



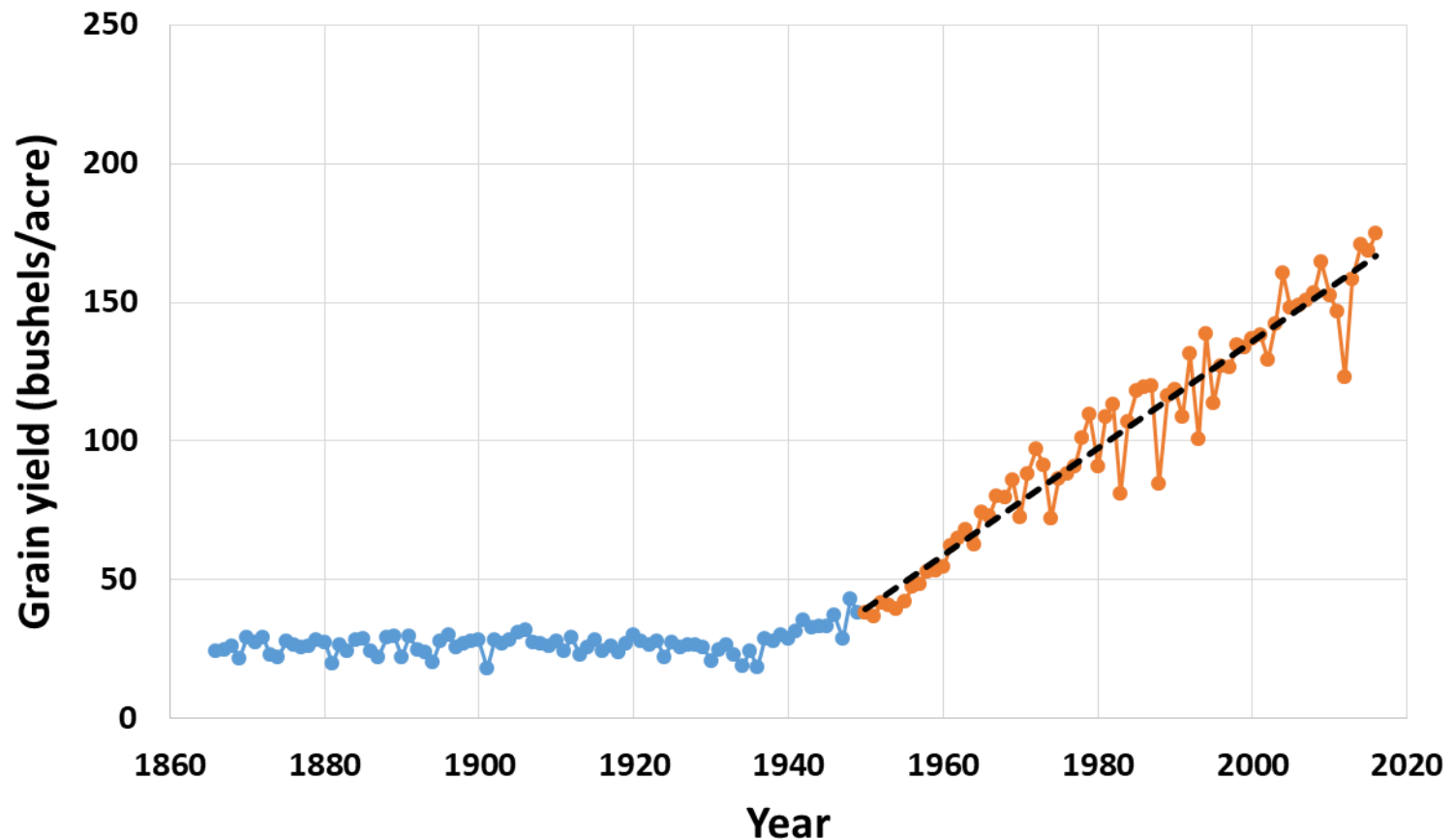
How do PGRs, biostimulants, and biologicals influence yield?

Jason Haegele

Agronomy Manager, WinField United

U.S. corn yields from 1866 to 2016

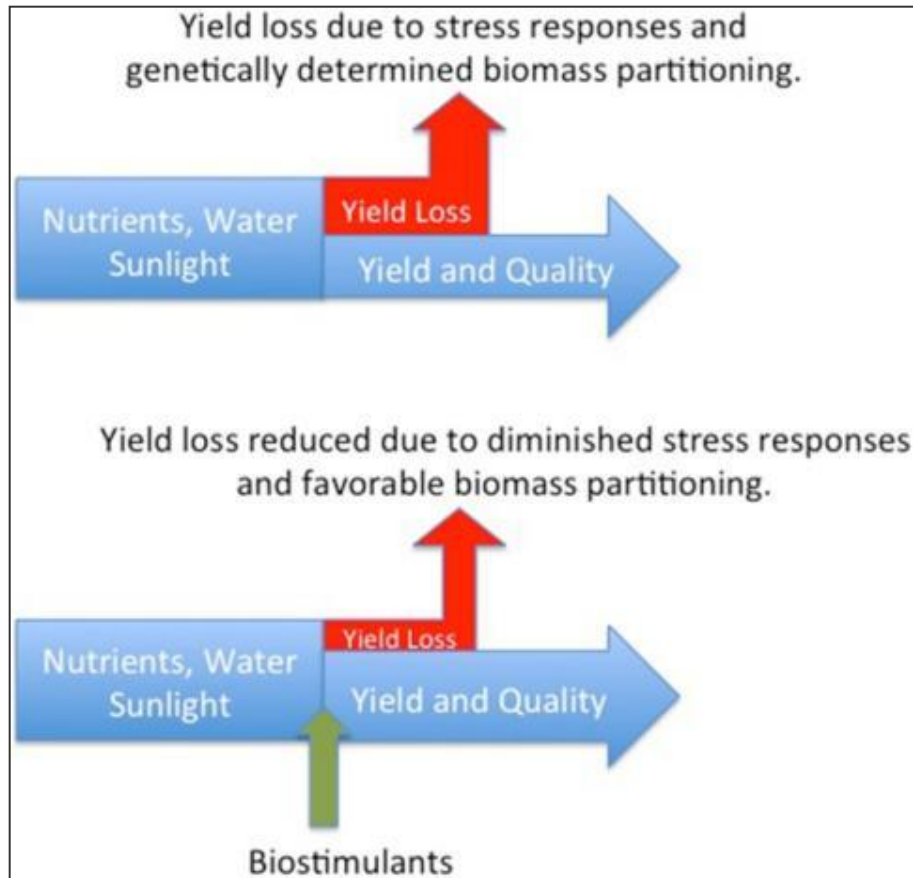
How did we get here and do we keep improving?



