

Seed Science and Technology

Seed Treatments for Improved

Tolerance to Biotic and Abiotic stress

DanSeed, March 19, 2019

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Cornell AgriTech, New York



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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_JJFFAbiAUJRMI3S7HfHq8aAswIEALw_wcB



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

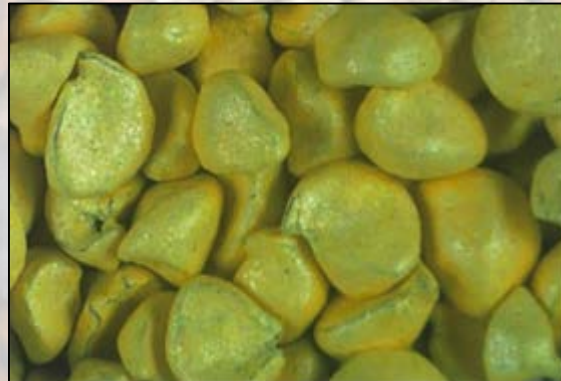


Seed Coating Technologies

<u>Seed Coating Method</u>	<u>Liquid</u>	<u>Solid Particulate</u>
Slurry	x	
Film Coating	x	
Encrusted	X	x
Pelleting	X	X



Slurry / Film coated



Encrusted Seed



Pelleted Seed



Hemp Seed Treatment and Coating Technologies



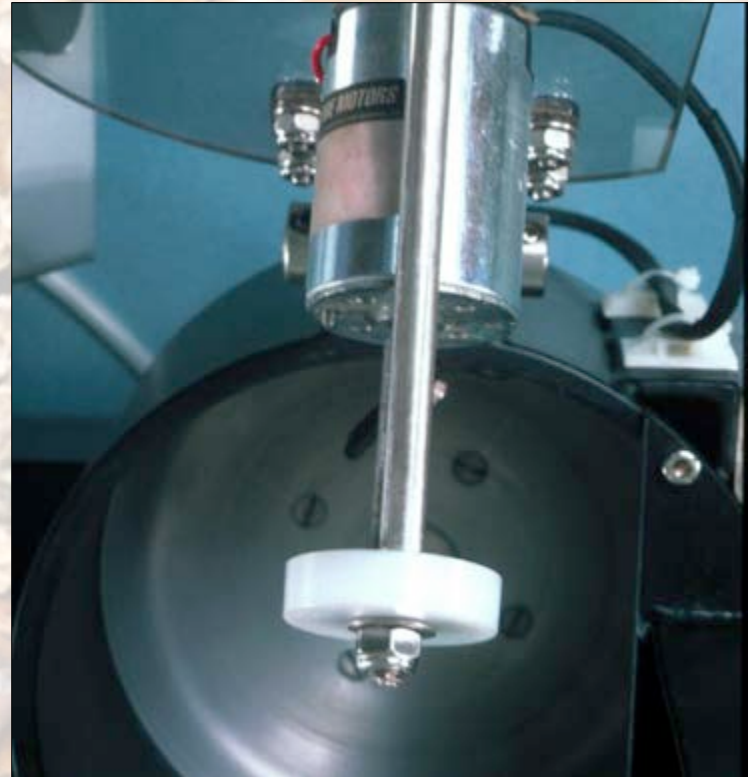
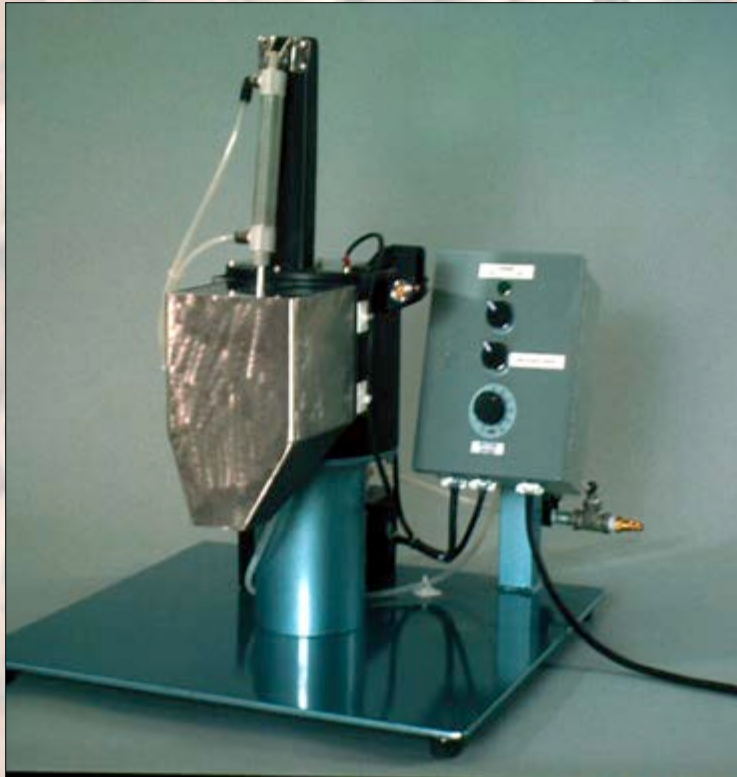
Nontreated

Standard coating

New seed coating



Seed Treating and Coating Technology



<https://www.youtube.com/watch?v=XIgnpLEJ8MU>



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Commercial Seed Coating



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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)



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**



Seed Treatment Application

Cornell AgriTech – Geneva, NY

IR-4

The diagram features a central text 'IR-4' surrounded by three purple lines that form a triangle. The bottom-left vertex of the triangle is labeled 'Seed Treatment Industry', the bottom-right vertex is labeled 'Field Efficacy Univ. Programs', and the top vertex is connected to a vertical purple line extending upwards towards the title area.

**Seed Treatment
Industry**

**Field Efficacy
Univ. Programs**

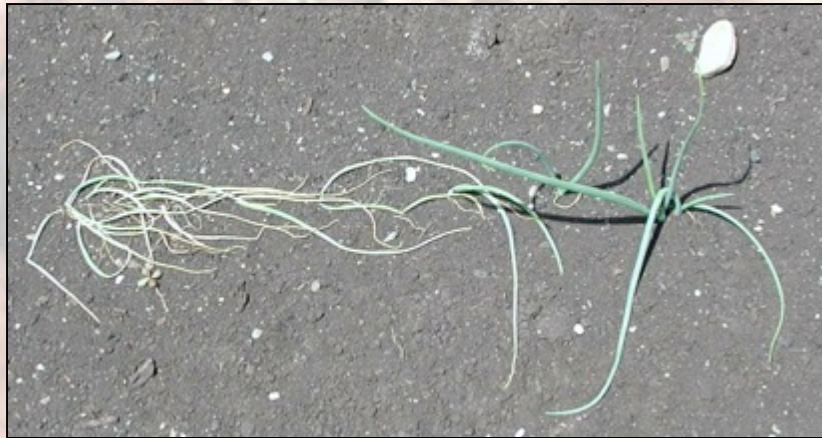


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Other Insecticide Seed Treatments

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,

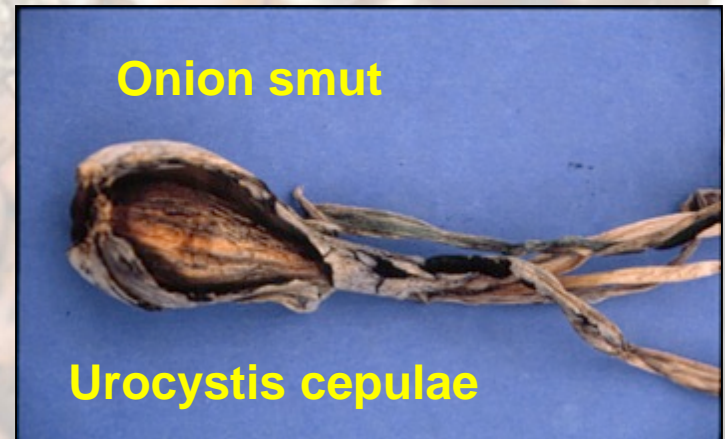
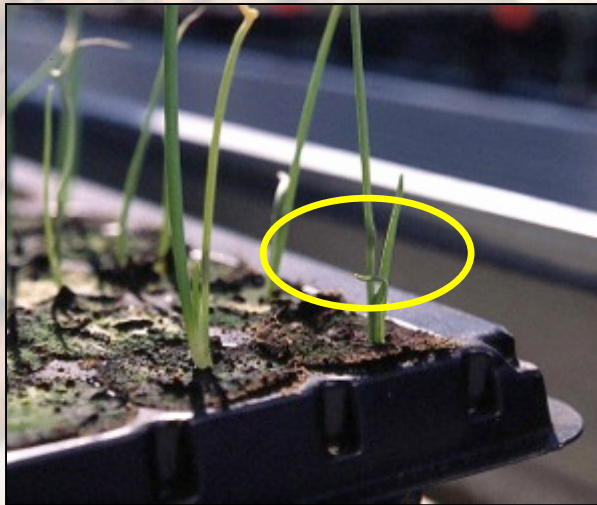
Delia antiqua

