Seed Treatments for Improved Tolerance to Biotic and Abiotic stress

DanSeed, March 19, 2019

Dr. Alan Taylor, agt1@cornell.edu
Cornell AgriTech, New York
Global Ag Chemical Industry

Companies with Seed Treatment divisions

- Bayer CropScience
- Syngenta
- BASF
- Monsanto
- Dow Agro Sciences
- Dupont
- FMC
Recent Mergers and Acquisitions in the Global Ag Chemical Industry

Seed Treatment value US$ +4 Billion

• Bayer CropScience + Monsanto now Bayer
• Syngenta – bought by ChemChina
• Dow + Dupont now Corteva
• BASF
• FMC
Divesting Bayer Seed Treatments to BASF as a result of merger with Monsanto

- Poncho (clothianidin) products including Poncho / Votivo. The major corn seed treatment in the US.
- ILeVO that contains the fungicide fluopyram used on soybeans for nematodes and Fusarium virguliforme, causal pathogen of Sudden Death Syndrome (SDS)
Global Biological Seed Treatment Trends

- The global biological seed treatment market is US$700 million in 2017 and is projected to reach more than US$1.2 billion by 2022. CGAR 11%
- Biologicals and Botanicals (fermentation products, natural polymers and derivatives)
- Biopesticides, Biostimulants, Biofertilizers

https://www.marketsandmarkets.com/Market-Reports/biological-seed-treatment-market-162422288.html?gclid=Cj0KCQiA5NPjBRDDARIsAM9X1GJ0-lp8T4c6UE5Cyphq1rR_-F0bHoC76_JJFFAbiAUJRMi3S7HzHq8aAswIwALw_wdB
 Seed Enhancements - post-harvest methods that improve germination or seedling growth, or facilitate the delivery of seeds and other materials required at the time of sowing (Taylor et al., Seed Science Research, 1998)

Seed Coating Technologies
- film coating, encrusting, pelleting

Seed Treatments
- plant protectants, biostimulants, reduce stress

Seed coat permeability and Systemic uptake of seed treatments
Overview of the Agronomic Life Cycle of Seeds

Seed Production and Harvesting

Seed Conditioning

Seed Enhancements

• seed treatment and coating technologies

• other enhancements

Packaging and Storage

Seed Testing – germination and vigor

Sowing and Crop Production
Seed Treatment and Coating Technologies
Seed Coating Components

Liquid – water based system
• Seed coating binders (adhesives)
• Colorants
• Water to provide uniform coverage

Solid particulates – filler material in coating
• < 100 µm
• Inert materials like talc, diatomaceous earth
• Binders can also be solid particulates

• Active ingredients can be added to liquid or solid particulates
• Components can be synthetic for conventional ag, but must be organic for organic crop production
# Seed Coating Technologies

<table>
<thead>
<tr>
<th>Seed Coating Method</th>
<th>Liquid</th>
<th>Solid Particulate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slurry</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Film Coating</td>
<td>x</td>
<td></td>
</tr>
<tr>
<td>Encrusted</td>
<td>x</td>
<td>x</td>
</tr>
<tr>
<td>Pelleting</td>
<td>x</td>
<td>x</td>
</tr>
</tbody>
</table>

- **Slurry / Film coated**
- **Encrusted Seed**
- **Pelleted Seed**
Hemp Seed Treatment and Coating Technologies

Nontreated  Standard coating  New seed coating
Seed Treating and Coating Technology

https://www.youtube.com/watch?v=XLgnpLEJ8MU
Commercial Seed Coating

Smith Seeds, Halsey, OR
Seed Treatment Insecticides

1. Largest value and growth rate of total seed treatment market, followed by seed trt. fungicides

2. Neonicotinoid seed treatments
   - systemic – control below and above ground pests
   - major class of insecticides used on a global basis
     - imidacloprid (Gaucho – BAY)
     - thiamethoxam (Crusier – SYN)
     - clothianidin (Poncho – BASF)

Brian Nault, Cornell AgriTech
Neonicotinoid Seed Treatments

Concerns in the environment and for pest management

1. Honey Bee and Other Insect Pollinators
   • implicated in colony collapse disorder
   • dust off from coated seeds from talc and graphite

2. Resistance management
   • thiamethoxam is converted to clothianidin in plants

3. Need alternate chemistries for efficient early season pest management
United States IR-4 Program

- Facilitates registration of agrochemicals and biopesticides for specialty crops
- Started seed treatment program in 2005
- Selected crop x pest combinations
- Multi-State participation
Other Insecticide Seed Treatments

Research at Cornell, IR-4 and other partners – examined spinosad as an insecticide seed treatment

• Spinosad (Dow AgroSciences – OMRI approved formulation, Entrust)

• Labeled product is Regard on onion for onion maggot control. Compound is not systemic.

