

Are nanoparticles the new weapon against plant disease?

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Plant Diseases

- Cost hundreds of millions of dollars to US agriculture every year.
 - Our current weapons against diseases are:
 - Host resistance - Breeding and genetically modified plants
 - Biological and Chemical Controls
 - Cultural Management
 - Rotation
- Fertilization!!!!** *Nutrition is the first line of defense against disease.*

Effect of Fertilizers on Root Rots and Mn

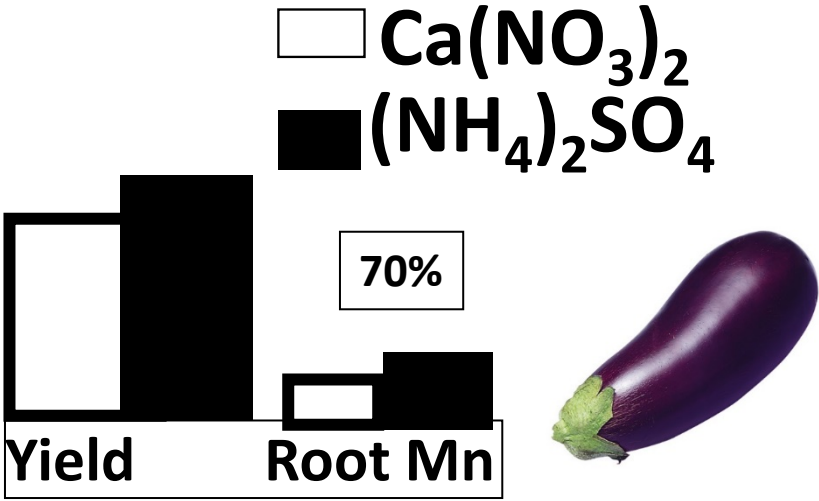


Asparagus /Fusarium

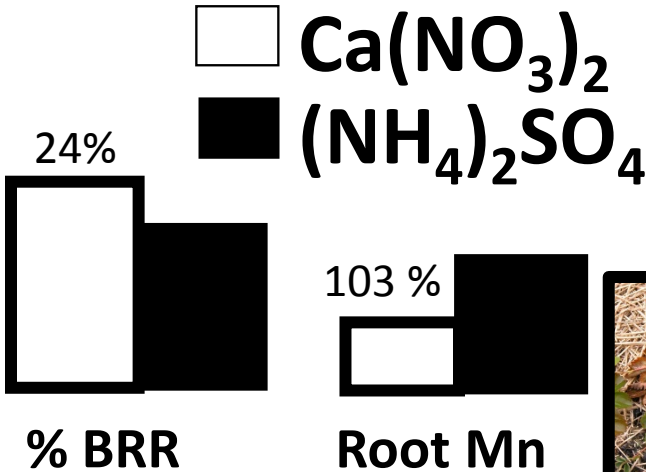
Beets/Rhizoctonia



Mn 53%



Eggplant/Verticillium



Strawberry/Root rot

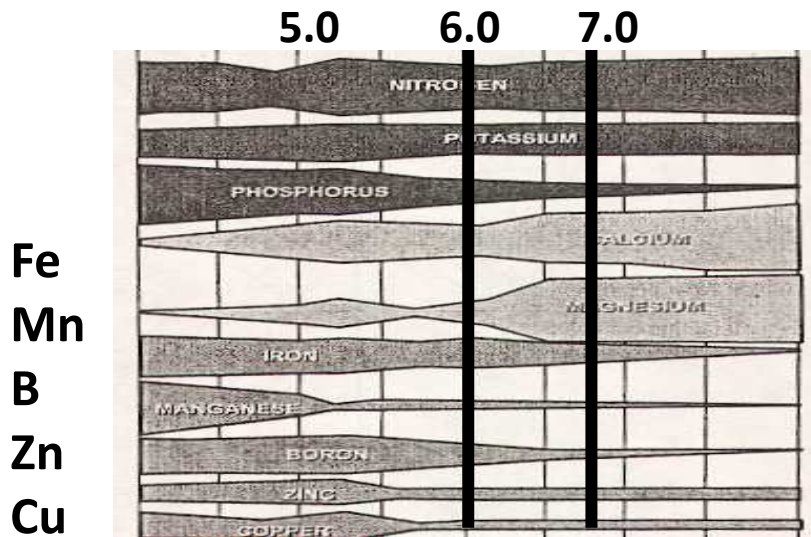
Micronutrients

Micronutrients protect roots against soilborne diseases by activating enzymes to create defense products.

Cu	activates polyphenoloxidases
Mn	activates the Shikimic acid and phenylpropanoid pathways
Cu, Mn & Zn	form superoxide dismutases that act as antioxidants in plants

Obstacles

- Micronutrients do not move freely in plant.
- When applied to leaves, they are quickly bound in the leaf.
- When applied to soils, they are unavailable unless applied at high rates.

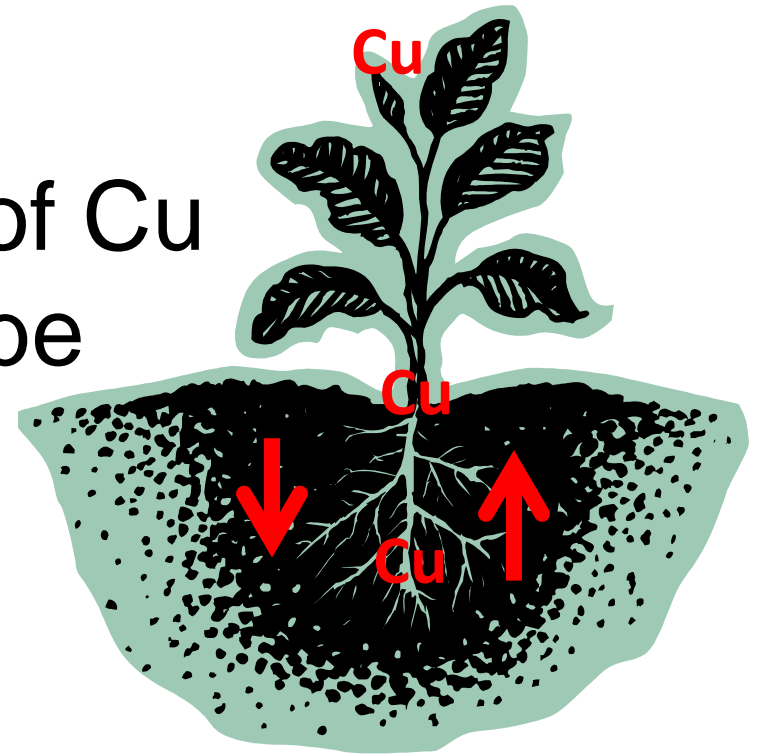


**How do we improve
micronutrient
availability in roots ?**

Cover crops, biochar, earthworms,
microbes,

CAES Scientists showed that when Nanoparticles of CuO were applied to plant, Cu was more mobile than the larger form.