Source: USDA-NASS, 2016



Why PGRs, biostimulants, and biologicals?



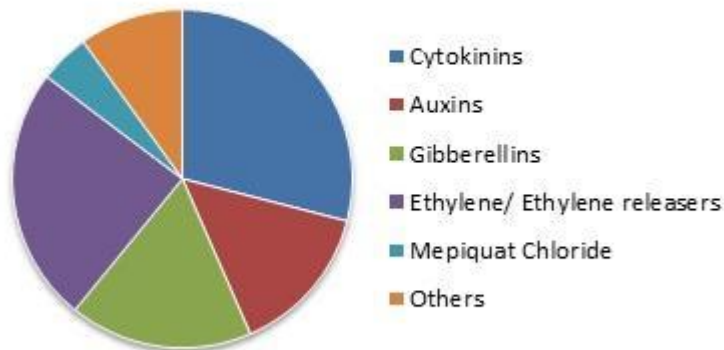
Products in these categories are often described as contributing to:

- 1. Stress mitigation**
- 2. Yield enhancement**

Source: Brown and Saa. 2015. Biostimulants in agriculture. *Frontiers in Plant Science* 6:671.

Plant growth regulators in agriculture

**Plant Growth Regulators Market Share,
By Chemicals Type, 2015 (%)**



Source: IndustryARC Analysis, Expert Insights

- **Systematic use of PGRs in crop production began in the 1930s.**
- **PGR use is widespread in high value crops, and is an indispensable component of some production systems (e.g., pineapple, seedless grapes).**
- **GA inhibitors for height and lodging management.**
- **Mixtures of cytokinin, auxin, and gibberellic acid in row crop production.**

Definition of plant growth regulators

FIFRA Definition [Sec 2(v)]

“...any substance or mixture of substances intended, through physiological action, for accelerating or retarding the rate of growth or rate of maturation, or for otherwise altering the behavior of plants or the produce thereof...”

Does not include:

- **Plant nutrients/nutritional chemicals,**
- **Trace elements,**
- **Plant inoculants,**
- **Soil amendments,**
- **Vitamin-hormone horticultural products**

Hormones regulate all stages of the plant life cycle

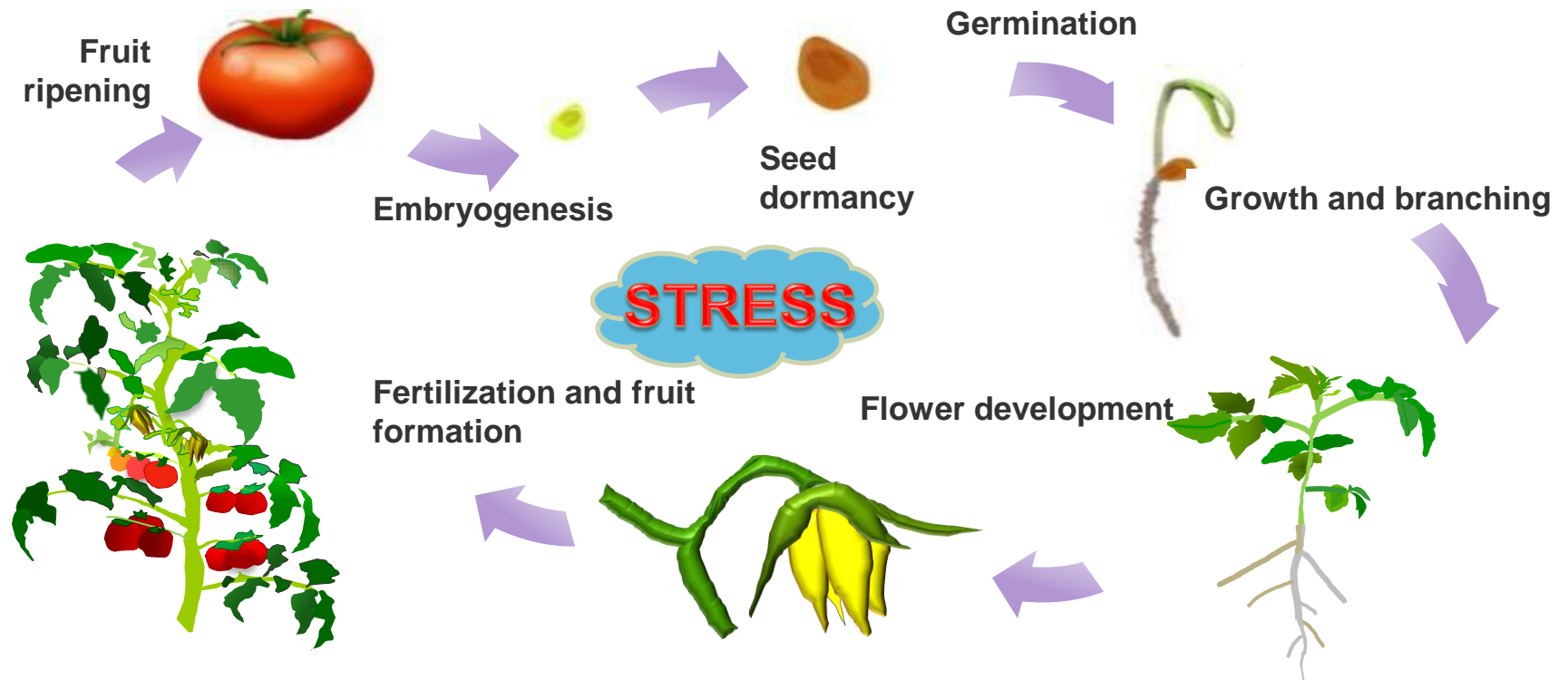


Image Source: Teaching tools in plant biology; American Society of Plant Biologists, © 2011.

Indolyl-occurring growth substance

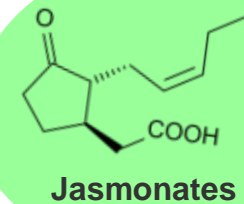
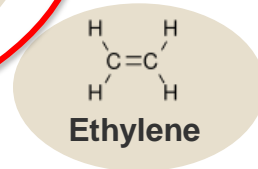
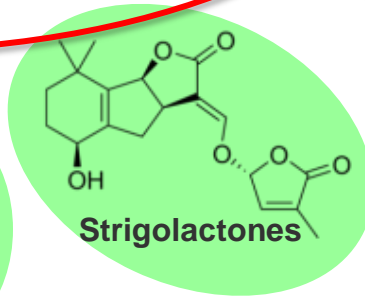
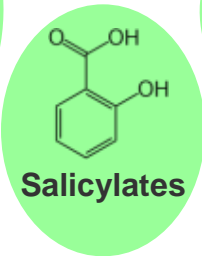
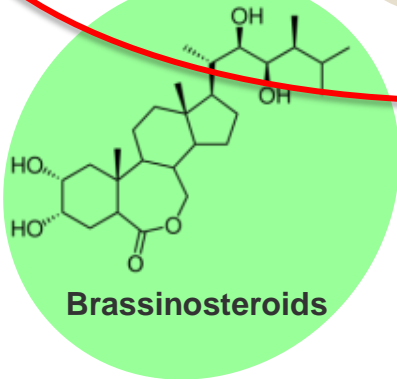
Auxin