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



2019 IR-4 Hemp Seed Treatment Fungicide Project

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



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

CONTROL



Germination 78%
Shoot 4.9 cm
Root 12.8 cm



Amplitude + Regalia

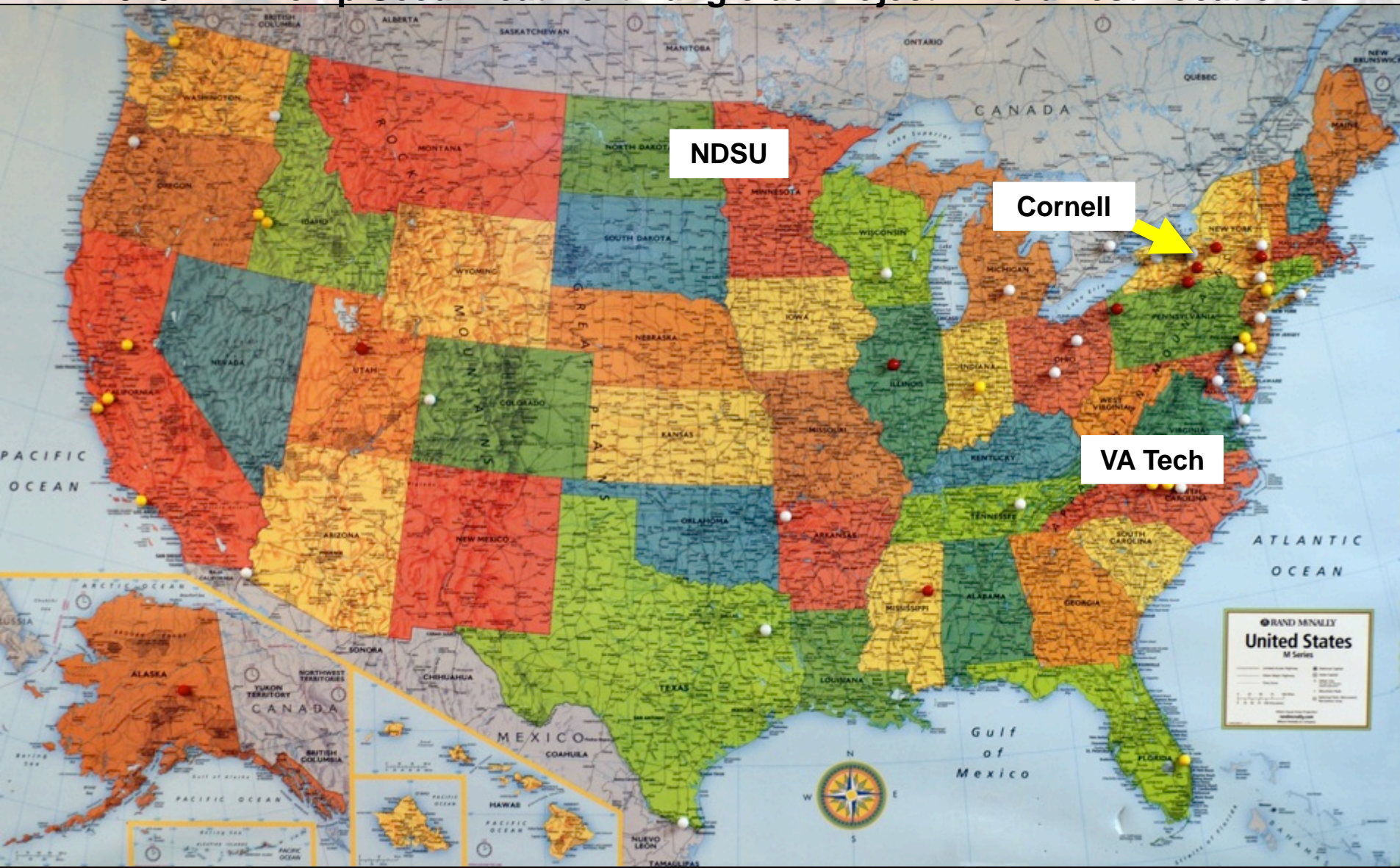
Germination 64% *
Shoot 5.0 cm
Root 12.4 cm

Control

Germination 78%
Shoot 4.9 cm
Root 12.8 cm



2019 IR-4 Hemp Seed Treatment Fungicide Project – Field Test Locations



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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**

Seed treatment: (Harwigsen and Evans (2000) *HORTSCIENCE*, 35, 1231–1233.

- **Seaweed extracts**

Seed treatment: (Michalak *et al.* 2017 *Appl. Sci.*)

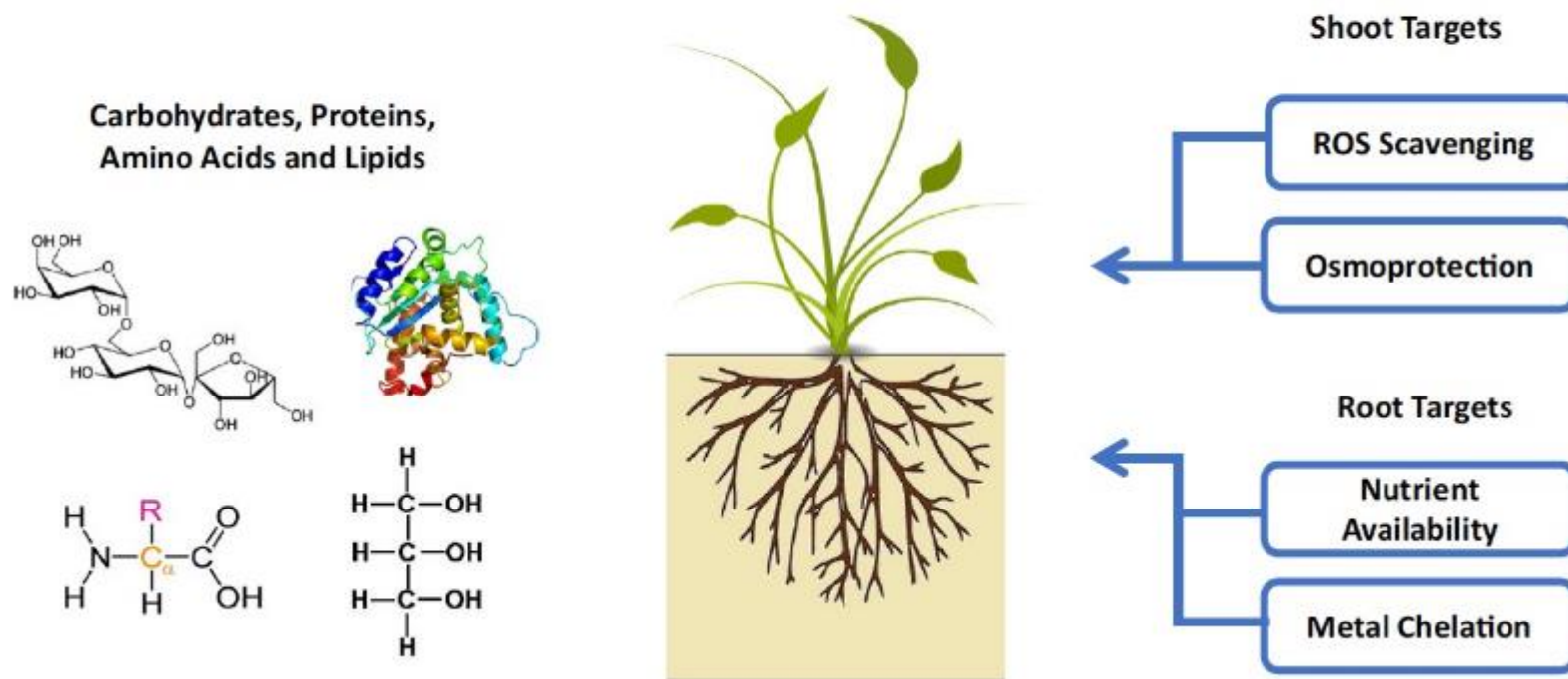


plant **biostimulant**



Summary of main key mechanisms targeted by carbohydrate-, protein-, amino acid-, and lipid-based biostimulants

KEY MECHANISMS TARGETED BY CARBOHYDRATES, PROTEINS, AMINO ACIDS AND LIPIDS BASED BIOSTIMULANTS



Van Oosten et al. Chem. Biol. Technol. Agric. (2017) 4:5 DOI 10.1186/s40538-017-0089-5



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

Treatments

Control

SF + DE (30:70)

SF + DE (30:70) + CVE liquid

SF+ MVC-1 (30:70)

SF + MVC-2 (30:70)

SF + MVC-3 (30:70)

Control

SF+DE

SF+DE+CVE



SF+MVC-1

SF+ MVC-2

SF+ MVC-3

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



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Nitrogen Composition of Seed Coating Materials

Materials	N %	Protein %	NH ₄ µg/g	NO ₃ +NO ₂ µg/g
MVC-1	3.2	6.38	199	6,560
MVC-2	3.6	7.15	93	6,812
MVC-3	2.6	7.17	20	3,442
CVE	-	-	3.4 mg/L	557 mg/L
Soy Flour	8.0	53.0	-	-

Research Question: Do the seed coatings serve as a Nitrogen fertilizer or do they act as a Biostimulant?