Would Nanoparticles of Cu applied to the foliage be able to move to the roots?



What is a nanoparticle

- Any particle that has a size of (1-100 nm)
- A soccer ball is about 17 nano-earths (one billionth in size)



Earth



17 Nano-Earths

The Hypothesis

Would spraying Nanoparticles of CuO, MnO and/or ZnO protect plants against disease.



Would the fruit be safe to eat?

Verticillium Wilt of Eggplant



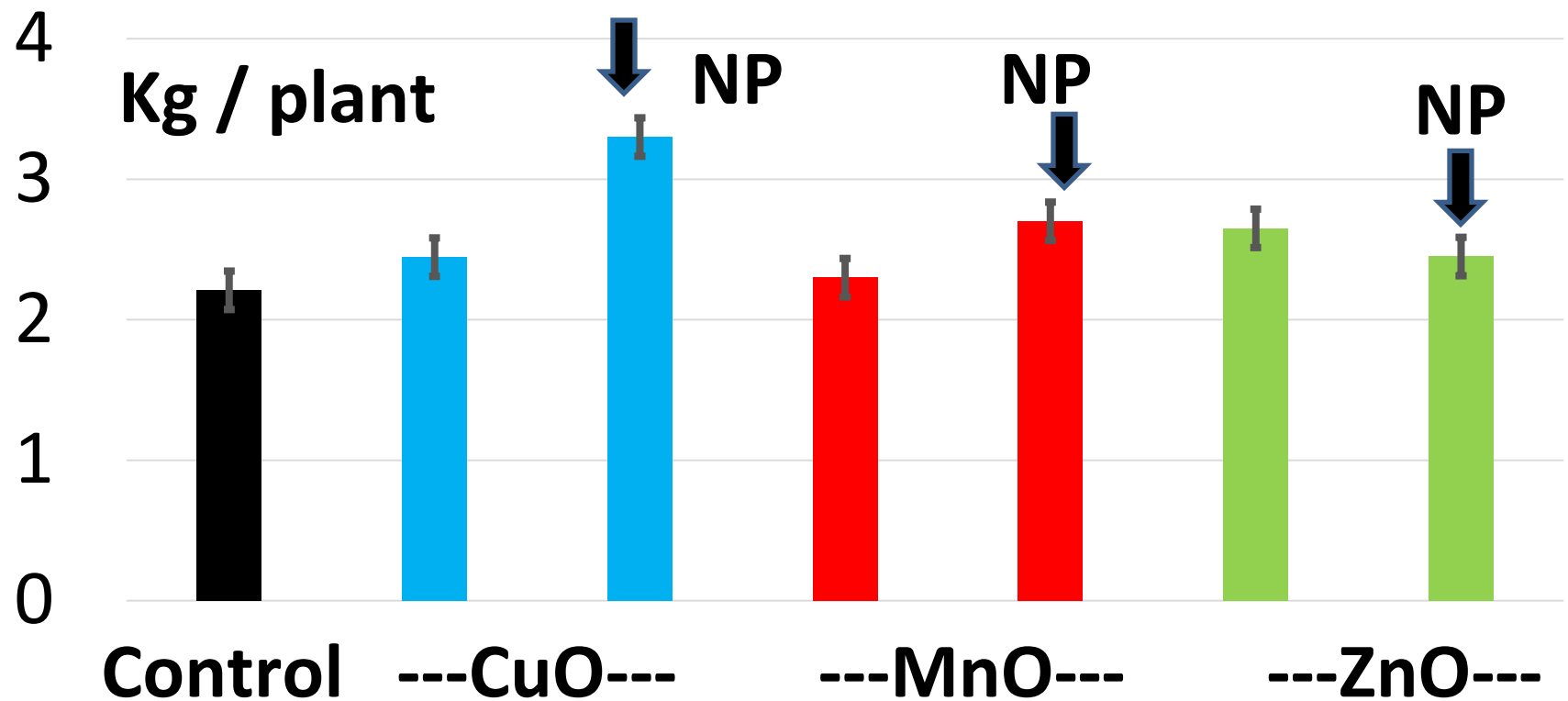
Caused by soilborne fungus *Verticillium dahliae*

Can reduced yields by 30%

Nanoparticle-Verticillium Field Trials 2013-2014



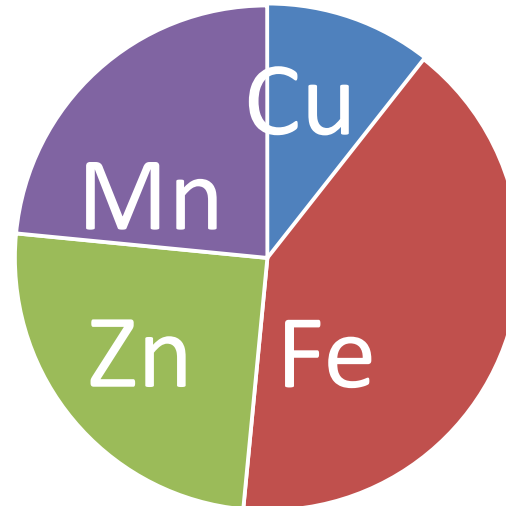
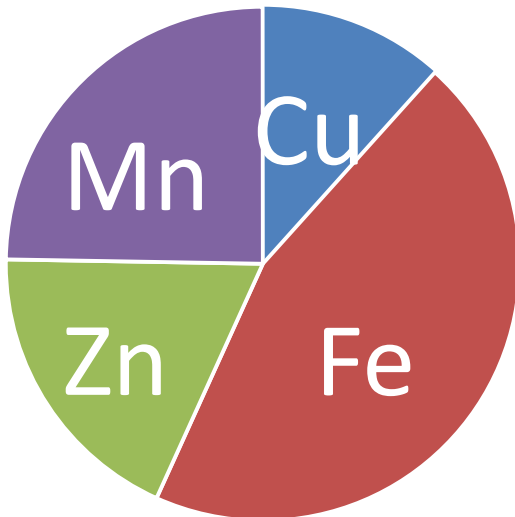
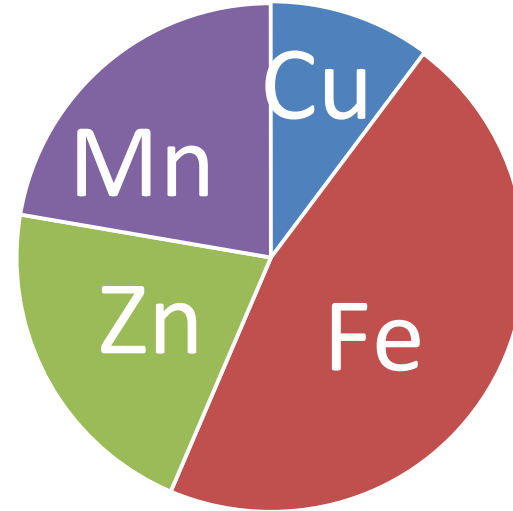
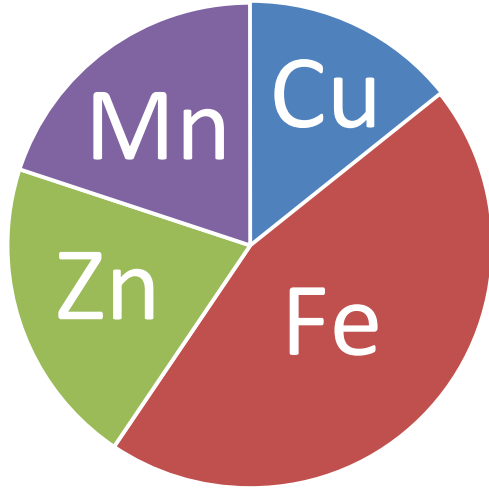
Effect of NPs of CuO, MnO and ZnO and their Bulk forms on eggplants yield with Verticillium wilt (2013 & 2014).