CC(=O)OCC1=CNC2=CC=CC=C12

Cytokinins

CC(C)=CCNC1=NC=NC2=C1N=CN2

Gibberellins

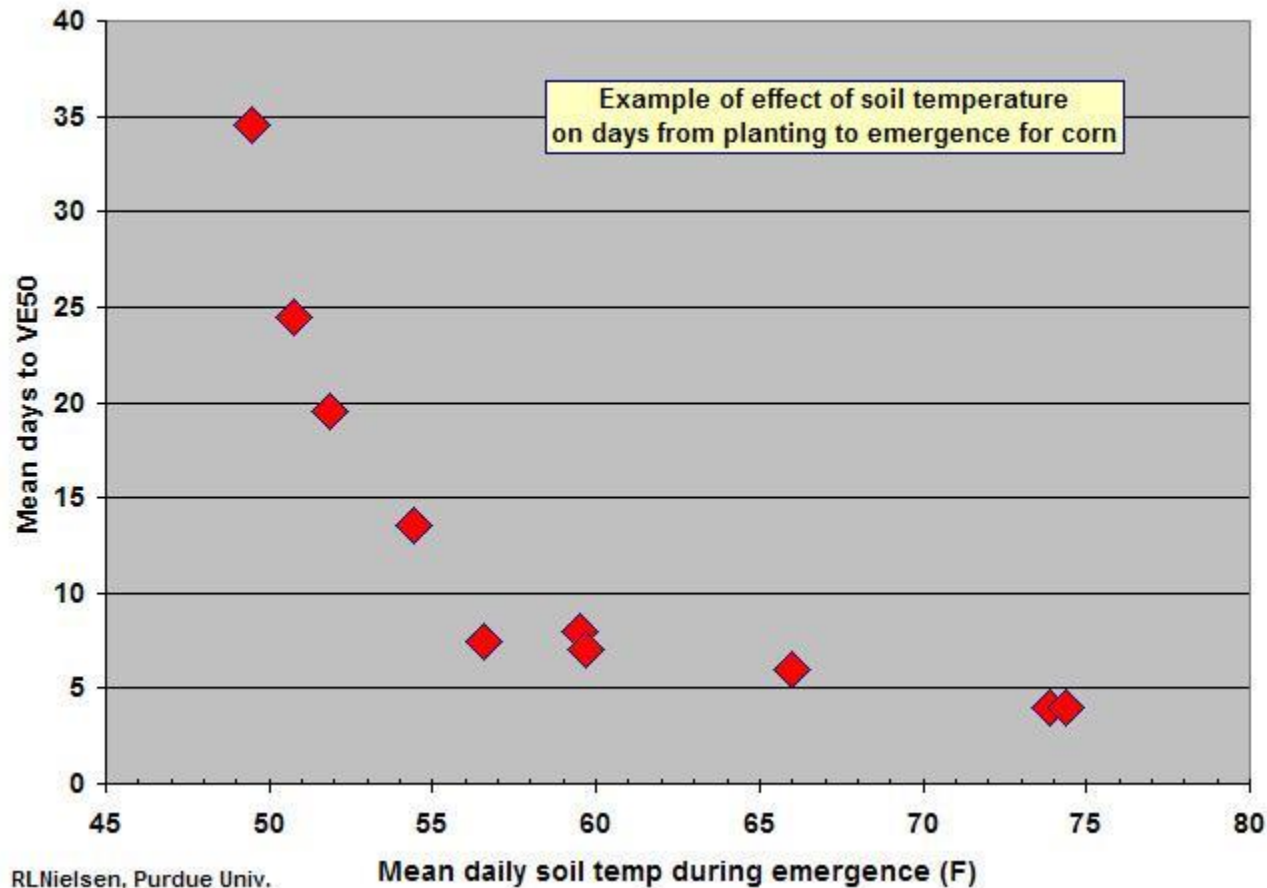
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WINFIELD[®]
UNITED

How might yield be increased by the use of plant growth regulators?

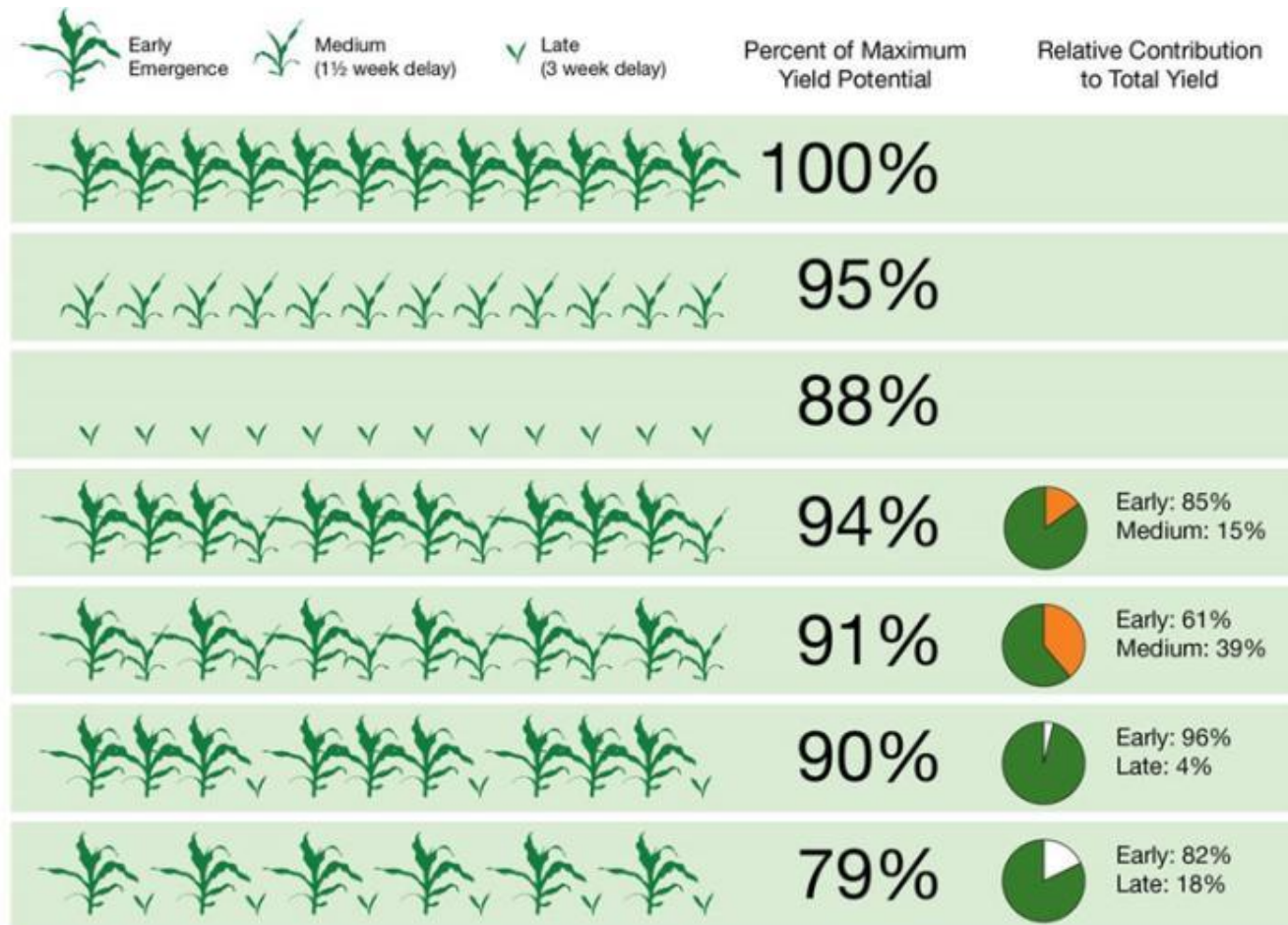
- Plant growth regulators influence the accumulation of biomass and its partitioning between root and shoot, as well as, reproductive development.
- Mechanistically, grain yield results from interception of solar radiation and its conversion into biomass.
 - **Rapid emergence and vegetative growth.**
- A portion of this biomass, typically 50 to 55% in a well managed crop, will be partitioned into grain.
 - **Manage seed abortion under stress, and maintain leaf photosynthetic activity through grain filling.**

