Stabilized silver nanoparticles - new fungicide to control potato diseases

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6000 years ago

Silver dishes

Silver salts

XVII c.

Colloid silver

XX век
Preparations on the basis of colloidal silver

Silver is registered as a food additive E174.
The mechanism of action of colloidal silver

- Oxidizer (oxygen from the air)
- Sustained release of silver ions

Protein

 NH₂
 SH
 OH

Ag⁺

inactive enzyme
Mechanism of action of colloidal silver

**Peptidoglycan shell, contains -NH2- groups**

- **Bacteria**
- **Cells of plants and animals**

**Cellulose, does not contain –NH2 groups**
Mechanism of action of colloidal silver

- Breaks down the cell wall
- After ingestion inhibits the enzymes and destroys cell DNA
Preparations of colloidal silver is effective in high concentrations (>1% Ag) and very expensive.

Colloidal silver easily precipitates.
Producing of colloidal silver

- **Ag** – atoms and small particles (clusters) silver
- **Ag⁺** – silver ions (water-soluble silver salt)

**Steps:**
1. **Reducing** agent (e.g., glucose)
2. **Ag⁺** (silver ions) reacts to form **Ag** (silver atoms and small particles)
3. **Ag** forms clusters
4. **Crystallization** of silver nanoparticles

**Surfactant-stabilizer**
What is Zeroxxe?

Silver nanoparticles, surface modified by amphoteric surfactant.
Non-toxic for human, plants and animals.
Testing of Zeroxxe in vitro
Growth on media with different concentrations of Zeroxxe

*Rhizoctonia solani* J.G.Kühn

EC$_{50}$ = 4,3 mg/l

![Graph showing diameter of colonies (mm) against concentration of silver, mg/l](image)

The colony on day 4 of growth
Sclerotinia sclerotiorum (Lib.) de Bary

The colony on day 7 of growth

EC$_{50}$ = 3.9 mg/l
Helminthosporium solani Durieu & Mont.

EC$_{50}$ = 10 mg/l

The colony on day 18 of growth
Alternaria solani Sorauer

EC$_{50}$ = 7.7 mg/l

Diameter of colonies (mm) vs. concentration of silver, mg/l

- 0
- 0.1
- 1
- 10
- 100

Day of growth:
- 2
- 4
- 6
- 8

The colony on day 8 of growth
**Alternaria alternata** (Fr.) Keissl.

**EC$_{50}$ = 28 mg/l**

The colony on day 8 of growth
**Fusarium solani** (Mart.) Sacc.

EC$_{50}$ = 8,3 mg/l

The colony on day 7 of growth
Colletotrichum coccodes (Wallr.) S. Hughes

$EC_{50} = 6,6 \text{ mg/l}$

The colony on day 6 of growth
Phytophthora infestans (Mont.) de Bary

\[ EC_{50} = 3.1 \text{ mg/l} \]
Influence of Zerokxe on the germinating of *P. infestans* zoosporangia

Average data for 5 tested isolates
## Comparison of fungicide effectiveness

<table>
<thead>
<tr>
<th></th>
<th>Zeroxxe</th>
<th>EC&lt;sub&gt;50&lt;/sub&gt;, mg/l</th>
<th>Fludioxonil</th>
<th>Pencicuron</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Alternaria alternata</strong></td>
<td></td>
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<tr>
<td><strong>Alternaria solani</strong></td>
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<tr>
<td><strong>Fusarium solani</strong></td>
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<tr>
<td><strong>Colletotrichum coccodes</strong></td>
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<tr>
<td><strong>Rhizoctonia solani</strong></td>
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<tr>
<td><strong>Sclerotinia sclerotiorum</strong></td>
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<tr>
<td><strong>Helminthosporium solani</strong></td>
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</tbody>
</table>

The table shows the EC<sub>50</sub> values for different fungicides against various fungal species. The EC<sub>50</sub> values are measured in mg/l. The results indicate the concentration of silver required to inhibit the growth of the fungi by 50%.
Tests on bacteria
Testing using method of paper discs

<table>
<thead>
<tr>
<th>Concentration</th>
<th><em>Pectobacterium carotovorum</em></th>
<th><em>Dickeya dianthicola</em></th>
<th><em>Agrobacterium tumefaciens</em></th>
<th><em>Xanthomonas vesicatoria</em></th>
<th><em>Clavibacter michiganensis</em></th>
<th><em>Xanthomonas campestris</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>Silver 100 mg/l</td>
<td>8</td>
<td>7</td>
<td>13</td>
<td>8</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>Silver 10 mg/l</td>
<td>1</td>
<td>0</td>
<td>5</td>
<td>1</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Silver 1 mg/l</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
Inhibition of growth of bacteria in liquid

1. Growth of bacteria on agar medium

2. Washout of bacteria

3. Incubation of bacteria with different concentrations of Zeroxxe within 30 min at 22°C

4. Resuspend of 10 mkl (mixed with 40 mkl of sterile water) of liquid after incubation

5. Accounting of the results after 24 hours incubation at 37°C
Inhibition of growth of bacteria in liquid
(30 min incubation)

1. Pectobacterium carotovorum
2. Dickeya dianthicola
3. Agrobacterium tumefaciens
4. Xanthomonas vesicatoria
5. Clavibacter michiganensis
6. Xanthomonas campestris

Bactericidal effect

concentration of silver, mg/l
2014 y. – epidemic of early blight in the Moscow region

Experiment in VNIIF 2014 y.
Application of Zeroxxe
Thank you for your attention!!