Composition of the Eggplant fruit

Untreated control

CuO Nanoparticles



MnO Nanoparticles

Zn Nanoparticles

Assume and we are only assuming

- 750-900 eggplant transplants/acre.
- Apply 1-2 mg CuO/plant applied to run off) = costs about \$15.00.
- We received a mean 24% yield increase.
- Eggplant averages = \$25,000 acre.

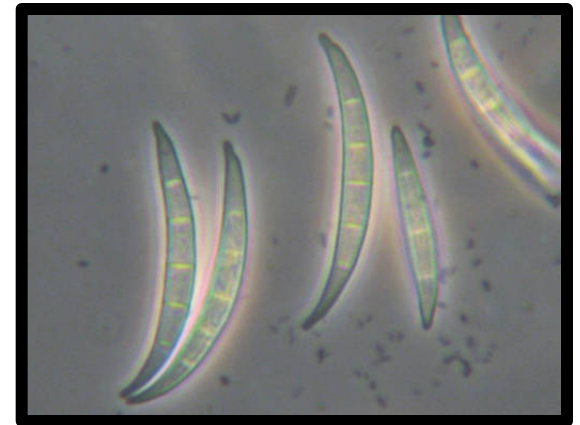
So a \$15.00 investment could increase gross returns by \$5,000 Acre.

Hard to believe

Fusarium Wilt of Watermelon



Caused by
Fusarium
oxysporum f. sp.
niveum



The disease had been managed with fumigants, but fumigation is longer used

The Hypothesis



Would nanoparticles of CuO decrease Fusarium disease on watermelon. **YES**



Would it perform better than the traditional fungicides like Kocide (a common $\text{Cu}(\text{OH})_2$ product)?