Cool soil temperatures result in delayed corn emergence



Source: <https://extension.entm.purdue.edu/pestcrop/2010/issue4/index.html>

Non-uniformity in emergence results in decreased yield potential



Source: <https://www.pioneer.com/home/site/us/agronomy/library/corn-stand-evaluation/>
 Adapted from: Nafziger, Carter and Graham, Crop Science 31: 811-815 (1991)

Promotion of seed germination by gibberellic acid

- Gibberellic acid is a signal for germination.
- After planting, imbibition of water triggers gibberellic acid production in the embryo, which in turn triggers production of enzymes that begin to remobilize nutrients stored in the endosperm.

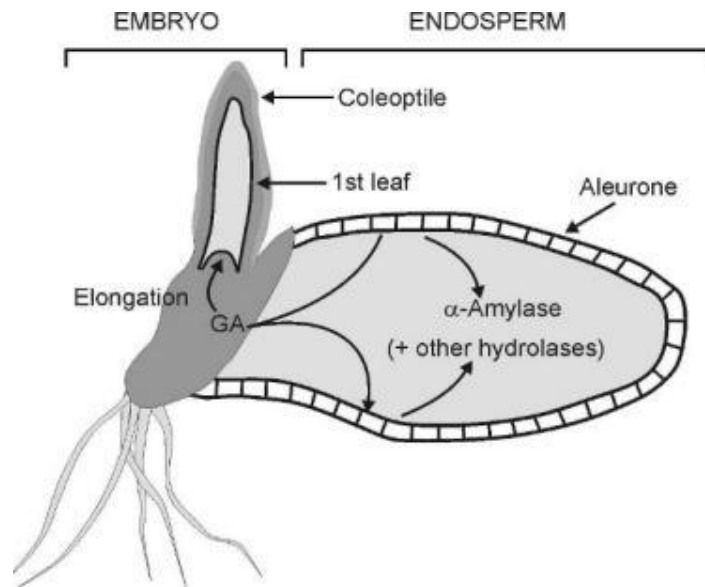


Image source: Woodger, Jacobsen and Gubler, Gibberellin action in germinated cereal grains, in Hormones, Davies (editor), 2010.

Auxin stimulates root growth and development

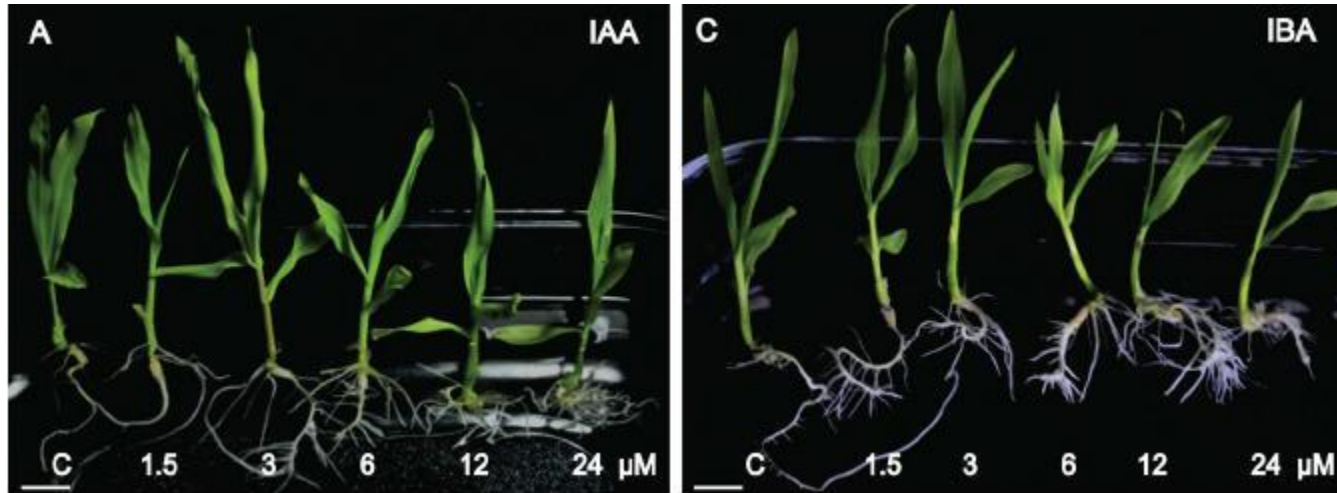


Image source: Martinez-de la Cruz et al. 2015. Auxins differentially regulate root system architecture and cell cycle protein levels in maize seedlings. *Journal of Plant Physiology* 176:147–156.