Broccoli Germination and Seedlings Growth Characteristics

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

Gmax = Total Germination (%)

GU = Germination Uniformity (h) $[T_{90}-T_{10}]$

T50 = Time to reach to 50% of germination (h) [Germination rate]

SVI = $Gmax/100 \times$ Seedling length



Broccoli Seedling length (Shoot and Root in cm)

Control

2.7

SF+DE

4.0

SF+DE+CVE

4.5

SF+MVC-2

5.4

SF+MVC-3

5.5

SF+MVC-1

5.8



9.3

11.0

11.1

11.5

11.0

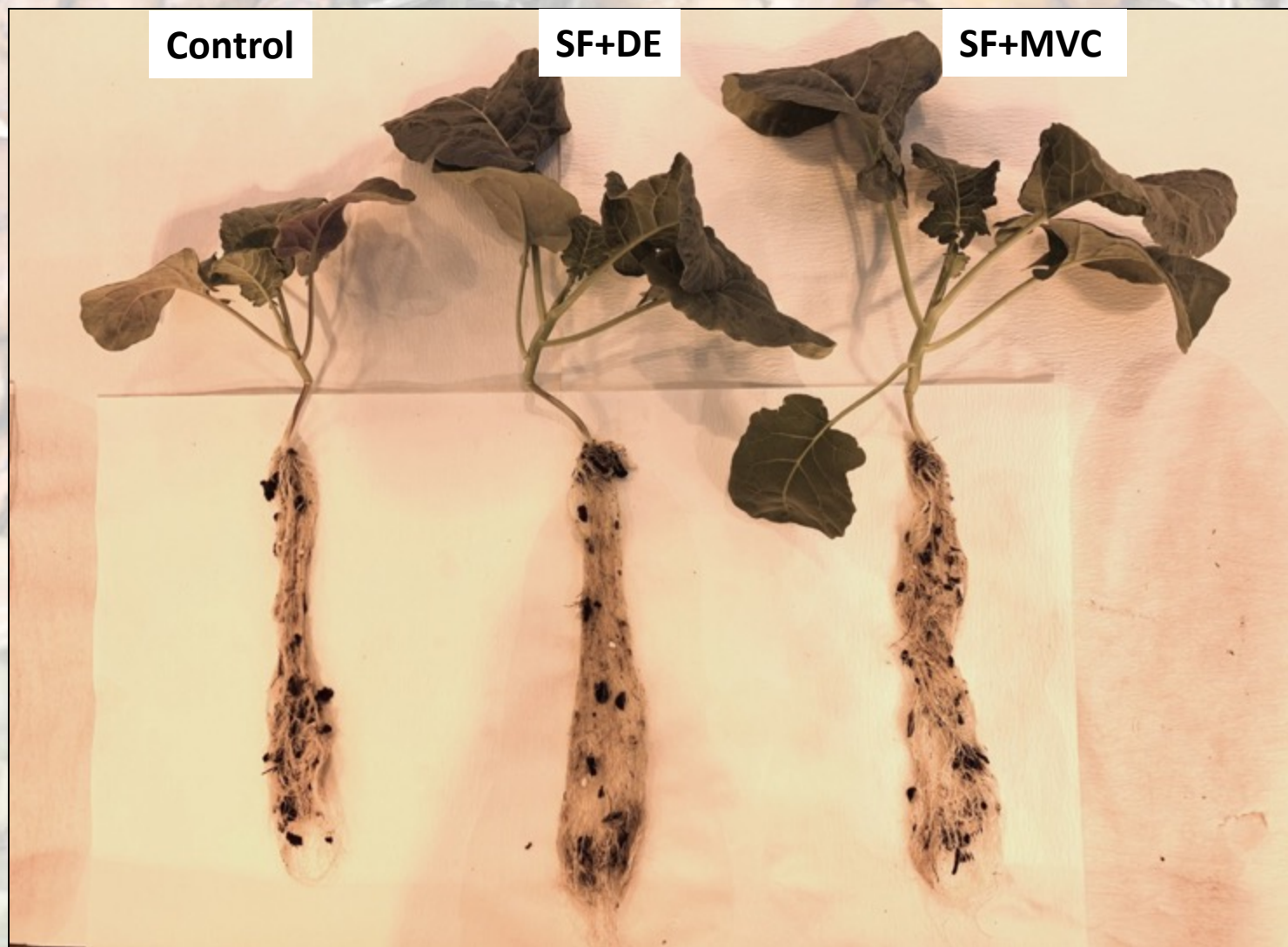
10.9



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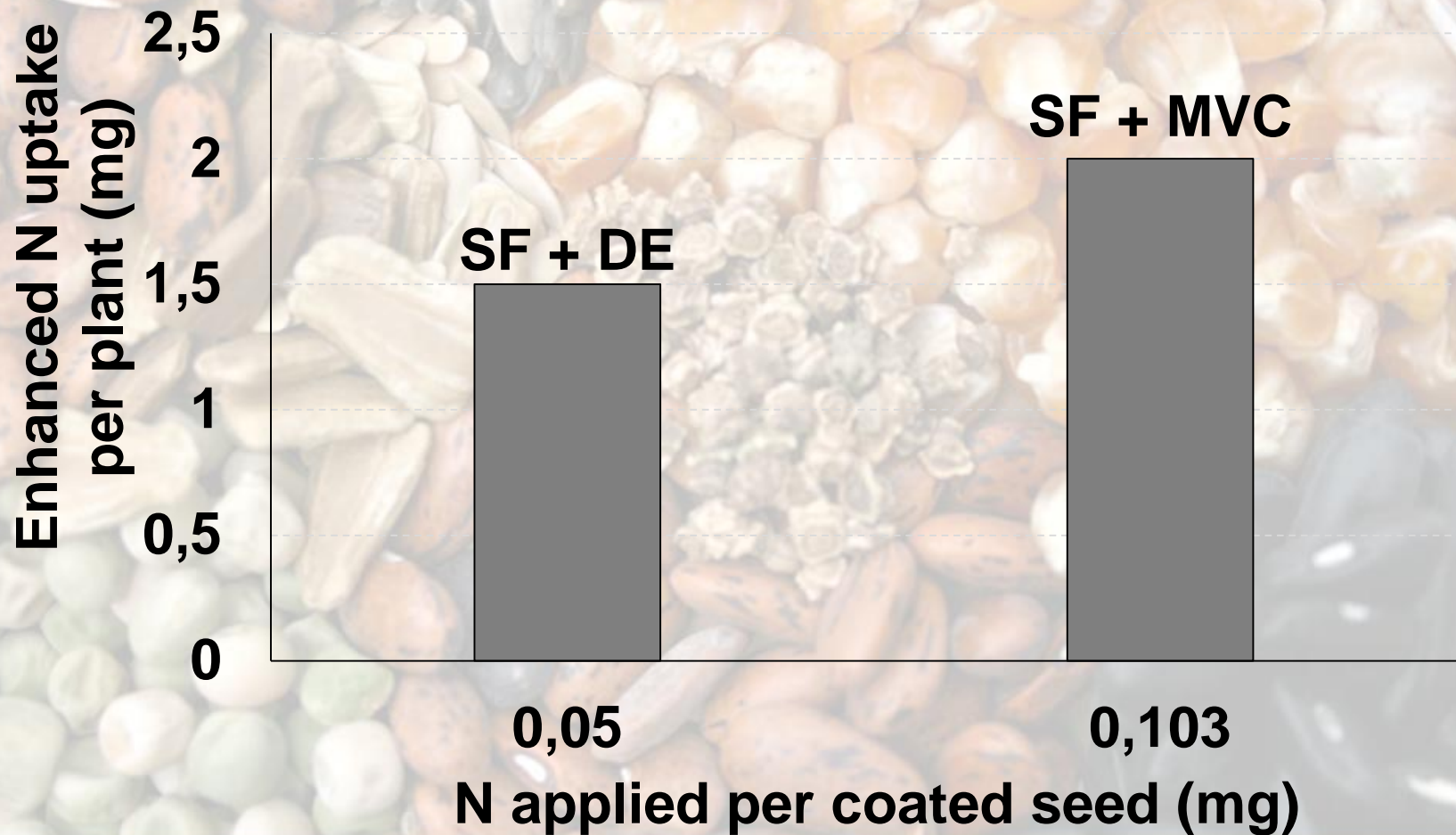