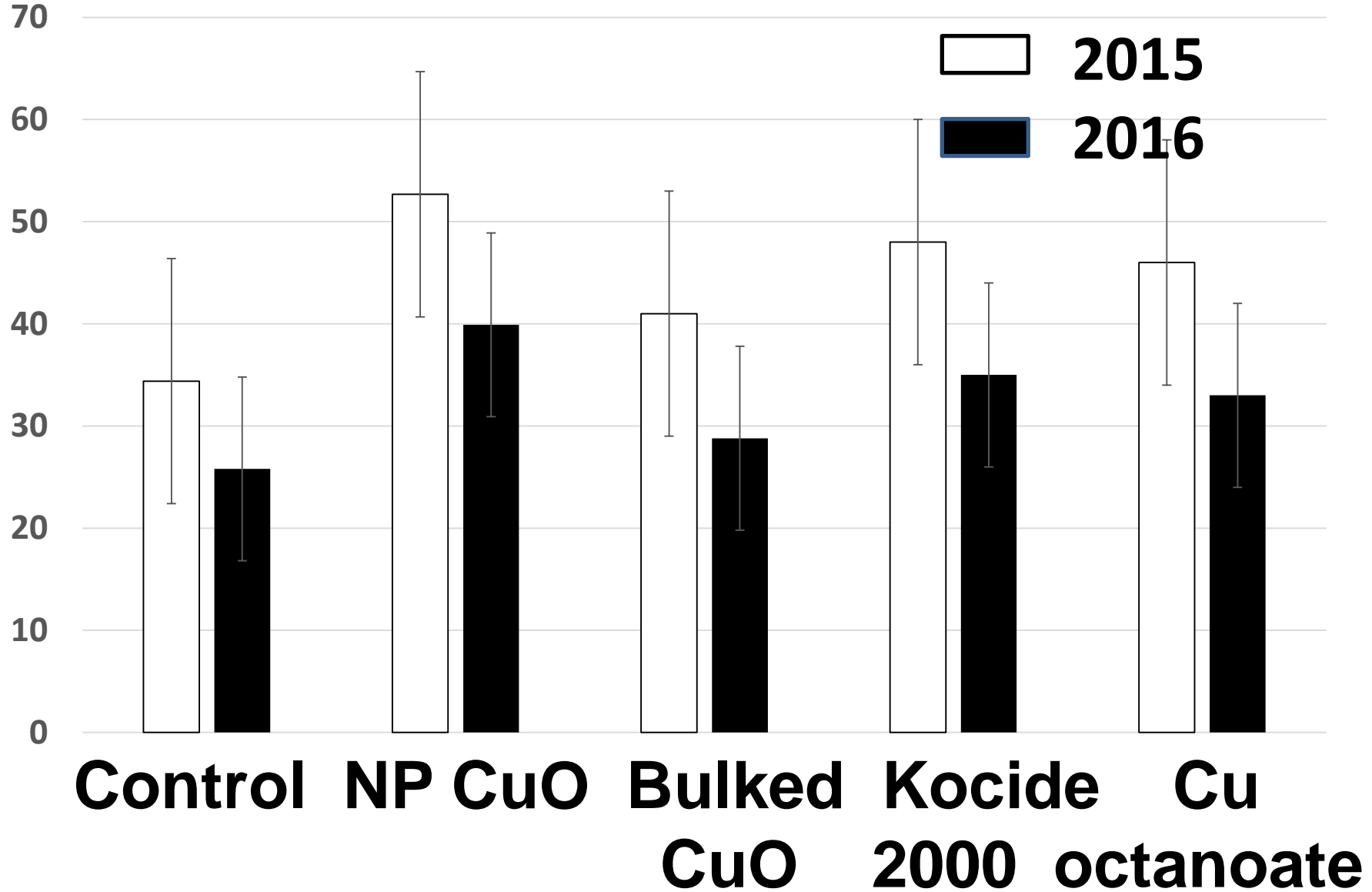
Field trials - Hamden, CT



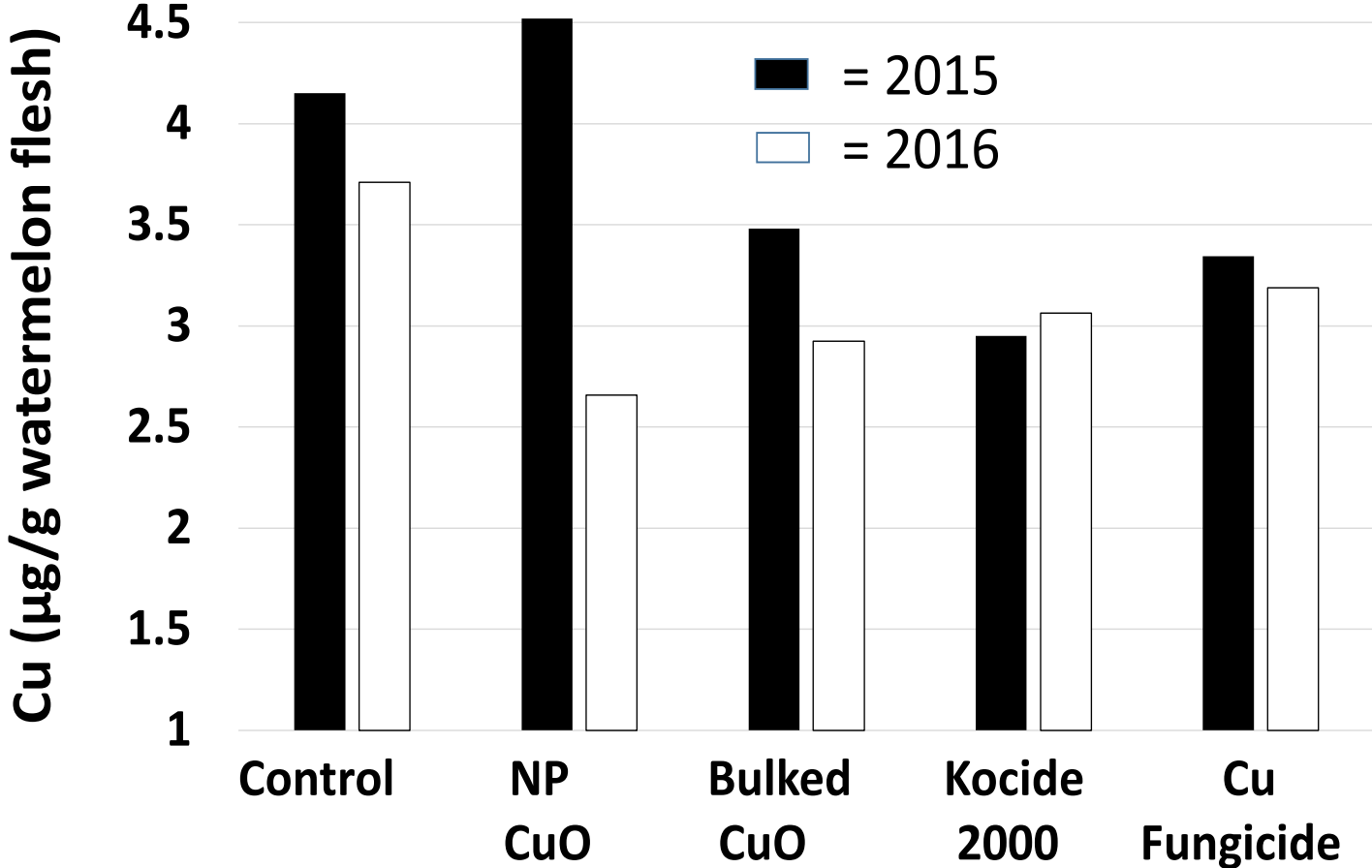
1. Control,
2. NP CuO
3. Bulked CuO
4. Kocide
2000
5. Cu Octonate
(organic Cu
soap)

