Comparison of the effects of ZnO nano/bulk materials on bean plants grown in different soil types

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Introduction

Nanomaterials
ZnO NMs
Environmental release
Previous studies
Beans
Nanomaterials (NMs)

- Thousands of commercially available products contain NMs
- Their volume of production and diversity of applications have grown over the past decade and continue to grow rapidly
- Although there are many benefits to using NMs in various applications, there is concern that their environmental implications are not fully understood

ZnO applications

- Agriculture
- Medicine
- Textiles
- Paints
- Cosmetics

33,400 tons of ZnO NMs produced yearly

Oceans and soils are among the main sinks of NMs in the environment.

Plant studies in ZnO NMs

Altered nutritional values [Peralta-Videa, et al. 2014]
Reduced biomass production and root elongation
No changes in N\textsubscript{2} fixation in nodules [Priester, et al. 2012]
Decreased biomass
Inhibited soil enzymes [Du, 2010]
Reduced production of developed cobs
Decreased net photosynthesis [Zhao, et al. 2015]
Increased fruit yield
Enlarged root and stems [Raliya, et al. 2015]

In-lab synthesized NMs
Beans

- Most consumed legume
- 26 million tons/year produced
- Large variety of environments
- High nutritional quality @ low cost

Methods

ZnO NMs
Experimental conditions
Plant exposure
Analysis
ZnO NMs

Z-COTE®

Uncoated

Amphiphilic

Commercial ZnO NMs

Z-COTE® HP1

Coated with triethoxycaprylylsilane -binder and emulsifier- Hydrophobic
Experimental conditions

**Plant:** Red Hawk kidney bean

**Treatments:** Z-COTE, Z-COTE HP1, bulk ZnO, ZnCl₂

**Concentrations:** 0, 62.5, 125, 250, 500 mg/kg

**Soils:** Natural soil, enriched soil (50% potting mix)

**Harvest:** 45 and 90 days
Plant exposure

Methods

1. Introduction
2. Methods
3. Results
4. Summary

- 4 concentrations
  - 62.5 ppm
  - 125 ppm
  - 250 ppm
  - 500 ppm
Tissues analysis

1. Introduction
   - Image of potted plants

2. Methods
   - Image of a balance and a ruler

3. Results
   - Image of a sample preparation device

4. Summary
   - Image of a test tube with a liquid sample

5. Image of ICP-OES equipment

6. Graph showing data analysis
Results

ZnO NMs
Soil characteristics
Physiological effects
Nutrients
**ZnO NMs**

- **Size**: 10-300 nm
- **Surface area**: 16.6 m$^2$/g
- **Zeta potential**: 21.8 ± 0.8 mV
- **Purity**: >99%

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- **Size**: 10-300 nm
- **Surface area**: 13.1 m$^2$/g
- **Zeta potential**: -23.6 ± 0.8 mV
- **Purity**: >98.7%

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**Z-COTE**

**Z-COTE HP1**
Soil characteristics

**Natural soil** (Loam)

- **Organic Matter:** 18%
- **pH:** 6.8
- **Total Diss. Solids:** 1876 mg/L
- **Phosphorus:** 985 ± 56 mg/100g
- **Zinc:** 5.4 ± 0.2 mg/100g

**Enriched soil** (50% NS, 50% PM)
Mature plants
Root length

Natural soil

- Longer roots at all concentrations in natural soil

Enriched soil

38% + 40%
228% - 53%

Compounds:
- Control
- ZnO Bulk
- Z-COTE
- Z-COTE HP1
- ZnCl₂
Zn in root

Soil I

The hydrophobic coating promotes root growth

Stem length

Natural soil

Enriched soil

Control  ZnO Bulk  Z-COTE  Z-COTE HP1  ZnCl$_2$

86% + 25% + 27%

Stem length (cm)

Compound
<table>
<thead>
<tr>
<th></th>
<th>Fresh weight (g)</th>
<th>Dry weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Natural</td>
<td>Enriched</td>
</tr>
<tr>
<td>Control</td>
<td>8.97± 0.41</td>
<td>17.16 ± 0.66</td>
</tr>
<tr>
<td>Treatments</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td>Control</td>
<td>10.71± 0.83</td>
<td>33.88 ± 1.36</td>
</tr>
<tr>
<td>Treatments</td>
<td>none</td>
<td>none</td>
</tr>
<tr>
<td></td>
<td>[↑ ZnO Bulk ∙ 250 42.85 ± 2.37]</td>
<td>none</td>
</tr>
</tbody>
</table>
These are not the only cases where Zn is significantly translocated.
Chlorophyll

Control   ZnO Bulk   Z-COTE   Z-COTE HP1   ZnCl₂

Mature pods
Seed production

Natural soil

<table>
<thead>
<tr>
<th>Compound</th>
<th>Number of seeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>16</td>
</tr>
<tr>
<td>ZnO Bulk</td>
<td>14</td>
</tr>
<tr>
<td>Z-COTE</td>
<td>12</td>
</tr>
<tr>
<td>Z-COTE HP1</td>
<td>10</td>
</tr>
<tr>
<td>ZnCl₂</td>
<td>8</td>
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Enriched soil

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</table>

Chloride affects plant system

- 79%
- 52%
The hydrophobic coating is playing an important role on the translocation to the seeds.
Summary

Agronomical

- Z-COTE HP1 enlarged roots in N.S.
- Bulk ZnO & Z-COTE HP1 (62.5) longer stems in N.S.

Physiology

- ZnCl$_2$ decreased chlorophyll in N.S.
- Zn uptake is dose-dependent.
- Si in the surface coating

Biochemistry

- Soil O.M. quenches Cl$^-$ toxicity
- Soil type affects yield
- ZnCl$_2$ affects plant system in N.S.
- Hydrophobic coating changes Zn translocation to the pods.

The soil type highly affects the way the nanomaterials interact with the plant system.
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Thank you for your attention