Treatment	Shoot Dry Wt (g)	Root Dry Wt (g)	Total Leaf Area (cm ²)	% Plants with 6 Leaves	SPAD
Control	1.27 B	0.539 B	249 B	4 C	50.0 C
SF+DE	1.82 A	0.714 AB	292 A	68 B	55.4 B
SF+MVC-2	1.82 A	0.817 A	304 A	84 A	58.0 A



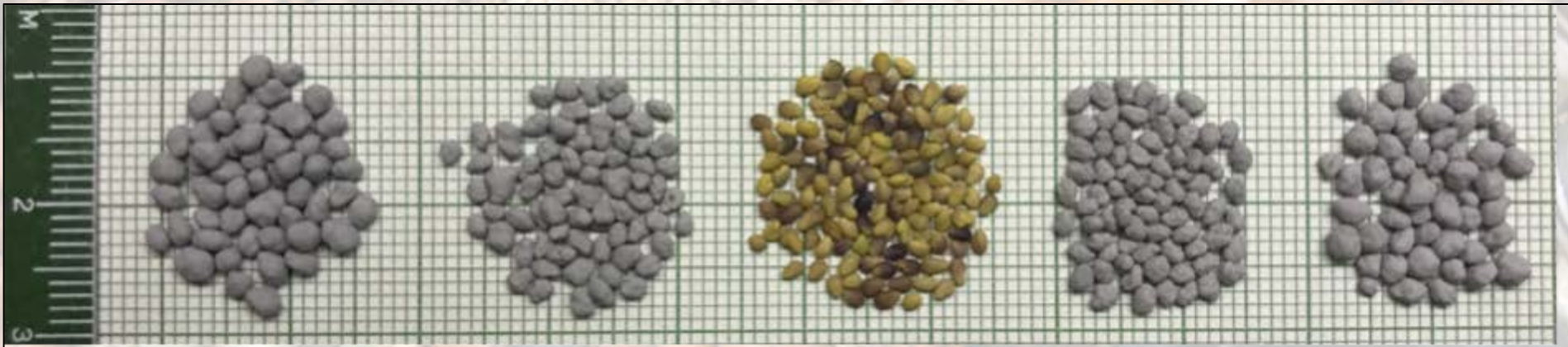
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Enhanced nitrogen uptake per plant (30 day old plants), and applied nitrogen per coated seed