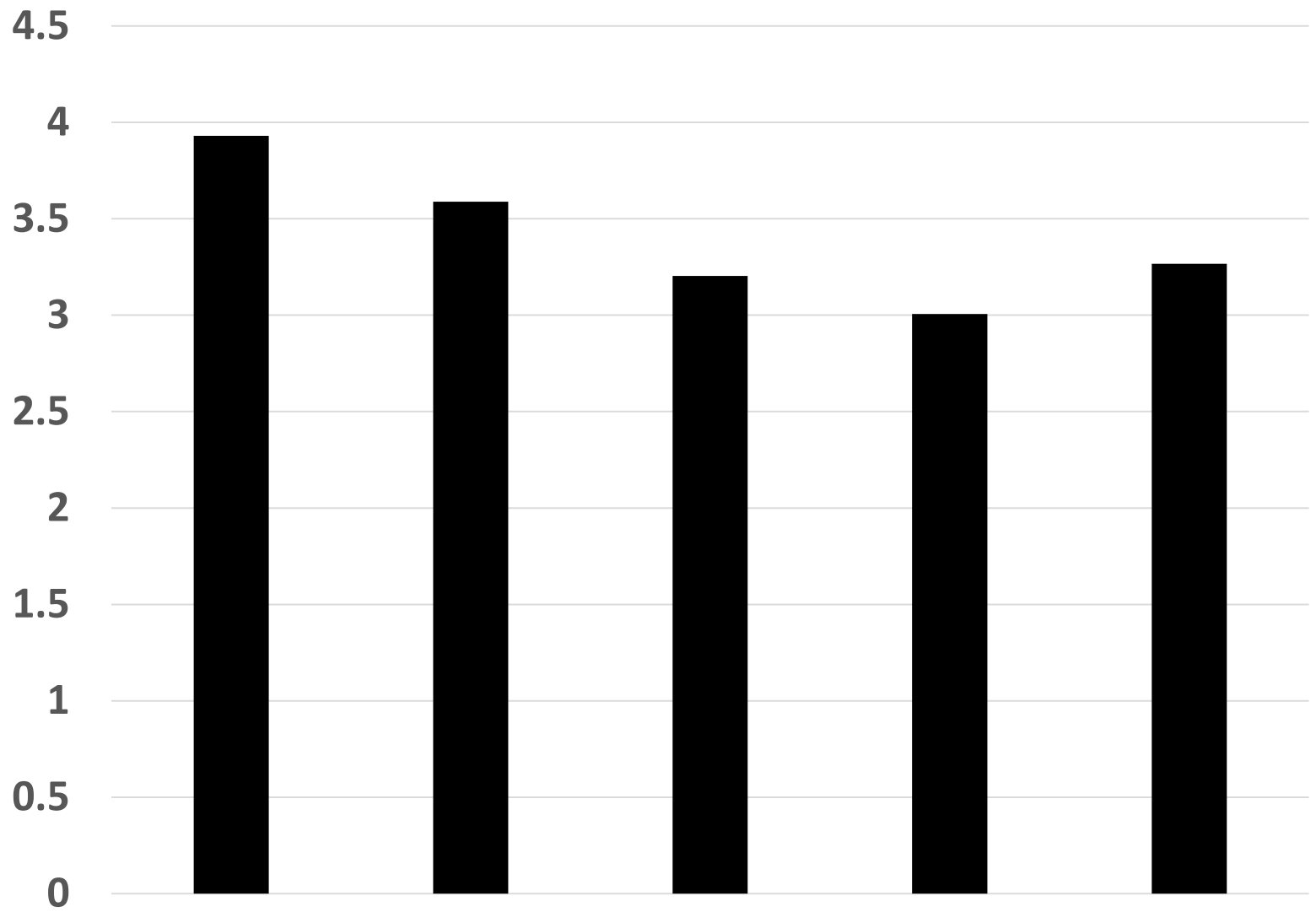
Hamden CT

Watermelon Yield (kg fruit/plot)

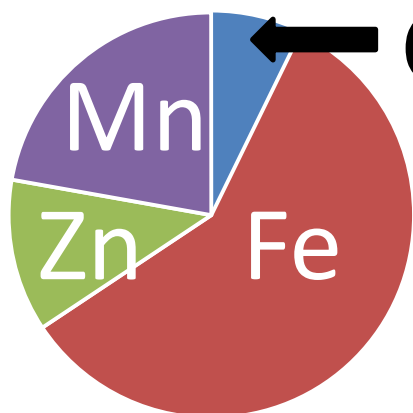


Cu levels in edible fruit of watermelon treated with NP of CuO.