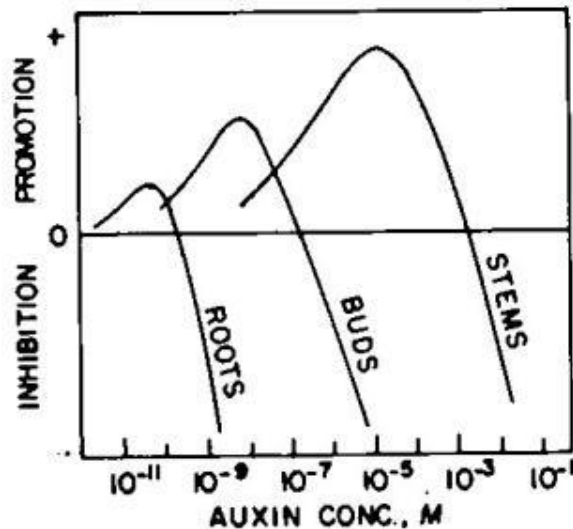
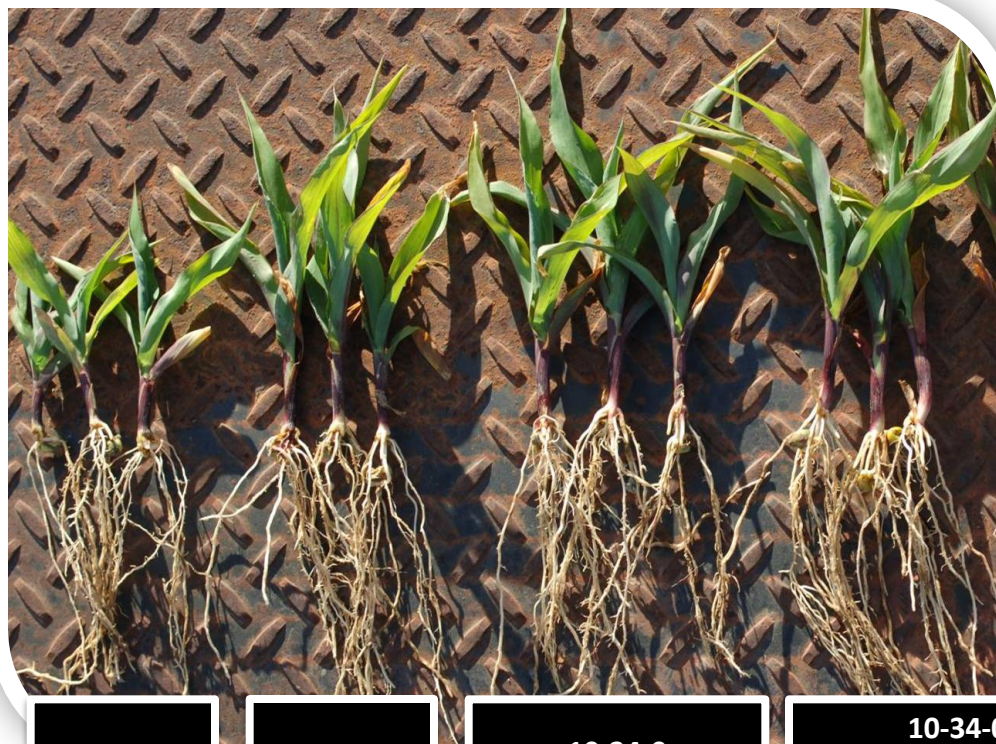


Image source: Gardner et al., *Physiology of Crop Plants*, 1985.

Ascend[®] SL

By WINFIELD
UNITED



Untreated

10-34-0

10-34-0
10% Citri-Che[®] Zn

10-34-0
10% Citri-Che[®] Zn
Ascend[®]

- Ascend is comprised of three plant hormones.
 - Auxin (IBA) – 0.045%
 - Cytokinin (kinetin) – 0.09%
 - Gibberellic acid – 0.03%
- Stimulates germination, shoot growth, and root initiation.

Increased speed and uniformity of emergence results in more uniform ears and higher yields



CROPLAN 6594VT2P/RIB planted April 25, 2017 in northern IL. Photo courtesy of Katie Hess (RAA).



2017 Proven Acre trial in northern IL. Photo courtesy of Katie Hess (RAA).

Improved early root development promotes productivity



Answer Plot[®] Research Data

3 year national response to Ascend data



Ascend[®] In-Furrow Corn Trials

Year	Yield Response	Site Response (% Positive)	Sites
2015	2.9	59.2	49
2013	4.7	60	63
2012	9.5	62.4	85
AVG	5.85	60.5	199

*10-34-0 and Zinc were applied to all treatments

Positioning of Ascend® SL

CORN RESPONSE TO ASCEND® PLANT GROWTH REGULATOR

ENVIRONMENTAL CONDITIONS		POSITIVE RESPONSE LOCATIONS	Answer Plot® by WINFIELD
2 Weeks Before Planting		72.2%	
<50° F			
<1 inch precipitation			
2 Weeks After Planting		69.2%	
<60° F			
>2 inch precipitation			

2011-2013 Answer Plot® Data

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Optify[®]/Stretch CPPA component

- CPPA – complex polymeric polyhydroxy acids
- Promotes root growth and nutrient uptake
- Increases emergence and early season vigor
- Improves the plant's ability to withstand yield limiting stress



CPPA affects gene expression related to key functions

Microarray Analysis of Gene Expression has Shown:

Genetic
EXPRESSION

- Plant hormone production and/or responses: **8 genes**
Auxin, GA, Cytokinins, ethylene, ABA. Enhanced root growth, flowering, and less senescence under stress
- Transcription factors, regulators or initiators: **36 genes**
Help deliver DNA information or sequences to mRNA for proper protein development
- Stress tolerance and defense related genes: **10 genes**
Heat Stress, Lack of Water
- Ion binding or movement: **20 genes**
Increased Chlorophyll and Nutrient Uptake: Zinc, Iron, Manganese, Calcium, etc.

CPPA and its relationship with nutrient genes

Genes: Nutrient Uptake and Movement

Genetic
EXPRESSION

Nutrient	Number of Genes Related *
Nitrogen (NO ₃ Form)	2
Phosphorus (P)	3
Calcium (Ca)	10
Zinc (Zn)	9
Iron (Fe) and Manganese (Mn)	4

* The number of genes that are related to uptake, transport or binding of these elements within the plant that had increased activity of 150% or more.

What are biostimulants?

- **“A group of ingredients that stimulate life.”**
- **Derived from natural or biological sources.**
- **Stimulate natural processes that enhance nutrient uptake or efficiency, tolerance to abiotic stresses, or crop quality when applied to plant or soil.**
 - **No direct action against pests.**
- **Many contain nutrients, but the effect of the biostimulant is independent of the nutritive benefit.**

Seaweed extracts



- Seaweed used as a fertilizer throughout history.
- *Ascophyllum nodosum* (brown seaweed)
- Seaweed extract is a diverse mixture of micronutrients, plant hormones, amino acids, polysaccharides, and other metabolites.