Onion maggot, Delia antiqua
Brian Nault, Cornell AgriTech
Seed Treatment Fungicides

- Captan and Thiram – old chemistry
- Metalaxyl and Mefenoxam (Allegiance – BAY and Apron XL – SYN) – first generation new chemistry
- Many new chemistry materials – specific target pathogens

M. R. McDonald, U. Guelph

Onion smut

Urocystis cepulae

M. R. McDonald, U. Guelph
## 2019 IR-4 Hemp Seed Treatment Fungicide Project

<table>
<thead>
<tr>
<th>Product name</th>
<th>Actives</th>
<th>Company</th>
</tr>
</thead>
<tbody>
<tr>
<td>Naturall</td>
<td>Three Trichoderma species</td>
<td>ABM</td>
</tr>
<tr>
<td>Amplitude</td>
<td><em>Bacillus amyloliquifaciens</em></td>
<td>Marrone (MBI)</td>
</tr>
<tr>
<td>Regalia</td>
<td>Extract of <em>Reynoutria sachalinensis</em></td>
<td>Marrone (MBI)</td>
</tr>
<tr>
<td>BioSeed</td>
<td>Five species: 3 <em>Bacillus</em>, 1 <em>Paenibacillus</em>, 1 <em>Trichoderma</em></td>
<td>Ag Biotech</td>
</tr>
<tr>
<td>Prudent 44 + Natrosol</td>
<td>Phosphite + Potassium phosphate</td>
<td>LidoChem</td>
</tr>
<tr>
<td>Varnimo</td>
<td><em>Bacillus amyloliquifaciens</em></td>
<td>LidoChem</td>
</tr>
<tr>
<td>Apron XL + Maxim 4FS</td>
<td>Mefenoxam + Fludioxonil</td>
<td>Syngenta</td>
</tr>
</tbody>
</table>
Prudent/Natrol

Germination 79%
Shoot 5.8 cm *
Root 12.6 cm

Control

Germination 78%
Shoot 4.9 cm
Root 12.8 cm
**Apron/Max 1.0 X**

Germination 85% *
Shoot 5.6 cm *
Root 14.5 cm *

**Control**

Germination 78%
Shoot 4.9 cm
Root 12.8 cm

Cornell University
College of Agriculture and Life Sciences
Amplitude + Regalia

Germination 64% *
Shoot 5.0 cm
Root 12.4 cm

Control

Germination 78% 
Shoot 4.9 cm 
Root 12.8 cm
2019 IR-4 Hemp Seed Treatment Fungicide Project – Field Test Locations

Map showing locations: NDSU, Cornell, VA Tech.
Biostimulants as Seed Treatments

Plant biostimulants - broad class of substances and microorganisms that enhance plant growth

Categories of biostimulants:

- **Protein hydrolysates and amino acids**
  
  Seed coating: (Animal-based protein-Wilson et al. 2018); (Plant-based protein-Amirkhani et al. 2016)

- **Microbial inoculants**
  
  Seed coating: (Ying Ma et al. (2019) Agronomy 2019, 9, 33)

- **Humic acid and fulvic acid**

- **Seaweed extracts**
  Seed treatment: (Michalak et al. 2017 Appl. Sci.)
Summary of main key mechanisms targeted by carbohydrate-, protein-, amino acid-, and lipid-based biostimulants

**Biostimulant Effect of Soy flour and Micronized Vermicompost Applied as a Seed Coating Blend**

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Control</th>
<th>SF+DE</th>
<th>SF+DE+CVE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF + DE (30:70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF + DE (30:70) + CVE liquid</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF+ MVC-1 (30:70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF + MVC-2 (30:70)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SF + MVC-3 (30:70)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- SF – soy flour, dry binder
- DE – diatomaceous earth
- CVE – conc. vermicompost extract
- MVC-1 – vermicompost - original
- MVC-2 – vermicompost - WormPower
- MVC-3 – vermicompost – Terra Vesco
## Nitrogen Composition of Seed Coating Materials