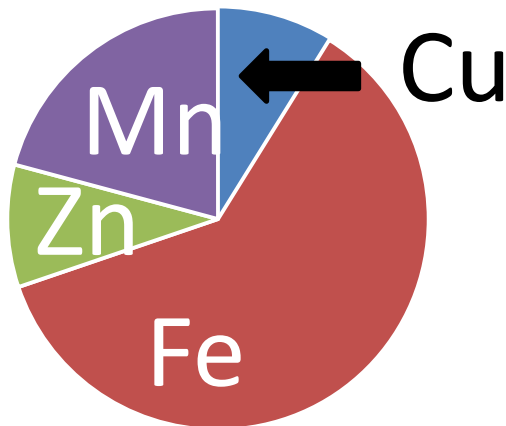




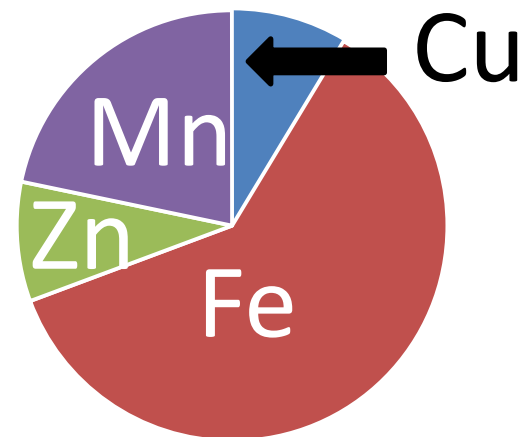
Composition of the Watermelon fruit



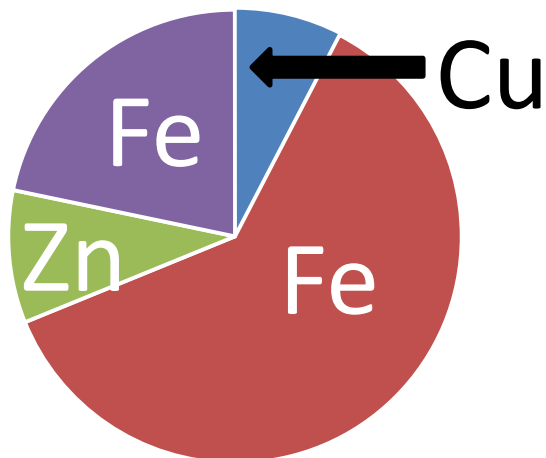
Untreated



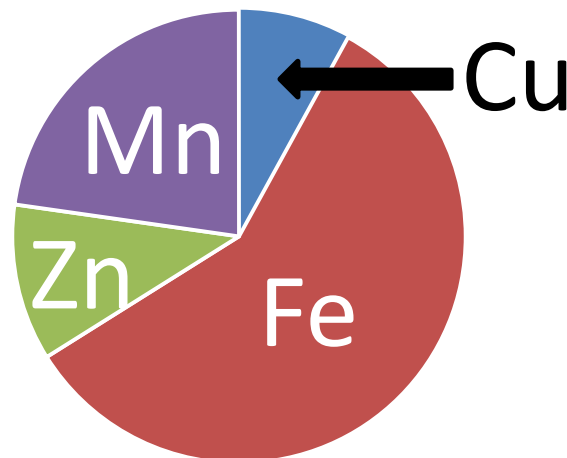
Bulk CuO



NP of CuO

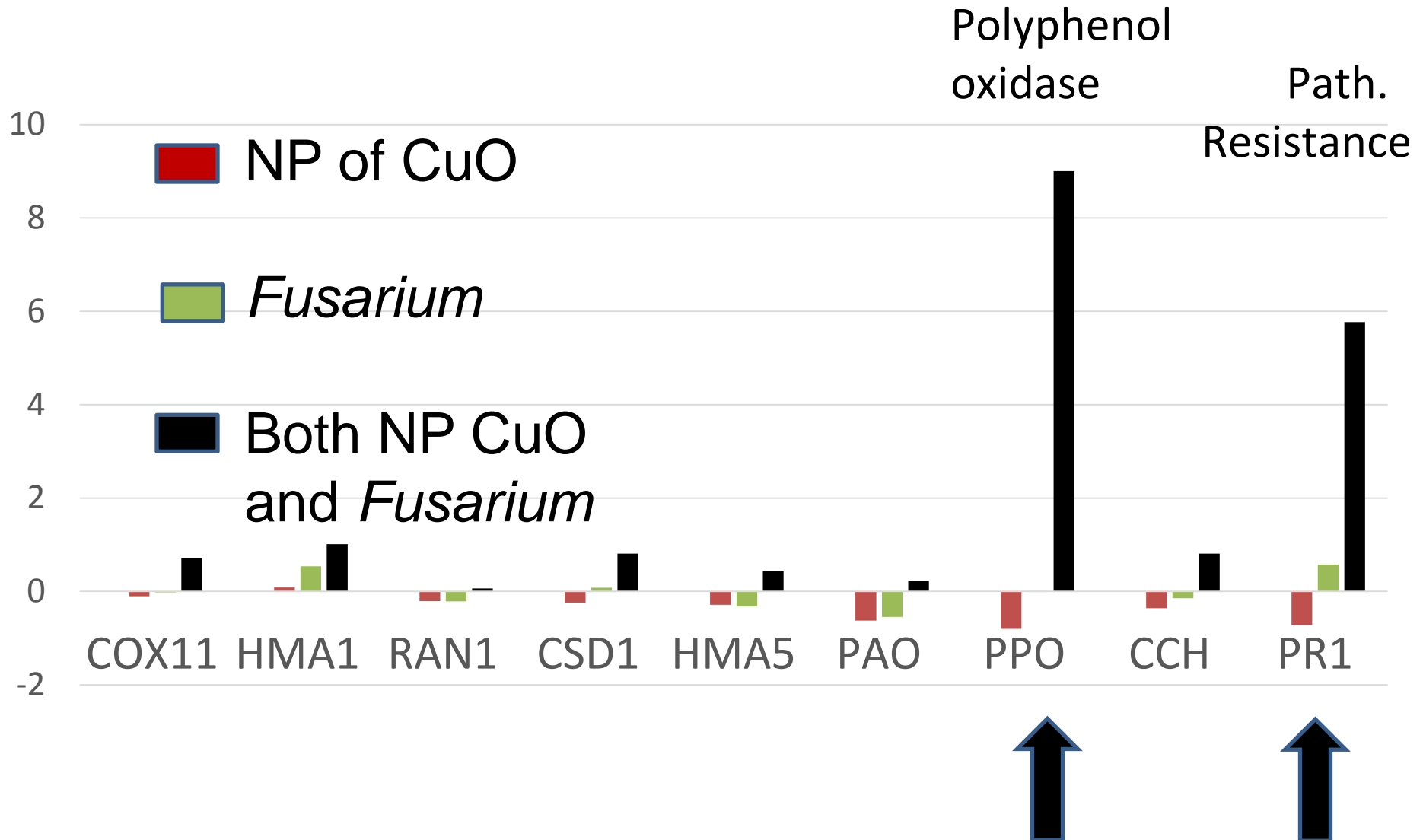


Kocide 2000



Cu Octanoate

Copper nanoparticles affect gene expression

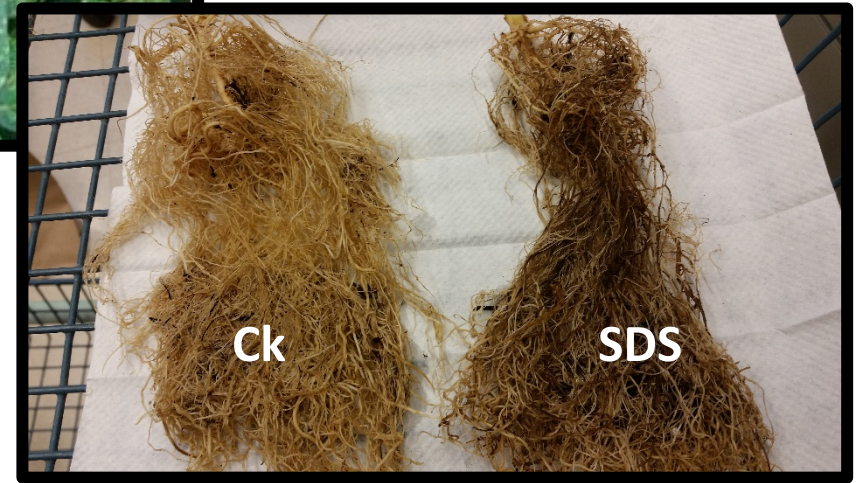


Soybean Sudden Death

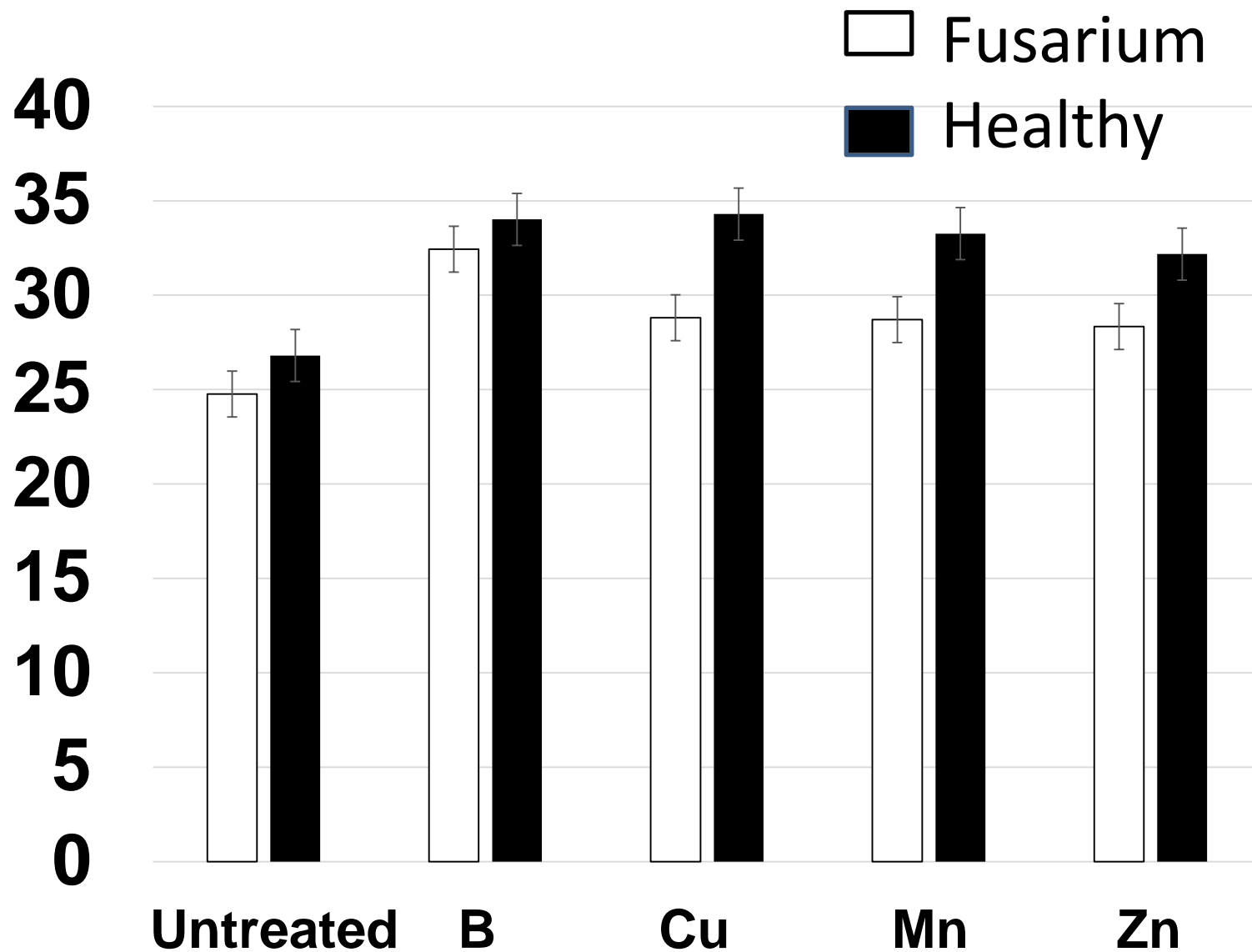


Caused by *Fusarium virguliforme*
Second most destructive disease

Together with Soybean cyst nematode, losses have reach 16 billion dollar in 2017