Optify/*stretch* **Acadian Technology component**

- **Complex array of biologically active compounds, scientifically proven to improve**
 - **Stress tolerance**
 - **Root development**
 - **Nutrient uptake**
- **Innovative technology to maximize corn and soybean growth during critical stages**
 - **Ear formation and development**
 - **Flowering and pod fill**
- **Developed by Acadian (industry leader in the science of marine based biological extracts)**

Where does Acadian technology come from?

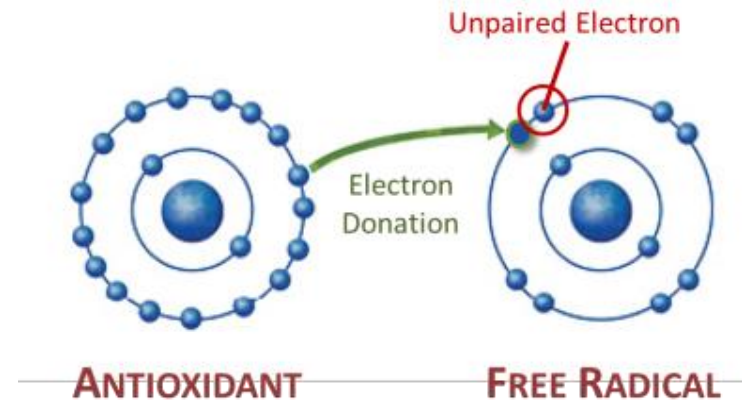


How does Acadian technology improve stress tolerance?

- Numerous biologically active compounds
 - Betaines: osmoprotectants
 - Oligosaccharides and proline: antioxidants, signal molecules and defense pathway
 - Alginates: encapsulation
 - Mannitol: osmoprotectant
- Stomates are quicker to close under stress
- Less cellular damage from stress
- Improved salt tolerance evidence

Acadian technology elicits protective compounds

- Elicits antioxidant production
 - Increases stress resistance and cell integrity
 - Neutralizes free radicals
- Elicits proline production
 - Strengthens cell wall membranes
 - Protects key metabolic enzymes
 - Mediates water balance in stress situations to prevent cell water loss



© 2015 Acadian Seaplants.

What are Reactive Oxygen Species?

Free radicals are an example of Reactive Oxygen Species. These molecules have unpaired electrons, making them both highly reactive and destructive. Antioxidants help neutralize these free radicals to protect cells and keep plants healthy.

Acadian technology contributes to improved rooting

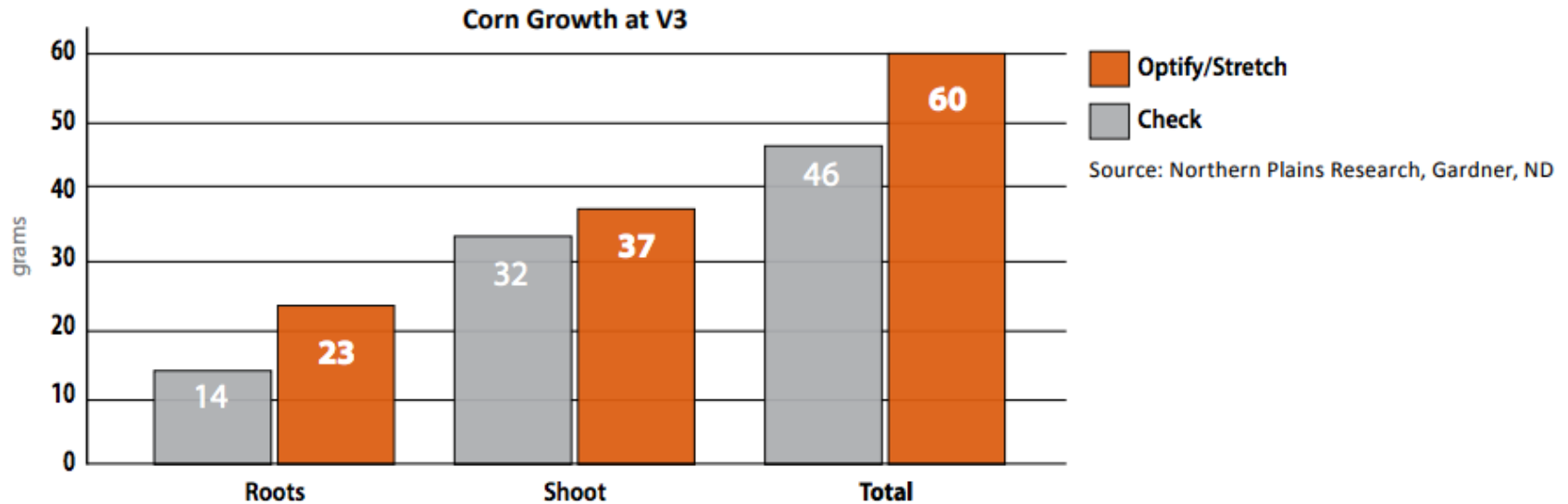
- Fucose-rich sulphated polysaccharides and alginates, bioactive compounds which:
 - Optimize hormone levels, resulting in larger root systems.
 - Elicit auxin-like activity, which stimulates root initiation and the formation of vascular tissue