<table>
<thead>
<tr>
<th>Materials</th>
<th>N %</th>
<th>Protein %</th>
<th>NH$_4$ µg/g</th>
<th>NO$_3$+NO$_2$ µg/g</th>
</tr>
</thead>
<tbody>
<tr>
<td>MVC-1</td>
<td>3.2</td>
<td>6.38</td>
<td>199</td>
<td>6,560</td>
</tr>
<tr>
<td>MVC-2</td>
<td>3.6</td>
<td>7.15</td>
<td>93</td>
<td>6,812</td>
</tr>
<tr>
<td>MVC-3</td>
<td>2.6</td>
<td>7.17</td>
<td>20</td>
<td>3,442</td>
</tr>
<tr>
<td>CVE</td>
<td>-</td>
<td>-</td>
<td>3.4 mg/L</td>
<td>557 mg/L</td>
</tr>
<tr>
<td>Soy Flour</td>
<td>8.0</td>
<td>53.0</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Research Question: Do the seed coatings serve as a Nitrogen fertilizer or do they act as a Biostimulant?
## Broccoli Germination and Seedlings Growth Characteristics

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Gmax (%)</th>
<th>GU (h)</th>
<th>T50 (h)</th>
<th>Shoot (cm)</th>
<th>Root (cm)</th>
<th>Seedling Vigor Index</th>
<th>Dry weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>98 A</td>
<td>22 A</td>
<td>36 A</td>
<td>2.7 D</td>
<td>9.3 B</td>
<td>11.8 D</td>
<td>0.308 C</td>
</tr>
<tr>
<td>SF + DE</td>
<td>97 A</td>
<td>24 A</td>
<td>37 A</td>
<td>4.0 C</td>
<td>11.0 A</td>
<td>14.5 C</td>
<td>0.397 B</td>
</tr>
<tr>
<td>SF + DE + CVE</td>
<td>98 A</td>
<td>22 A</td>
<td>36 A</td>
<td>4.5 B</td>
<td>11.1 A</td>
<td>15.3 B</td>
<td>0.380 B</td>
</tr>
<tr>
<td>SF + MVC-1</td>
<td>96 A</td>
<td>22 A</td>
<td>36 A</td>
<td>5.8 A</td>
<td>10.9 A</td>
<td>16.0 A</td>
<td>0.440 A</td>
</tr>
<tr>
<td>SF + MVC-2</td>
<td>97 A</td>
<td>23 A</td>
<td>36 A</td>
<td>5.4 A</td>
<td>11.5 A</td>
<td>16.4 A</td>
<td>0.420 A</td>
</tr>
<tr>
<td>SF + MVC-3</td>
<td>98 A</td>
<td>24 A</td>
<td>36 A</td>
<td>5.5 A</td>
<td>11.0 A</td>
<td>16.2 A</td>
<td>0.420 A</td>
</tr>
</tbody>
</table>

Gmax = Total Germination (%)  
GU = Germination Uniformity (h) \([T_{90}-T_{10}]\)  
T50 = Time to reach to 50% of germination (h) [Germination rate]  
SVI = \(\frac{\text{Gmax}}{100} \times \text{Seedling length}\)
<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>SF+DE</th>
<th>SF+DE+CVE</th>
<th>SF+MVC-2</th>
<th>SF+MVC-3</th>
<th>SF+MVC-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shoot (cm)</td>
<td>2.7</td>
<td>4.0</td>
<td>4.5</td>
<td>5.4</td>
<td>5.5</td>
<td>5.8</td>
</tr>
<tr>
<td>Root (cm)</td>
<td>9.3</td>
<td>11.0</td>
<td>11.1</td>
<td>11.5</td>
<td>11.0</td>
<td>10.9</td>
</tr>
</tbody>
</table>

**Broccoli Seedling length (Shoot and Root in cm)**
<table>
<thead>
<tr>
<th>Treatment</th>
<th>Shoot Dry Wt (g)</th>
<th>Root Dry Wt (g)</th>
<th>Total Leaf Area (cm²)</th>
<th>% Plants with 6 Leaves</th>
<th>SPAD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>1.27 B</td>
<td>0.539 B</td>
<td>249 B</td>
<td>4 C</td>
<td>50.0 C</td>
</tr>
<tr>
<td>SF+DE</td>
<td>1.82 A</td>
<td>0.714 AB</td>
<td>292 A</td>
<td>68 B</td>
<td>55.4 B</td>
</tr>
<tr>
<td>SF+MVC-2</td>
<td>1.82 A</td>
<td>0.817 A</td>
<td>304 A</td>
<td>84 A</td>
<td>58.0 A</td>
</tr>
</tbody>
</table>
Enhanced nitrogen uptake per plant (30 day old plants), and applied nitrogen per coated seed