Effect of NP on Soybean Biomass (g)



Fusarium wilt of Chrysanthemum



NP (500 ppm)

Control

B

CuO

MnO

ZnO

Fungicides



Control

Inoculated

Untreated

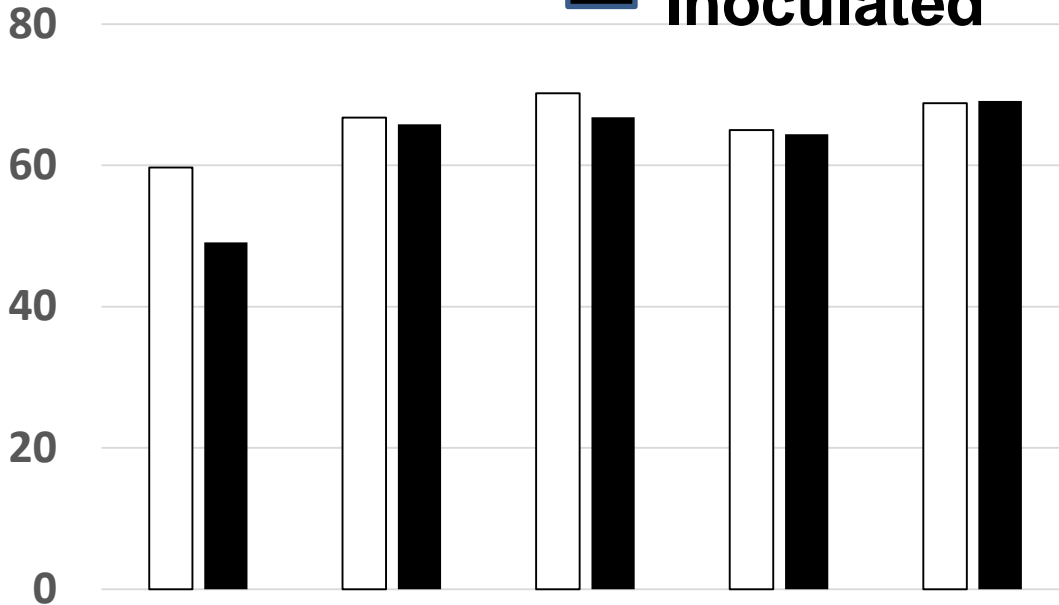


NP CuO



Dry Weights (g) *Control*
80 **Inoculated**

NP MnO



NP ZnO



Fungicides



Control CuO MnO ZnO Fung.

Effect of Nanoparticles of Metallic oxides on Powdery mildew of pumpkin

Ten treatments



Untreated

NP CuO

NP MnO

NP SiO

NP ZnO

CuSO₄

MnSO₄

K₂SiO₃

ZnSO₄

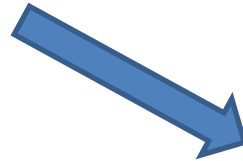
Fungicide

(Bravo+
systemic)

