a long history in agriculture

- 1807: seed treatment for wheat
- 1882: Bordeaux mixture (copper sulfate + lime)

How copper controls pathogens:

- Copper ions (Cu^{++}) denature proteins and enzymes.
- Toxicity of copper is non-selective: it will kill exposed plant cells as well as bacteria and fungi.
- It works as a fungicide/bactericide without damage to plants so long as it stays on plant surfaces.
- Copper sprays do not have post-infection activity because they cannot access pathogens that have already entered plant tissue.

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Background on Copper Sprays

Many forms of copper are labeled on tree fruit:

- Copper sulfate (copper sulfate pentahydrate)
  - > Soluble in water (320 mg/L at 68 F)
  - > High solubility increases phytotoxicity and decreases its residual activity on plant surfaces.
- Fixed coppers make better fungicides:
  - > low solubility in water (2 to 6 mg/L)
  - > After deposition on plants, Cu^{++} ions are slowly released from the non-soluble deposits when water is present.
  - > Complex interactions on the plant surface have huge effects on efficacy of copper sprays.

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Background on Copper Sprays

Many forms of copper are labeled on tree fruit:

- Copper sulfate (copper sulfate pentahydrate, $CuSO_4 \cdot 5H_2O$)

  (Mastercop, Magnabon, Phyton 27AG ?)

  Not the same !!

- Fixed coppers
  - > Tribasic copper sulfate . . . . . $3Cu(OH)_2 \bullet CuSO_4$
  - > Basic copper sulfate *(Cuprofix Ultra Disperss)*
  - > Copper oxide *(Nordox)* . . . . . Cu_2O or CuO
  - > Copper hydroxide *(Kocide, Champ)* . . . . . $Cu(OH)_2$
  - > Copper oxychloride sulfate *(COCS)*

    $3Cu(OH)_2 \bullet CuCl_2 + 3Cu(OH)_2 \bullet CuSO_4$
  - > Copper linked to fatty acids *(TennCop, Cueva)*
  - > others ??

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Background on Copper Sprays

Critical factors:

- Copper ions (Cu^{++}) denature proteins and enzymes.
- Fixed coppers have low solubility in water (2 to 6 mg/L)
  - Effectiveness of copper sprays is highly correlated with the amount of elemental copper that is applied.
  - Elemental (metallic) copper content varies by product !!

ACTIVE INGREDIENT:	
Copper Octanoate	10.0%
OTHER INGREDIENTS:	90.0%
TOTAL	100.0%
metallic copper equivalent	1.8%

ACTIVE INGREDIENT:	
Cuprous Oxide (Cu_2O)*	83.9%
OTHER INGREDIENTS:	16.1%
TOTAL	100.0%

*Metallic copper equivalent: 75%

HOWEVER, other factors also impact efficacy.

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Background on Copper Sprays

Factors that impact efficacy of copper sprays:

1. Particle size: smaller particles adhere better, last longer

> Due to low solubility, most copper is in crystalline form.

> Large particles are more easily dislodged by rain.

> More small particles/lb = better spray coverage.

- Median particle sizes range from 0.7 to 3.1 microns
- When diameter doubles, volume increases 8 times and surface area increases 4 times.
- Copper at 0.75 microns will have 64 X more particles per pound than copper at 3.0 microns.

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2013 copper trial at Highland

Table 1. Products tested, amounts used, and amounts of elemental copper applied per acre.

trt #	Products applied, formulations, and amounts per 100 gal of dilute spray[z]	Elemental copper content (%)	Rate range on label for green tip fire blight spray	Am't of product/A used in the trial		Amount of elemental copper/A in rate tested	
1.	Control						
2.	Champ Formula 2 Flowable[y] 4.5F 3.5 pt	24%	5.33 to10.5 pt/A	10.5	pt	3.85	lb
3.	Champ Formula 2 Flowable[y] 4.5F 1.91 pt	24%	5.33 to10.5 pt/A	5.73	pt	2.10	lb
4.	Nordox[x] 75WG 0.93 lb	75%	5 to 10 b/A	2.80	lb	2.10	lb
5.	Cuprofix Disperss[w] 36.9%DF 1.75 lb	40%	5 to 7.5 b/A	5.25	lb	2.10	lb
6.	Kocide 2000[y] 53.8%DF 2 lb	35%	6 to 12 b/A	6.00	lb	2.10	lb
7.	Kocide 3000[y] 46.1%DF 2.33 lb[t]	30%	3.5 to 7 lb/A	7.00	lb	2.10	lb
8.	Kocide 3000[y] 2.33 lb + Biocover Oil 3 gal	30%	3.5 to 7 lb/A	7.00	lb	2.10	lb
9.	Kocide 3000[y] 2.33 lb + spray lime 4 lb	30%	3.5 to 7 lb/A	7.00	lb	2.10	lb
10.	Kocide 3000[y] 2.33 lb + Biocover Oil 3 gal + lime 4 lb	30%	3.5 to 7 lb/A	7.00	lb	2.10	lb
11.	Phyton 27AG 1.92L[v] 61.3 fl oz/A in 100 gal/A	5.4%	20-40 fl oz/100 gal	61.3	fl oz	0.23	lb
12.	Mastercop 1.92L[v] 61.3 fl oz/A in 100 gal/A	5.4%	3-6 pt/A	61.3	fl oz	0.23	lb
13.	MagnaBon CS2005 1.79L[v] 64 fl oz[s]/A in 100 gal/A	5.0%	51.2 to 64 oz/A	64.0	fl oz	0.23	lb
14.	Cueva 10%L[u] 193 fl oz/A in 100 gal/A	1.8%	0.5 to 1 gal/100	193	fl oz	0.23	lb