Seed Coatings with Hydrophilic additives

Cover Crop Seed Technology - Red Clover



4:1 Exceed

1:1 Exceed

Control

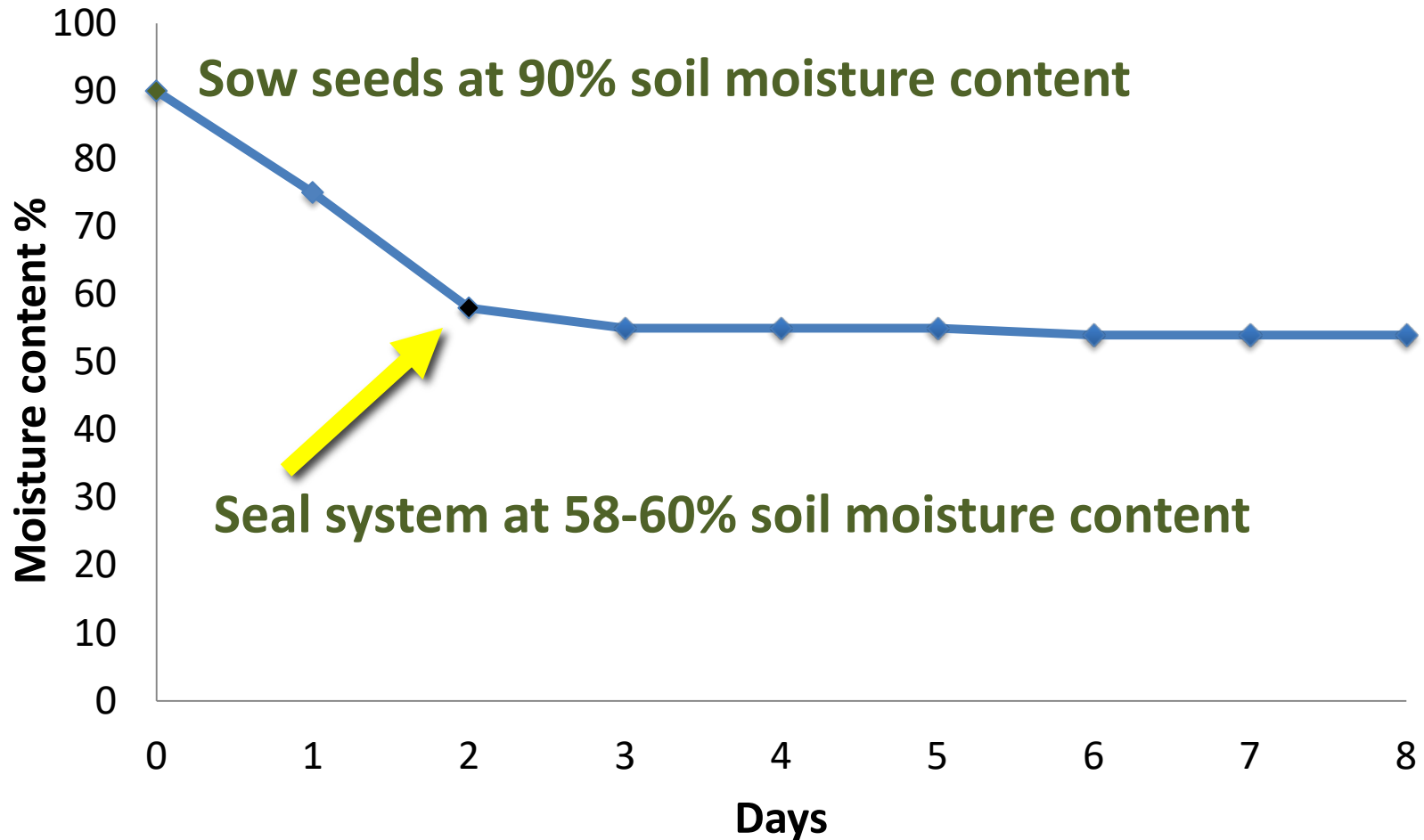
1:1 Hydroloc

4:1 Hydroloc

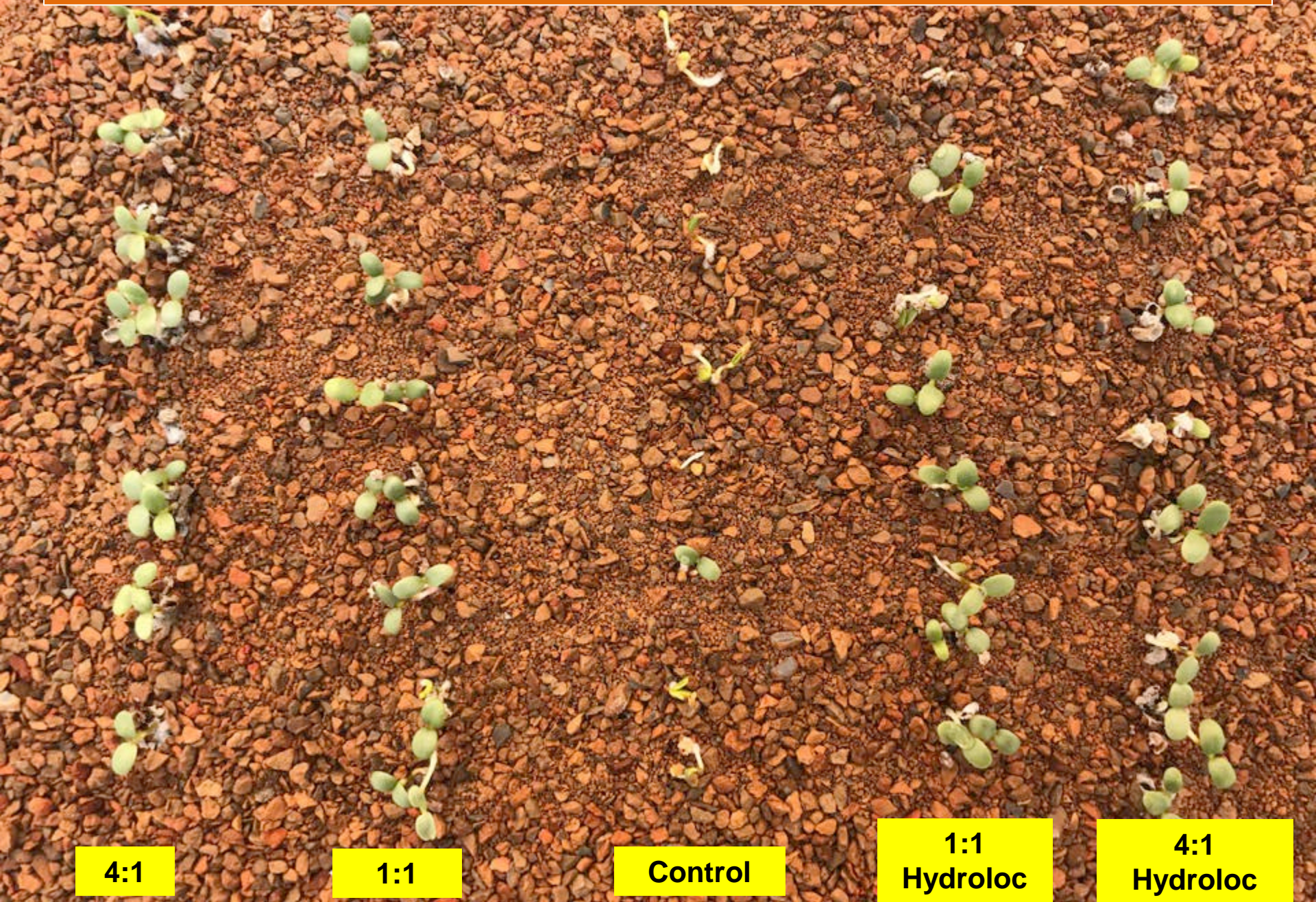


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Greenhouse Test to Simulate Drought Stress after Planting



Plant day 0 and sealed day 2^{ed} — Picture taken 4 days after planting



4:1

1:1

Control

**1:1
Hydroloc**

**4:1
Hydroloc**

Stockosorb, cross-linked polyacrylate. Absorbs water instantly and makes a clear gel



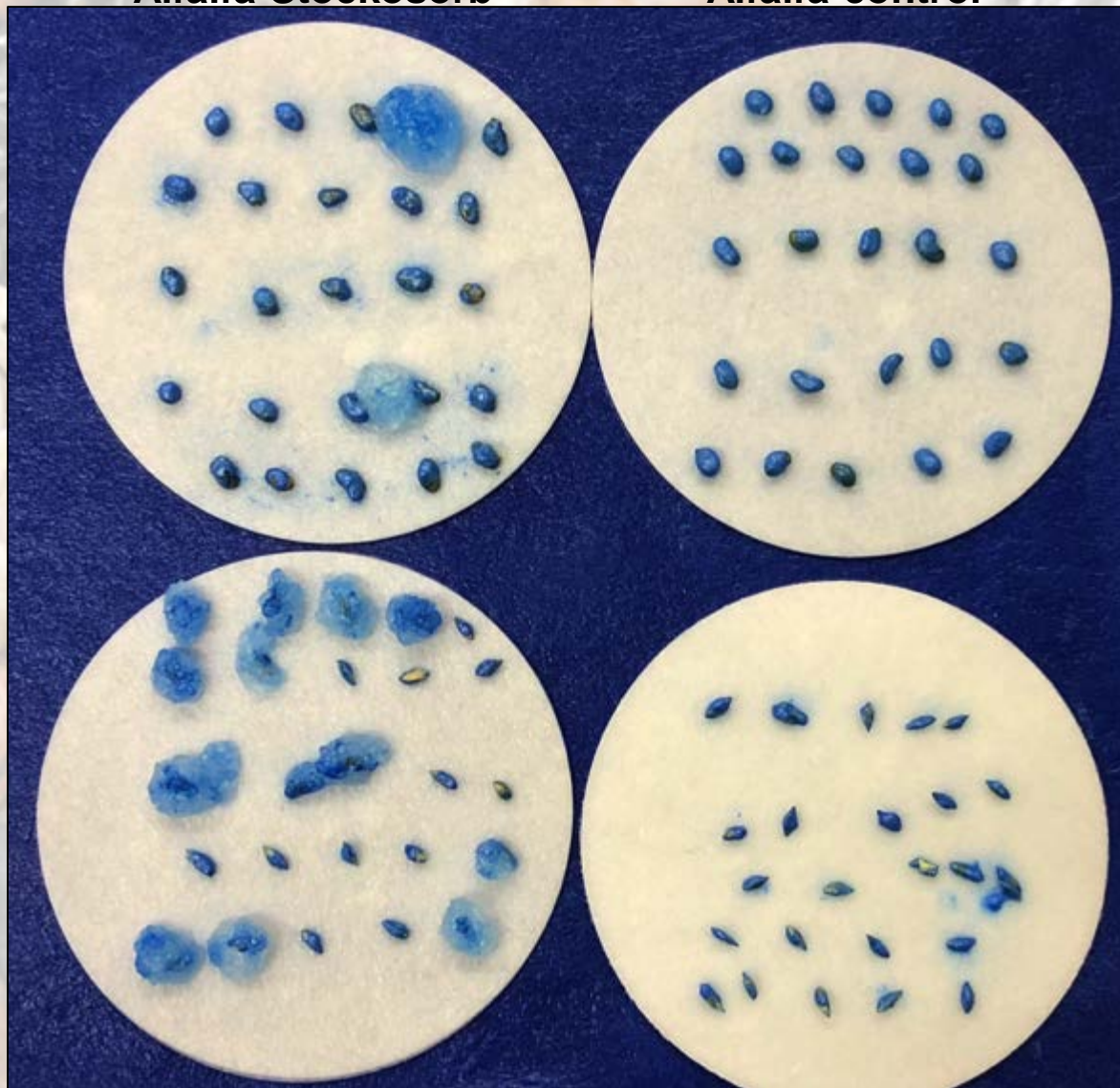
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**19% coatings
show gel**

