Table of Contents

Nutrien™
Feeding the Future™

Importance of Cybersecurity within Agribusiness

Agenda

Introduction

Legal Guidance: Nutrien Ltd. and its affiliates do not provide information security advice. This material has been prepared for informational purposes only, and is not intended to provide, and should not be relied on for any information security or other advice. You should consult or engage your own information security experts.

Cyber Terminology

1	Malware	Software that is specifically designed to disrupt, damage, or gain unauthorized access to a computer system.
2	Phishing	The fraudulent practice of sending malicious emails in order to induce individuals to reveal personal information.
3	Internet of Things (IoT)	the interconnection via the internet of computing devices embedded in everyday objects, enabling them to send and receive data.
4	Ransomware	A type of malicious software designed to block access to a computer system until a sum of money is paid.
6	IT	Information technology (IT) is the development, management, and application of computer equipment, networks, software, and systems. IT is crucial to modern business operations because it enables people and machines to communicate and exchange information.
7	OT	Operational technology (OT) uses hardware and software to manage industrial equipment and systems. OT controls high-tech specialist systems, like those found in the energy, industrial, manufacturing, oil and gas, robotics, telecommunications, waste control, and water control industries.
8	Patching	A patch is a set of changes to a computer program, or its supporting data designed to update, fix, or improve it
9	State Sponsored Actor	Motivated by military, economic, or political interests, typically employing malicious cyber campaigns to gain access to sensitive assets for competitive advantage

Cyber Safety

Phishing Awareness

When fraudulent messages attempt to trick you into giving up information or payment.

Safe Web Browsing

Ensuring you travel to known good websites and avoid malicious sites is key.

Password Management

Passphrases > Passwords where applicable. Learn how to securely store all your passwords.