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2013 copper trial at Highland

Table 3. Copper detected in bud samples collected 14 days after the copper sprays had been applied.

Material and rate of formulated product per 100 gal	Residual copper (ppm) from trees sprayed 8 Apr 2013* Royal Court buds 22 Apr	Cameo buds 22 Apr	Grand means for treatments
1. Control	38.6 i**	38.2 h	38.4 i
2. Champ Flowable 3.5 pt	189.4 a	125.5 a	157.5 a
3. Champ Flowable 1.91 pt	144.0 c	98.5 b	121.2 bc
4. Nordox 0.93 lb	105.3 f	70.2 e	87.7 ef
5. Cuprofix Disperss 1.75 lb	141.0 cd	84.0 d	112.5 bcd
6. Kocide 2000 2 lb	127.0 e	85.1 cd	106.0 cd
7. Kocide 3000 2.33 lb	117.2 ef	81.8 de	99.5 de
8. Kocide 3000 2.33 lb + Biocover Oil 3 gal	159.5 b	97.9 bc	128.7 b
9. Kocide 3000 2.33 lb + Spray Lime 4 lb	129.2 de	79.9 de	104.6 cde
10. Kocide 3000 2.33 lb + Oil 3 gal + Lime 4 lb.	153.3 bc	99.6 b	126.4 b
11. Phyton 27AG 61.3 fl oz	85.1 g	57.1 f	71.1 fg
12. Mastercop 61.3 fl oz	48.9 i	41.3 gh	45.1 hi
13. MagnaBon CS2005 64.0 fl oz	72.2 gh	52.4 fg	62.3 g
14. Cueva 193 fl oz	68.5 h	55.2 f	61.9 gh
Grand means for cultivar	112.8 A	76.2 B	

22 Apr was 14 days and 1.8 in of rain from the time of copper applications

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2013 copper trial at Highland

Table 5. Copper in bark samples collect on 22 Apr and in Cameo bud samples collected on 9 May.

Material and rate of formulated product per 100 gal	Residual copper (ppm) from trees sprayed 8 Apr 2013	
	Cameo bark samples* 22 Apr	Cameo buds** 9 May
1. Control		22.5
2. Champ Flowable 3.5 pt	40.8 a***	29.3
3. Champ Flowable 1.91 pt	21.5 b	26.5
4. Nordox 0.93 lb	9.2 cdef	25.8
5. Cuprofix Disperess 1.75 lb	14.2 bc	26.5
6. Kocide 2000 2 lb	10.3 cde	25.3
7. Kocide 3000 2.33 lb	22.0 b	25.0
8. Kocide 3000 2.33 lb + Biocover Oil 3 gal	12.0 bcd	27.8
9. Kocide 3000 2.33 lb + Spray Lime 4 lb	10.3 cde	23.8
10. Kocide 3000 2.33 lb + Oil 3 gal + Lime 4 lb	14.6 bc	23.3
11. Phyton 27AG 61.3 fl oz	3.1 def	22.8
12. Mastercop 61.3 fl oz	-0.8 f	19.5
13. MagnaBon CS2005 64.0 fl oz	1.2 def	22.0
14. Cueva 193 fl oz	0.8 ef	21.5
P value	<0.001	0.473

22 Apr was 14 days and 1.8 in of rain from the time of copper applications;
9 May, was 31 days and 2.47 in from the time of copper applications.

Question: How does copper suppress fire blight when residues are often gone before pink?

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Copper questions

- How do Green Tip copper sprays affect fire blight (or do they?)
- How does water temperature affect copper effectiveness?
- Cherry growers state that they need lime + copper to control bacterial spot: Why? Is lime part of the control?
- What should we tell growers about adding lime?
  What kind of lime?
  Does lime work better with some formulations than others?
- What new applications should be considered with the low-rate soluble coppers that are now available?

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