**24% coatings
show gel**

Alfalfa Stockosorb

Alfalfa-control



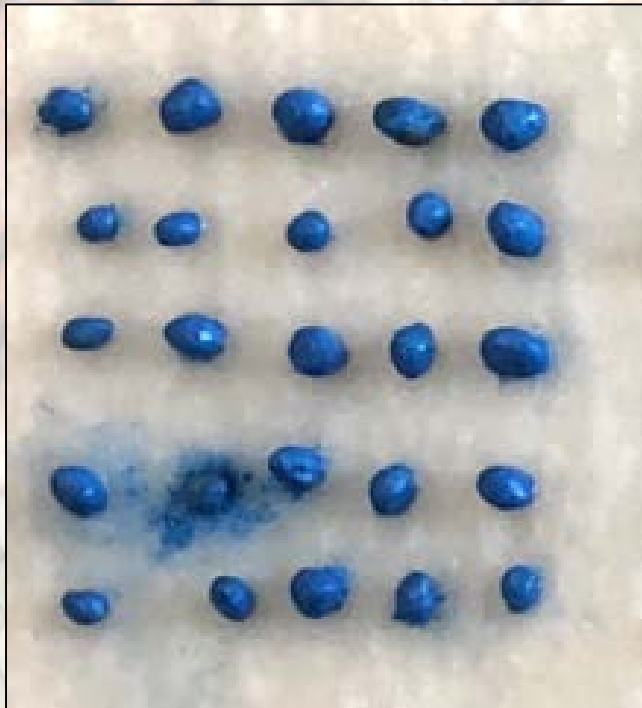
**Bermudagrass
Stockosorb**

**Bermudagrass
- control**

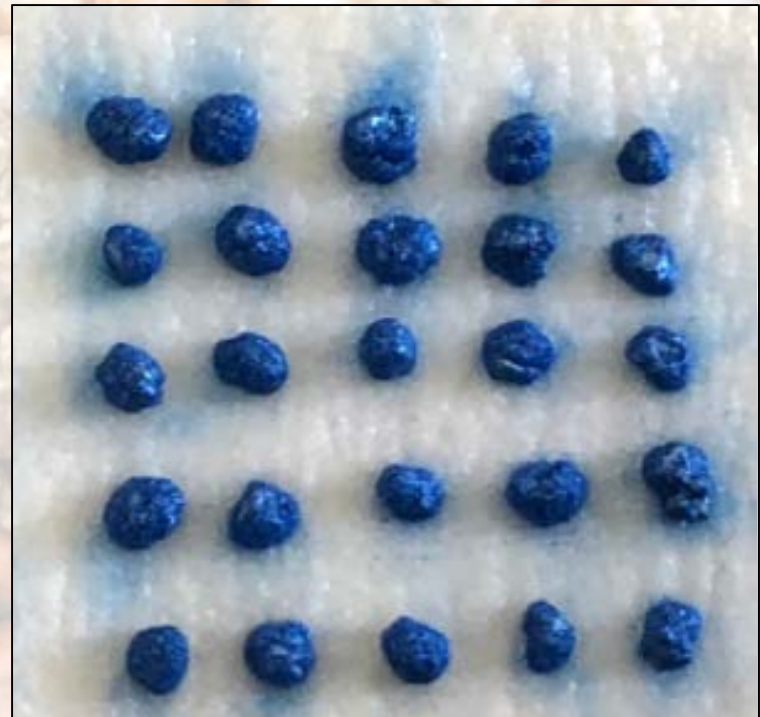


Red Clover Seeds Coated with SAP (Hydrophilic Polymer) less than 325 mesh

Coating control



Coating + SAP



Systemic Seed Treatments for Early Season Pest Management

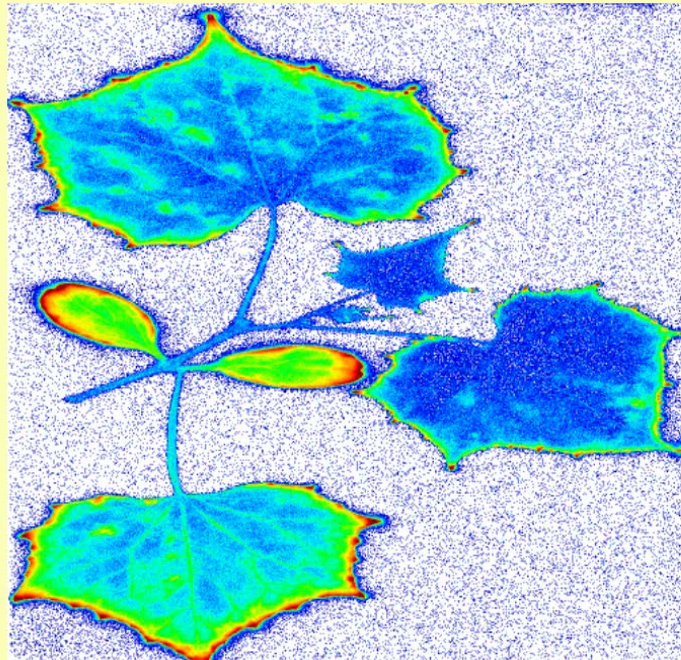


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Systemic Movement in Plants

Labeled thiamethoxam uptake in cucumber leaves

application on soil
normal soil condition

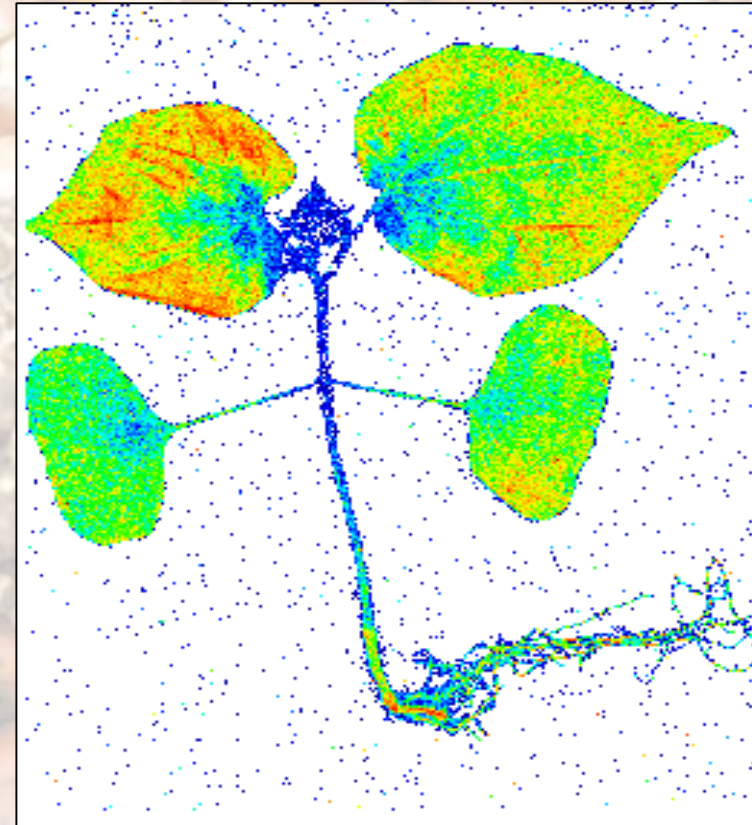


low

high

Syngenta

Imidacloprid movement in cotton leaves



Bayer



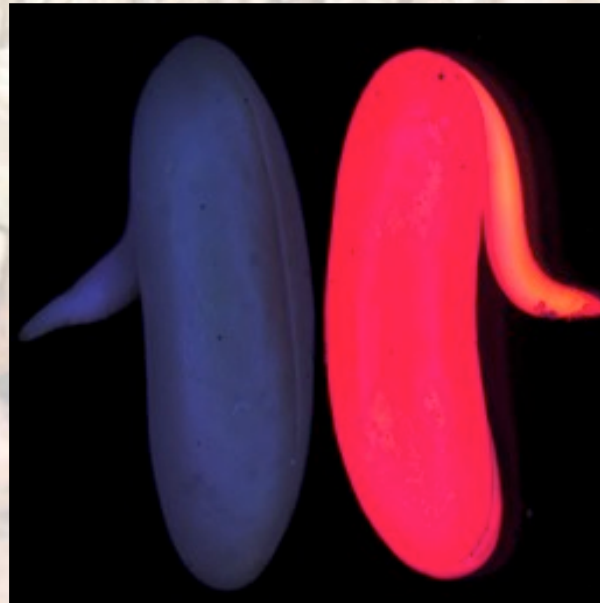
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Fluorescent Tracers for Cornell Seed Treatment Uptake Research