Griswold 6 reps, sprayed 3 times Jul 6, 19, Aug 10th

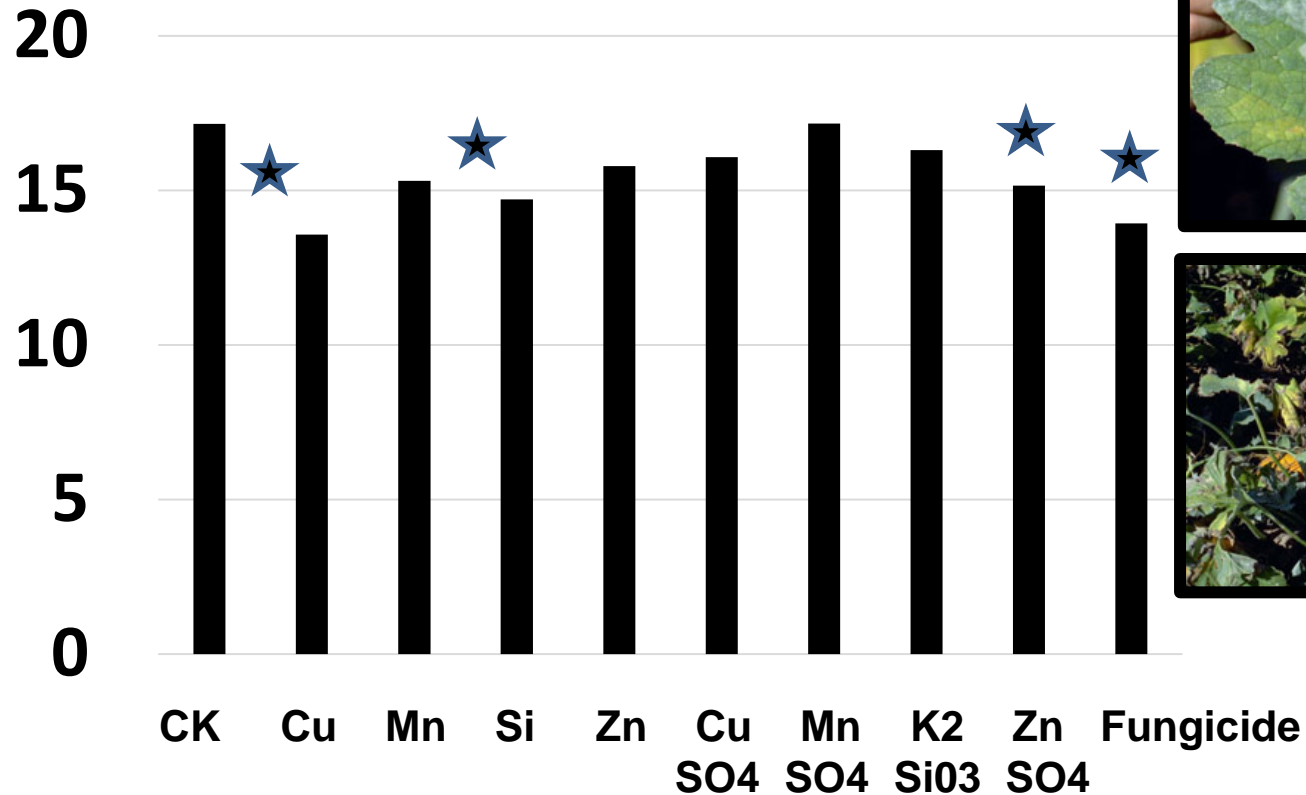


Lockwood - 8 reps, sprayed 4 times Jul 10, 17, 28, Aug 17

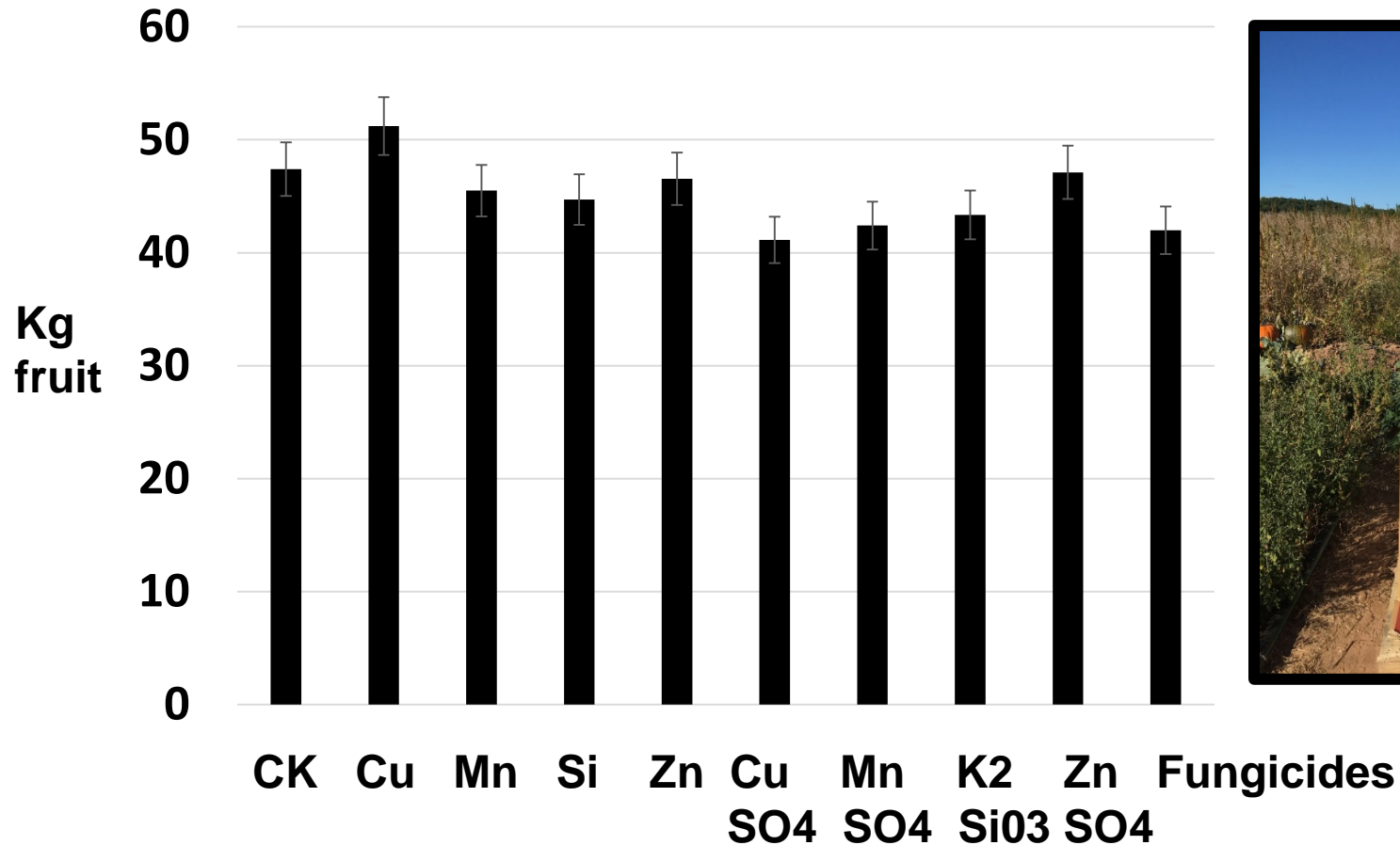


Powdery mildew ratings

Rank Sum of five disease ratings



Pumpkin yield (2017), Combined Lockwood and Griswold



Nano Nano



Acceptance of Nanotechnology is slowly increasing in Plant Pathology.

It is the new weapon for increasing sustainable yields without having to cultivate more land, use more water, or apply more chemicals.

Conclusions

- NP of CuO, MnO, SiO, and ZnO had disease suppressive properties;
- NP CuO appear to turn on genes that make defense products in watermelon root tissue.
- **Season long effects** were observed following single applications to young transplants.
- Field applications also have potential to suppress Powdery mildew diseases.

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