Enhanced N uptake per plant (mg)

N applied per coated seed (mg)

<table>
<thead>
<tr>
<th>SF + DE</th>
<th>SF + MVC</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.05</td>
<td>0.103</td>
</tr>
</tbody>
</table>
Seed Coatings with Hydrophilic additives

Cover Crop Seed Technology - Red Clover

4:1 Exceed 1:1 Exceed Control 1:1 Hydroloc 4:1 Hydroloc
Greenhouse Test to Simulate Drought Stress after Planting

Sow seeds at 90% soil moisture content

Seal system at 58-60% soil moisture content
Plant day 0 and sealed day 2\textsuperscript{ed} Picture taken 4 days after planting
Stockosorb, cross-linked polyacrylate. Absorbs water instantly and makes a clear gel.
19% coatings show gel

24% coatings show gel
Red Clover Seeds Coated with SAP (Hydrophilic Polymer) less than 325 mesh
Systemic Seed Treatments for Early Season Pest Management
Systemic Movement in Plants

Labeled thiamethoxam uptake in cucumber leaves

application on soil
normal soil condition

Syngenta

Imidacloprid movement in cotton leaves

Bayer

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Fluorescent Tracers for Cornell Seed Treatment Uptake Research

- Coumarin uptake in soybeans
- Rhodamine B uptake in snap beans
- Fluorescein blocked in Tomato seed
Soybean (same as Phaseolus)

Both Coumarin 151 (nonionic) and Rhodamine B (ionic) diffuse through the seed coat

Permeable Seed Coat Characteristic

Coumarin uptake
Soybean Seeds Treated with Selected Fluorescent Tracers

C = Coumarin
Corn, Switchgrass, Onion, Tomato and Pepper Seeds

Only Coumarin diffuses through the seed coat, but Rhodamine does not till the root is emerged -

Selective Permeable Seed Coat Characteristic
Neither Coumarin nor Rhodamine diffuses through the seed coat.

Non-Permeable Seed Coat Characteristic
# Seed Coat Permeability Characteristics of Selected Crop Seeds

<table>
<thead>
<tr>
<th>Vegetable Crop Seed</th>
<th>Seed Coat Permeability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soybean and Snap bean</td>
<td>Permeable</td>
</tr>
<tr>
<td>Field and Sweet corn</td>
<td>Selective permeability</td>
</tr>
<tr>
<td>Switchgrass</td>
<td>Selective permeability</td>
</tr>
<tr>
<td>Onion, Hemp (2018)</td>
<td>Selective permeability</td>
</tr>
<tr>
<td>Tomato and Pepper</td>
<td>Selective permeability</td>
</tr>
<tr>
<td>Lettuce</td>
<td>Non-permeable</td>
</tr>
<tr>
<td>Cucumber</td>
<td>Non-permeable</td>
</tr>
</tbody>
</table>

Salanenka and Taylor, 2009 and 2011 and Dias et al., 2014
# Seed Coat Permeability Test

## Embryo staining results

<table>
<thead>
<tr>
<th>Coumarin (nonionic)</th>
<th>Rhodamine B (ionic)</th>
<th>Seed Coat Permeability Characteristic</th>
</tr>
</thead>
<tbody>
<tr>
<td>+</td>
<td>+</td>
<td>Permeable</td>
</tr>
<tr>
<td>+</td>
<td>-</td>
<td>Selective permeability</td>
</tr>
<tr>
<td>-</td>
<td>-</td>
<td>Non-permeable</td>
</tr>
</tbody>
</table>
Why Understanding Seed Coat Permeability is Essential – Eradicate Seed-Borne Pathogens

Xanthomonas spp.
The Bigger Story

People have soaked seeds in water containing chemicals for centuries with the goal that these chemicals get into the seed and to the embryo of that seed.

Seed Soak
The Bigger Story

People have soaked seeds in water containing chemicals for centuries with the goal that these chemicals get into the seed and to the embryo of that seed.

**Conclusion** – seed uptake depends on the **chemical nature of the compound** and the **crop seed**, whether a chemical will diffuse through the seed coat or be blocked.
Uptake of Seed Treatments

Chemical nature: Nonionic vs Ionic

Molecular size < 500 MW
Acknowledgements

Dr. Masi Amirkhani, Biostimulant and SAP seed coating

Questions?