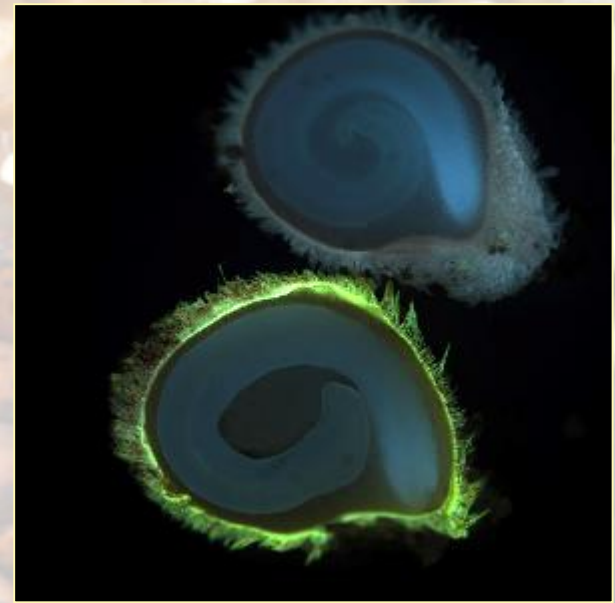
**Coumarin uptake
in soybeans**



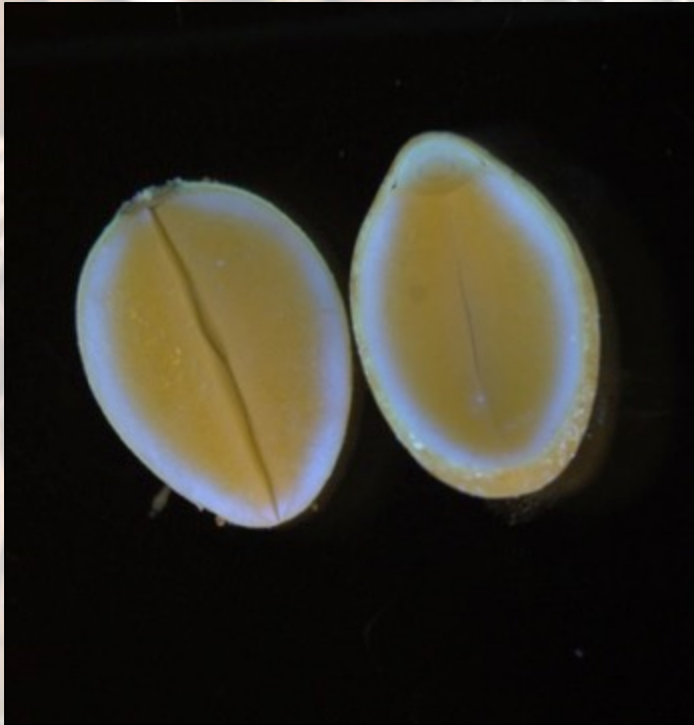
**Rhodamine B uptake
in snap beans**



**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

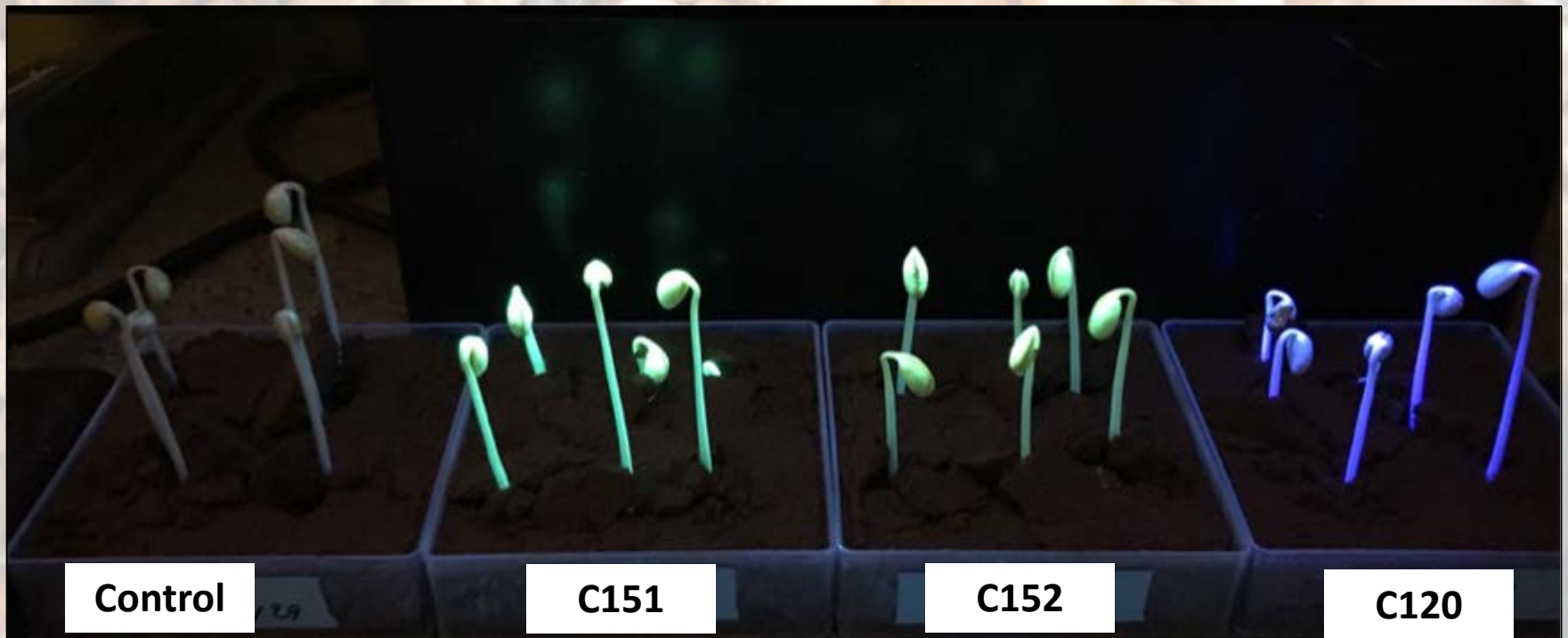
Coumarin uptake



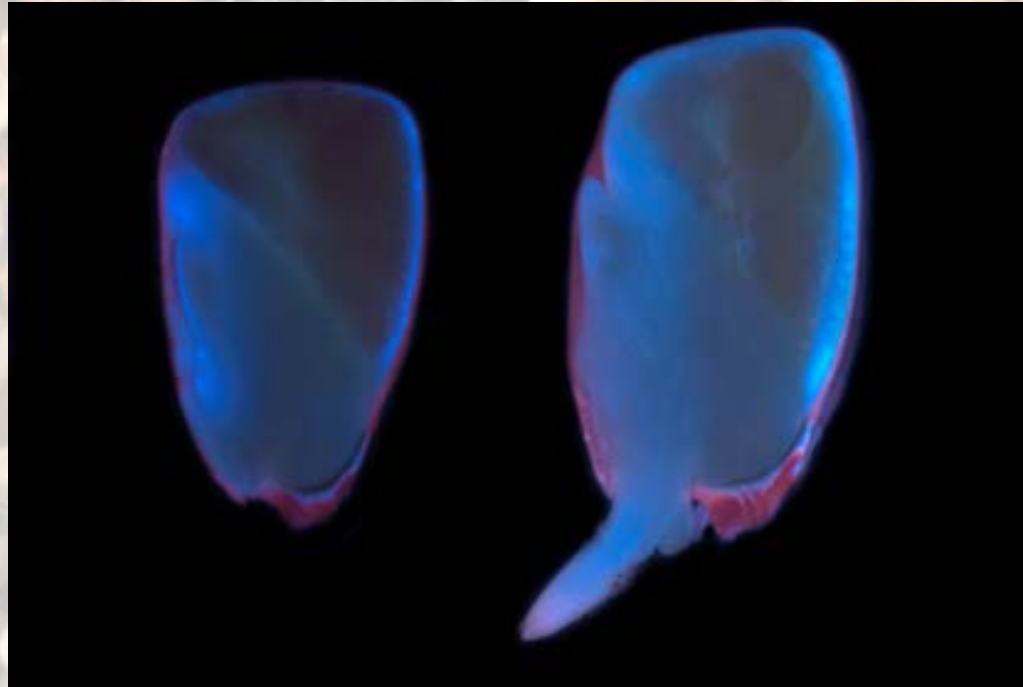
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Soybean Seeds Treated with Selected Fluorescent Tracers

C = Coumarin



Corn, Switchgrass, Onion, Tomato and Pepper Seeds



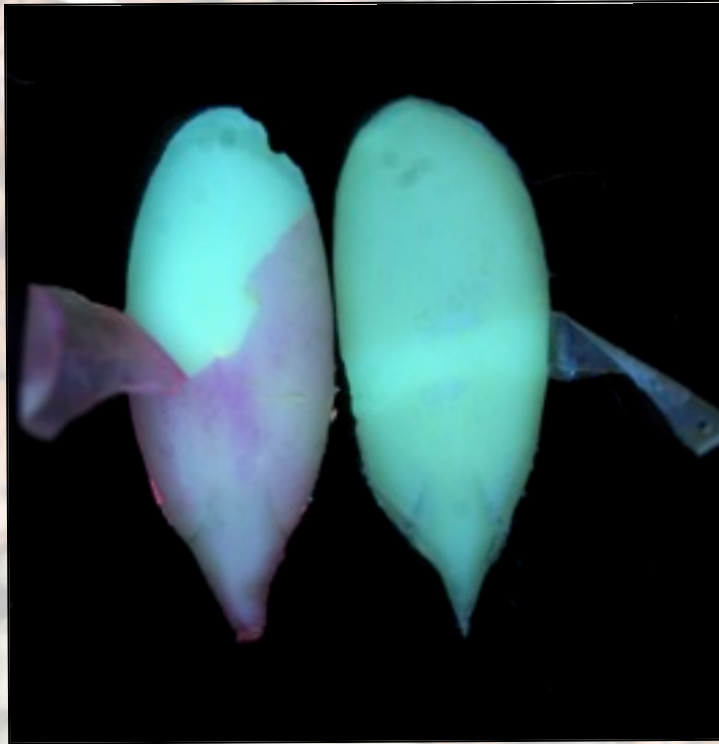
Only Coumarin diffuses through the seed coat, but Rhodamine does not till the root is emerged -

Selective Permeable Seed Coat Characteristic



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Cucumber



**Neither Coumarin nor
Rhodamine diffuses
through the seed coat**

**Non-Permeable Seed
Coat Characteristic**

Rhodamine staining



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Seed Coat Permeability Characteristics of Selected Crop Seeds

Vegetable Crop Seed	Seed Coat Permeability
Soybean and Snap bean	Permeable
Field and Sweet corn	Selective permeability
Switchgrass	Selective permeability
Onion, Hemp (2018)	Selective permeability
Tomato and Pepper	Selective permeability
Lettuce	Non-permeable
Cucumber	Non-permeable

Salanenka and Taylor, 2009 and 2011 and Dias et al., 2014



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Seed Coat Permeability Test

Embryo staining results

Coumarin
(nonionic)

+

+

-

Rhodamine B
(ionic)