Control

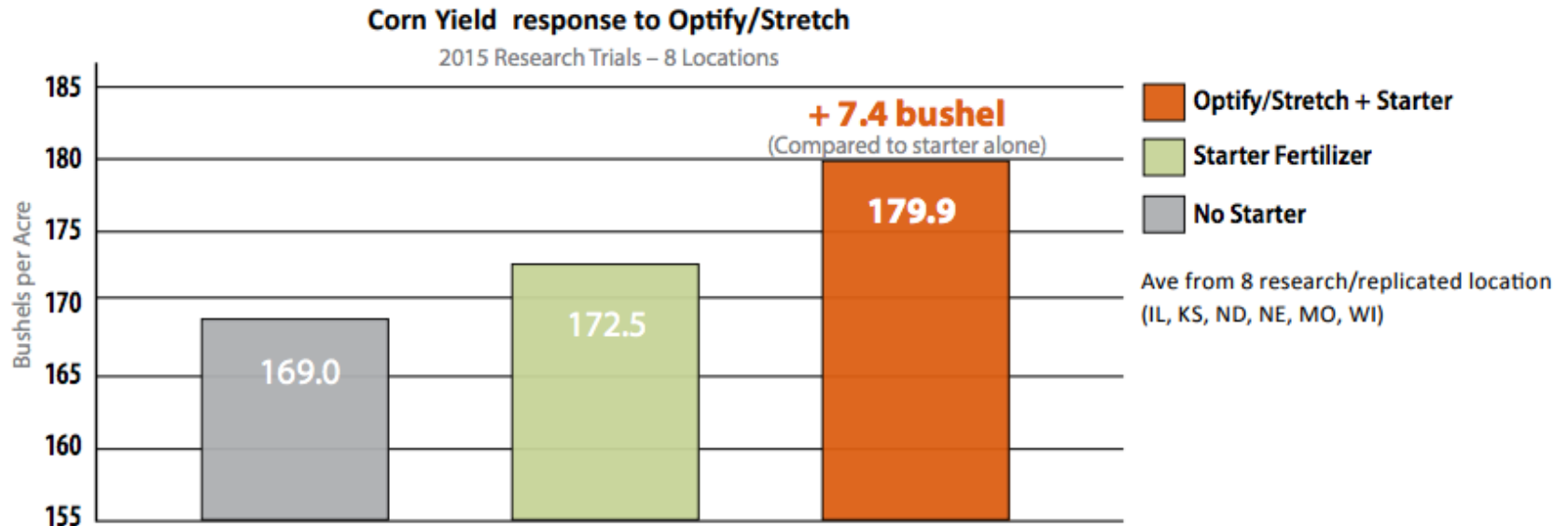
Acadian Technology

Optify®/Stretch – Improved root and plant growth



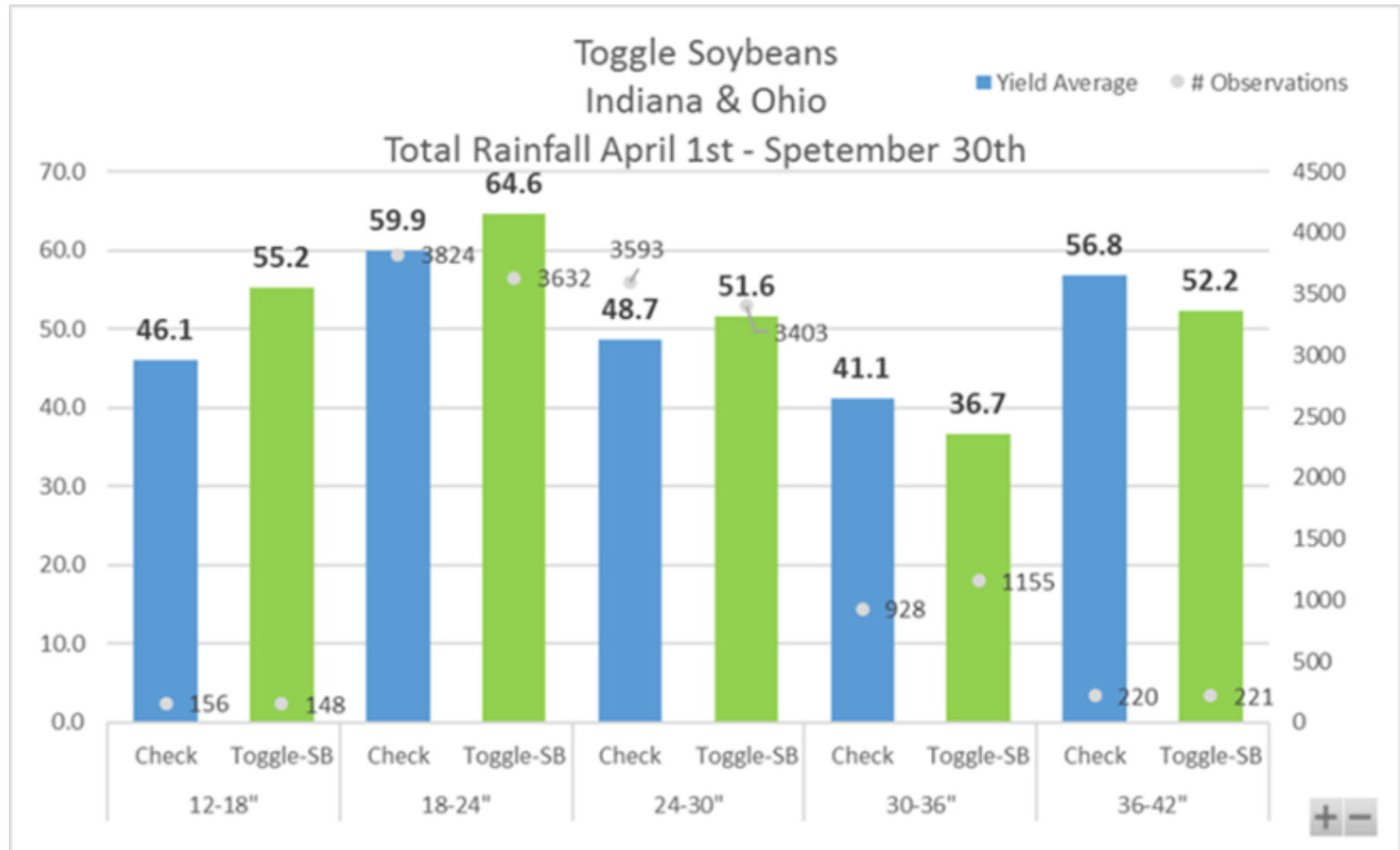
- Helps improve rooting, growth and establishment during the first few weeks of the season, when corn growth is negatively impacted by saturated soils, high residue or cold soil temperatures.

Optify®/Stretch – Increases yield when included as a component of starter



- Average positive yield increase:
 - 7.4 bu/A
 - 2015 research trials in 8 locations across 6 states.

When should Toggle (foliar application of Acadian technology) be used?

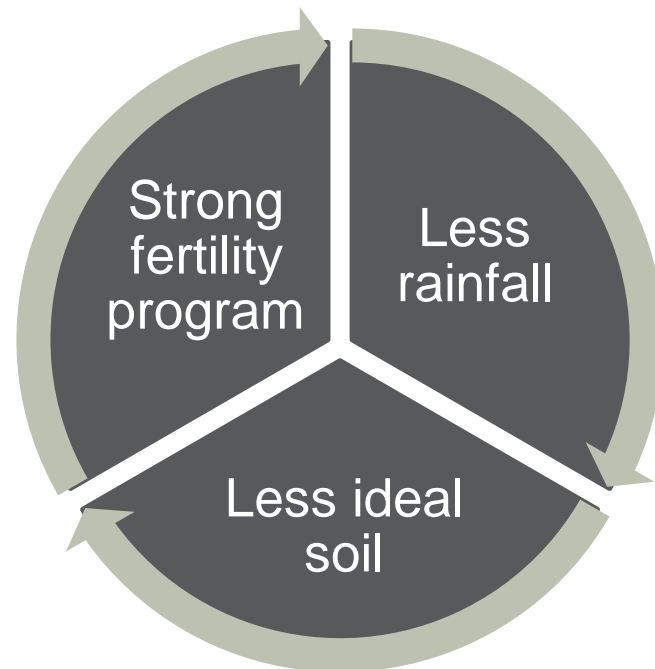


VoyagroTM

By WINFIELD
UNITED

VoyagroTM
at 16 oz./A

Untreated



When and where does Voyager™ work?

