Physiological and biochemical effects of copper nanoparticles in bell pepper (*Capsicum annum* L.) plants

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INTRODUCTION
Properties of Nanomaterials

- Materials with at least 2 dimensions between 1 nm and 100 nm.
- Size range between individual molecules and the corresponding bulk materials.
- High surface energy.
- Quantum confinement.
- High redox activity.
Global flows for Cu and oxides of Cu (metric tons/yr) in 2010

Application of NPs in agriculture

Hong, J., Peralta-Videa, J.R. & Gardea-Torresdey, J. 2013, "Nanomaterials in agricultural production: benefits and possible threats?".
Bell pepper plants (*Capsicum annuum* L.)

- *Capsicum annuum* L.
- Chilli or pungent flavor attributed to the chemical *capsaicin* 8-methyl-N-vanillyl-6-noneamide.
- Rich in anti-oxidants like carotenoid, sugars, vitamin C.
- Average consumption 10.6 lbs/person/year.
- 46,500 acres of land cultivated to produce 1535 million lbs.
- 60% of the nations bell peppers grown by California.
- Average yield 33,000 lbs/acre.

[Source](https://authoritynutrition.com/foods/bell-peppers)
Bell pepper world production, yield, hg/ha

➢ Effect of contaminant particle size on the growth and physiological parameters of bell pepper plant

➢ Effect of exposure period (45 vs 90 days) on the elemental concentration of plants
METHODOLOGY
Soil collected Socorro, TX (N 31° 40.489’, W 106° 17.198’, elevation: 1,115 m asl).

Soil characterization conducted on Malvern Mastersizer Hybrid 2000G
- Sand: 19.7%
- Silt: 64.92%
- Clay: 15.38%

Natural soil: silty loam
Preparing pots in the lab for seedling transplantation
Plant growth stages

Seedlings growing

Seedlings ready for transplantation

Plants 10 days post transplantation

Freshly transplanted seedlings
Plants 30 days post transplantation

Plants 45 days post transplantation, flowering

Fully matured plants, 90 days post transplantation

Plants 60 days post transplantation, fruiting
Gas exchange measurement: CIRAS-3 portable photosynthesis system
Harvesting
Acid digestion and sample analysis on the ICP-OES
RESULTS
Comparison of the evapotranspiration (ET) between vegetative stage and reproductive stage study

Evapotranspiration at 45 and 90 days

<table>
<thead>
<tr>
<th>Treatment Concentration (mg/kg)</th>
<th>Veg.</th>
<th>Rep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62.5nCu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62.5bCu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500nCu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500bCu</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Legend:
- Veg.: Vegetative stage
- Rep.: Reproductive stage

Graph shows the comparison of evapotranspiration in mmol/m²/s at 45 and 90 days for different treatment concentrations.
Comparison of the stomatal conductance between vegetative stage and reproductive stage study

Stomatal conductance at 45 and 90 days

<table>
<thead>
<tr>
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<th>Rep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>ab</td>
<td>ab</td>
</tr>
<tr>
<td>62.5nCu</td>
<td>ab</td>
<td>ab</td>
</tr>
<tr>
<td>62.5bCu</td>
<td>ab</td>
<td>b</td>
</tr>
<tr>
<td>500nCu</td>
<td>a</td>
<td>ab</td>
</tr>
<tr>
<td>500bCu</td>
<td>ab</td>
<td>ab</td>
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</table>
Comparison of the photosynthesis between vegetative stage and reproductive stage study

Photosynthesis at 45 and 90 days

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<th>Rep.</th>
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<td>a</td>
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<td>a</td>
<td>ab</td>
</tr>
<tr>
<td>500bCu</td>
<td>ab</td>
<td>ab</td>
</tr>
</tbody>
</table>

Photosynthesis µmol/m²/s
Elemental analysis, comparison between treatments and controls

Root Cu, vegetative stage vs reproductive stage study

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<th>Veg.</th>
<th>Rep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>c</td>
<td>c</td>
</tr>
<tr>
<td>62.5 nCu</td>
<td>cd</td>
<td>c</td>
</tr>
<tr>
<td>62.5 bCu</td>
<td>bc</td>
<td>c</td>
</tr>
<tr>
<td>500 nCu</td>
<td>cd</td>
<td>a</td>
</tr>
<tr>
<td>500 bCu</td>
<td>ab</td>
<td>ab</td>
</tr>
</tbody>
</table>
Elemental analysis, comparison between treatments and controls

Stem Cu, vegetative stage vs reproductive stage study

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Veg.</th>
<th>Rep.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62.5 nCu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>62.5 bCu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 nCu</td>
<td></td>
<td></td>
</tr>
<tr>
<td>500 bCu</td>
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</tr>
</tbody>
</table>
Leaf Cu, vegetative stage vs reproductive stage study

Elemental analysis, comparison between treatments and controls

Control
62.5 nCu
62.5 bCu
500 nCu
500 bCu

mg of Cu/kg dry wt of leaf

Veg.
Rep.

The University of Texas at El Paso
Elemental analysis, comparison between treatments and controls

**Fruit Cu, vegetative stage vs reproductive stage study**

<table>
<thead>
<tr>
<th>Treatment</th>
<th>mg of Cu/kg dry wt of fruit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>62.5 nCu</td>
</tr>
<tr>
<td></td>
<td>62.5 bCu</td>
</tr>
<tr>
<td></td>
<td>500 nCu</td>
</tr>
<tr>
<td></td>
<td>500 bCu</td>
</tr>
</tbody>
</table>

Veg. = Vegetative stage
Rep. = Reproductive stage
45 day study had significantly higher evapotranspiration measurements as compared to the 90 day study, except at 500 nCu treatment.

The stomatal conductance and photosynthesis were significantly lower at 62.5 bCu treatment as compared to select other treatments at the concentrations studied.

For the 90 day study, root Cu was significantly high at both nCu and bCu 500 mg/kg concentrations compared to control. For the 45 day study, root Cu was significantly high at both bCu concentrations compared to control.

In the stem tissue, nCu significantly increased the Cu concentration at the 90 day time point compared to the 45 day treatment interval.

The leaf Cu was significantly higher at 45 day exposure period for bCu treatments as compared to the nCu ones. The concentration of Cu in the fruit tissue was not significantly affected under treatments.
Acknowledgements

➢ UCCEIN for funding the research and the adjoining sponsors

➢ Texas A&M Agrilife Research and Extension Centre at El Paso, TX.

➢ University of Texas at El Paso

➢ Lab Mates

➢ Faculty
  - Dr Youping Sun
  - Dr Genhua Niu
  - Dr Jose A. Hernandez
  - Dr Jose R. Peralta
  - Dr Jorge Gardea Torresday

➢ The SNO conference organizers
References


➢ Hong, J., Peralta-Videa, J.R. & Gardea-Torresdey, J. 2013, "Nanomaterials in agricultural production: benefits and possible threats?".

Thank you for the attention.
Questions?