+

-

-

Seed Coat Permeability
Characteristic

Permeable

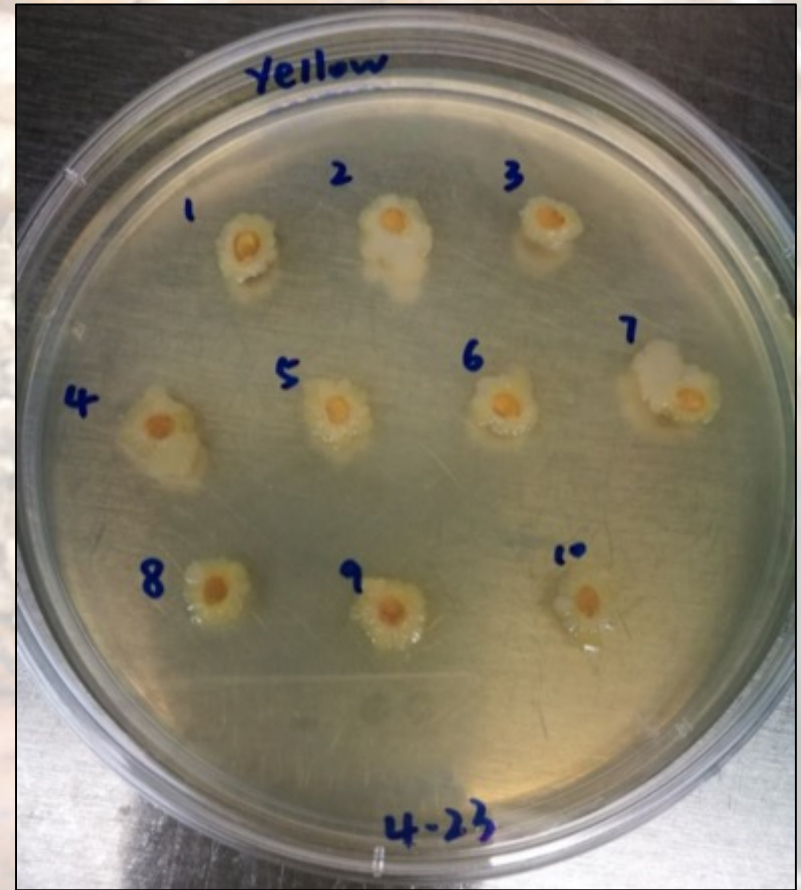
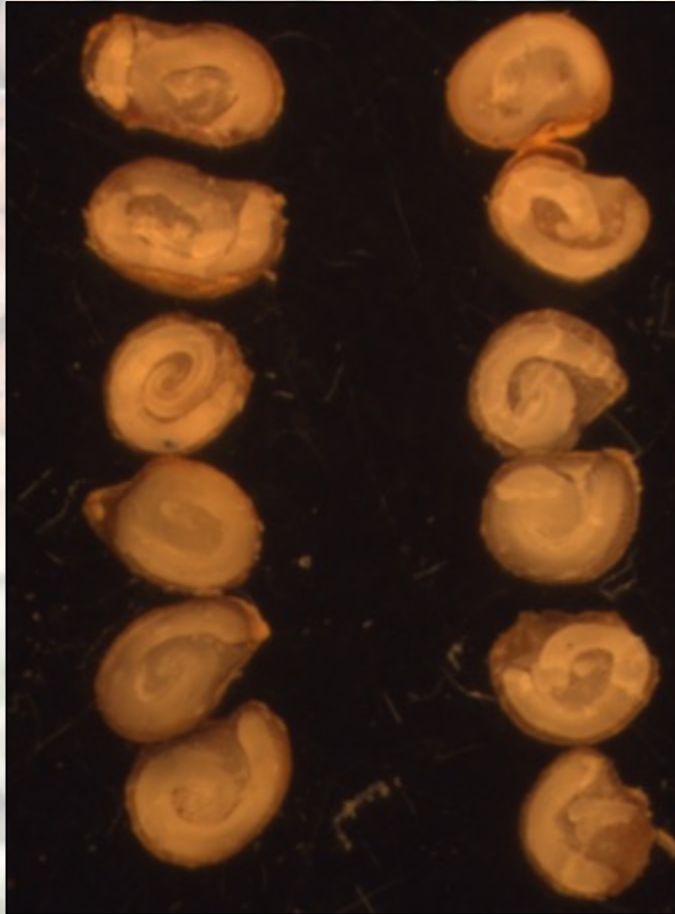
Selective permeability

Non-permeable



Why Understanding Seed Coat Permeability is Essential – Eradicate Seed-Borne Pathogens

Xanthomonas spp.



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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.

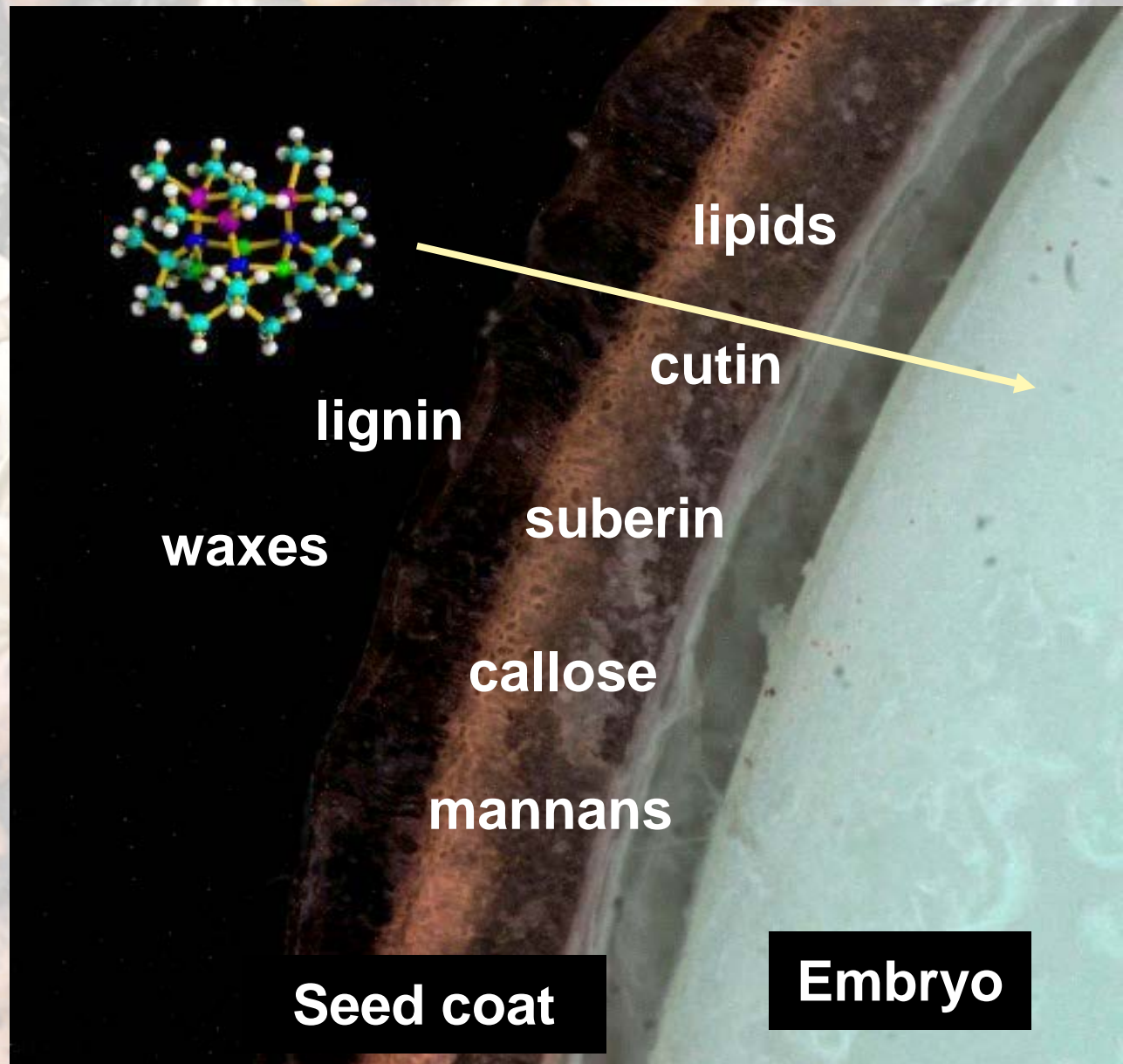
Conclusion – seed uptake depends on the **chemical nature of the compound** and the **crop seed**, whether a chemical will diffuse through the seed coat or be blocked.



Uptake of Seed Treatments

Chemical nature:
Nonionic vs Ionic

Molecular size
< 500 MW



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Acknowledgements

Dr. Masi Amirkhani, Biostimulant and SAP seed coating



Questions?



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