➤ **Voyager™ works when fertility is in place.**

- 2014 (20 sites): 70% response when K was sufficient
- 2015 (20 sites west of the Mississippi): 80% response when K and N were sufficient.

➤ **Voyager™ works when rain is less than adequate.**

- 2015 (20 sites west of the Mississippi): 90% response with <2 inches of rain post application.

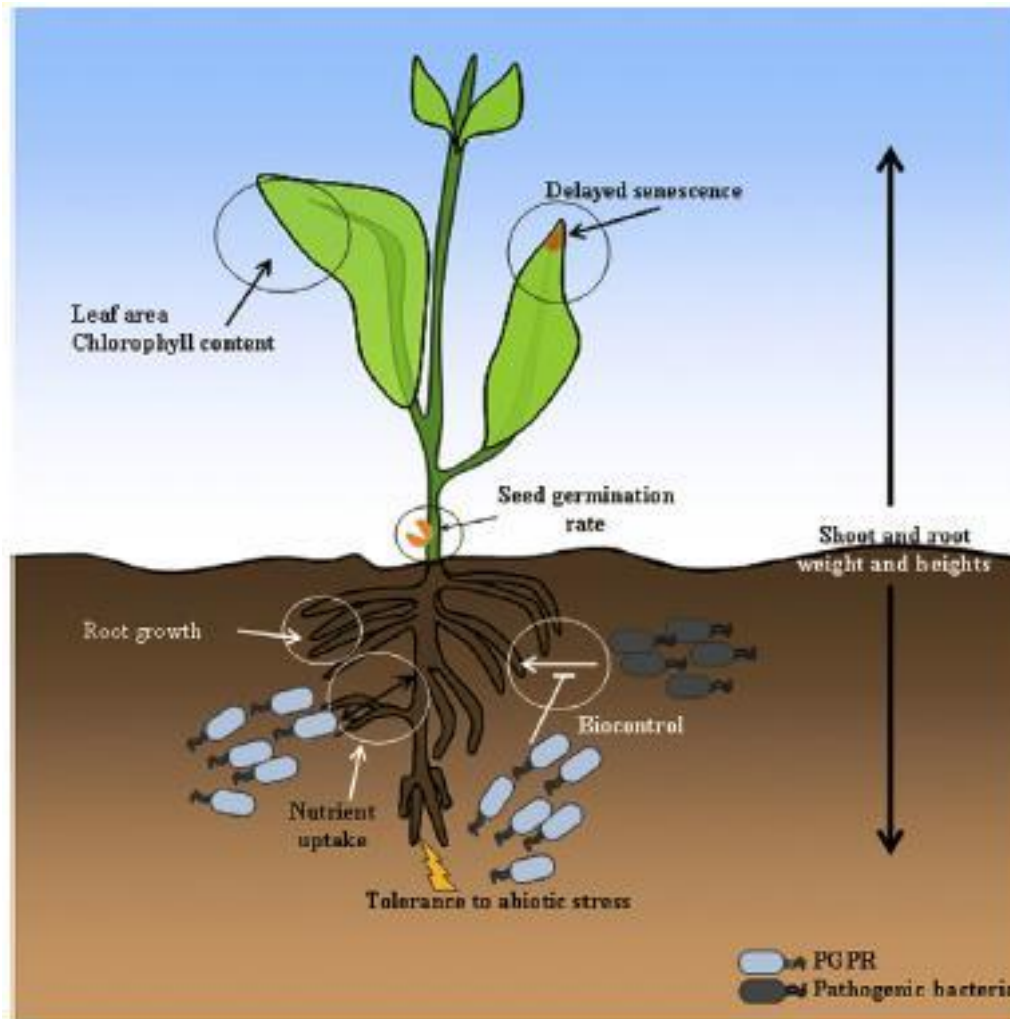
What are biologicals?

- Biologicals are live organisms that positively influence crop growth, development, health, or quality.
- These organisms exist naturally or are supplied to the crop as an inoculant, seed treatment, foliar spray, etc.
- Other types of biologicals may be referred to as 'biopesticides' and their use benefit the crop indirectly as a consequence of controlling insects or plant pathogens.
 - Example: ClarivaTM pn is bacterium applied as a seed treatment for the control of soybean cyst nematode.

Examples of biological organisms that influence crop growth and productivity

- *Azospirillum spp.* – soil bacteria that form symbiotic relationships with monocots like sugarcane.
- *Bacillus subtilis*, *B. pumilus*, *B. amyloliquefaciens* – spore forming soil bacteria that possess diverse functions.
 - Biopesticides
 - Soil nutrient availability
 - Production of plant growth regulators
- Fungi including *Trichoderma*, *Glomus*, *Pennicillium*

Plant growth promoting rhizobacteria (PGPR)



Source: Perez-Montana et al. 2014. Plant growth promotion in cereal and leguminous agricultural important plants: from microorganism capacities to crop production. Microbiological Research 169:325-336.

We have been using biologicals in crop production for a long time!

- Inoculant is a term used for rhizobia bacteria that are applied to legume seeds or soils to be planted with legumes.
- Rhizobia infect root hairs of the specific host legume they are adapted to. They form a nitrogen producing nodule that will produce nitrogen for the host plant if soil nitrogen is limited and the crop is not stressed.



FIG. 4.—INOCULATING SOYBEANS BY THE “MUDDY-WATER” METHOD

Well-inoculated soil must be used and every seed moistened with the muddy water. At the same time it is very important that an excess of water be avoided, for it injures the beans by causing the seed coats to “slip” and the result is a poor stand.

Source: “Soybean Production in Illinois”, University of Illinois Agricultural Experiment Station Bulletin no. 310, June 1928.

Why might inoculation be necessary?

- Rhizobia bacteria are found in the soil if a legume crop and its specific Rhizobia has been present in the field within about 10 years. (Except in sandy soil where they may die out rapidly)
- However:
 - Rhizobia become lazy over time, they will still infect the root hairs of the plant but will not aggressively fix nitrogen.
 - There may not be enough Rhizobia present to ensure good nodulation
 - New, more effective strains are being identified or created all the time.

Closing thoughts

- **Yield potential is the highest it will ever be the day we plant seed in the ground!**
- **PGRs and biostimulants that enhance emergence, root development, and early vegetative development allow growers to protect yield potential at the beginning of the season.**
- **Prescriptive applications of foliar PGRs or biostimulants are tools to overcome transitory periods of stress.**