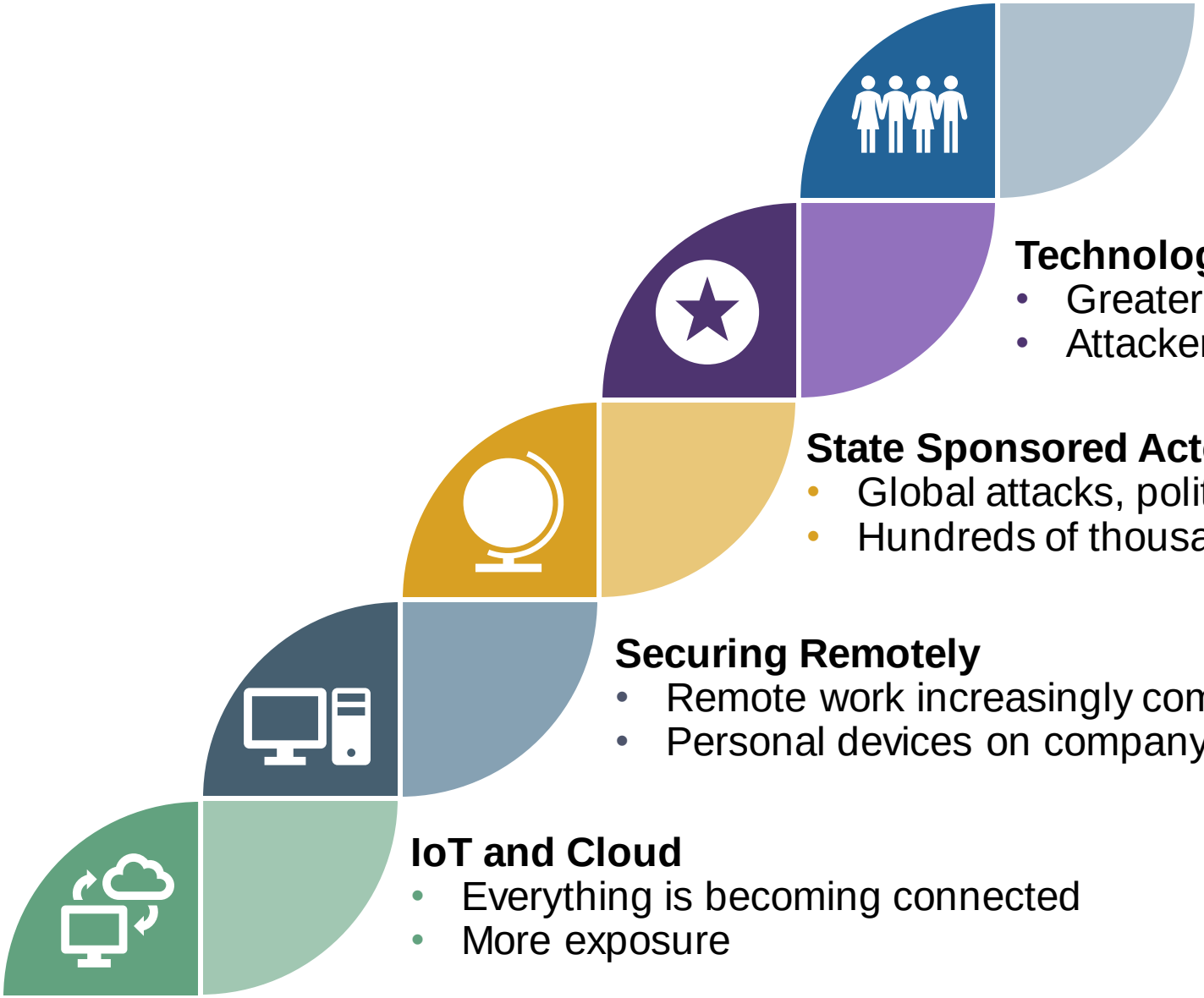
Social Engineering

Threats can come in more than just emails, be wary of suspicious text messages, phone calls etc.

Multi-Factor Authentication

MFA is key to securing accounts wherever it is possible to enable.

Cybersecurity Trends



Security Awareness
- Everyone is a target
- Ensuring a cyber-secure work force is key

Technology Race
- Greater reliance on technology
- Attackers are using new tech as well

State Sponsored Actors
- Global attacks, politically motivated
- Hundreds of thousands of these attacks

Securing Remotely
- Remote work increasingly common
- Personal devices on company networks

IoT and Cloud
- Everything is becoming connected
- More exposure

Global State of Cybersecurity

Ransomware is on the rise

Hitting the brands that you know: JBS, Honda, CWT, Uber, Jack Daniels, Colonial Pipelines

Attacking through trusted contacts

Business email compromise attacks are on the rise, attackers are abusing trusted contacts and connections

How do we prepare

It begins with having a conversation. Raising awareness for cybersecurity and having discussion on how to best implement.

Agriculture Becoming a Targeted Sector

Crystal Valley Farm Coop
NEW Cooperative
JBS Foods

Agriculture a Growing Threat Target – Why attack us?

Global operations in some of the most targeted countries

Heavy reliance on connections and third party business within supply chains

Targets by state sponsored groups, part of China Five Year Plan

Attackers do their research! Strong years and earnings in ag put us in attackers' crosshairs.

As the Agriculture industry shifts more towards internet enabled technologies this increases the risk of cyber incidents occurring.

More reliance on the internet means more targets to attack and more potential points of access and compromise.

Important Timely Events

CYBER NEWS

Wednesday, April 20th, 2022

Vol 13-15

FBI WARNS OF 'TIMED' RANSOMWARE ATTACKS ON AGRICULTURE SECTOR

Farming and agriculture seen as a lucrative target where victims could be more willing to pay a ransom for a decryption key because of the time-sensitive nature of the industry.

Cyber News

CYBER NEWS

Monday, May 9th, 2022

Vol 13-16

AGCO RANSOMWARE ATTACK DISRUPTS TRACTOR SALES DURING U.S. PLANTING SEASON

Cyber News

CYBER NEWS

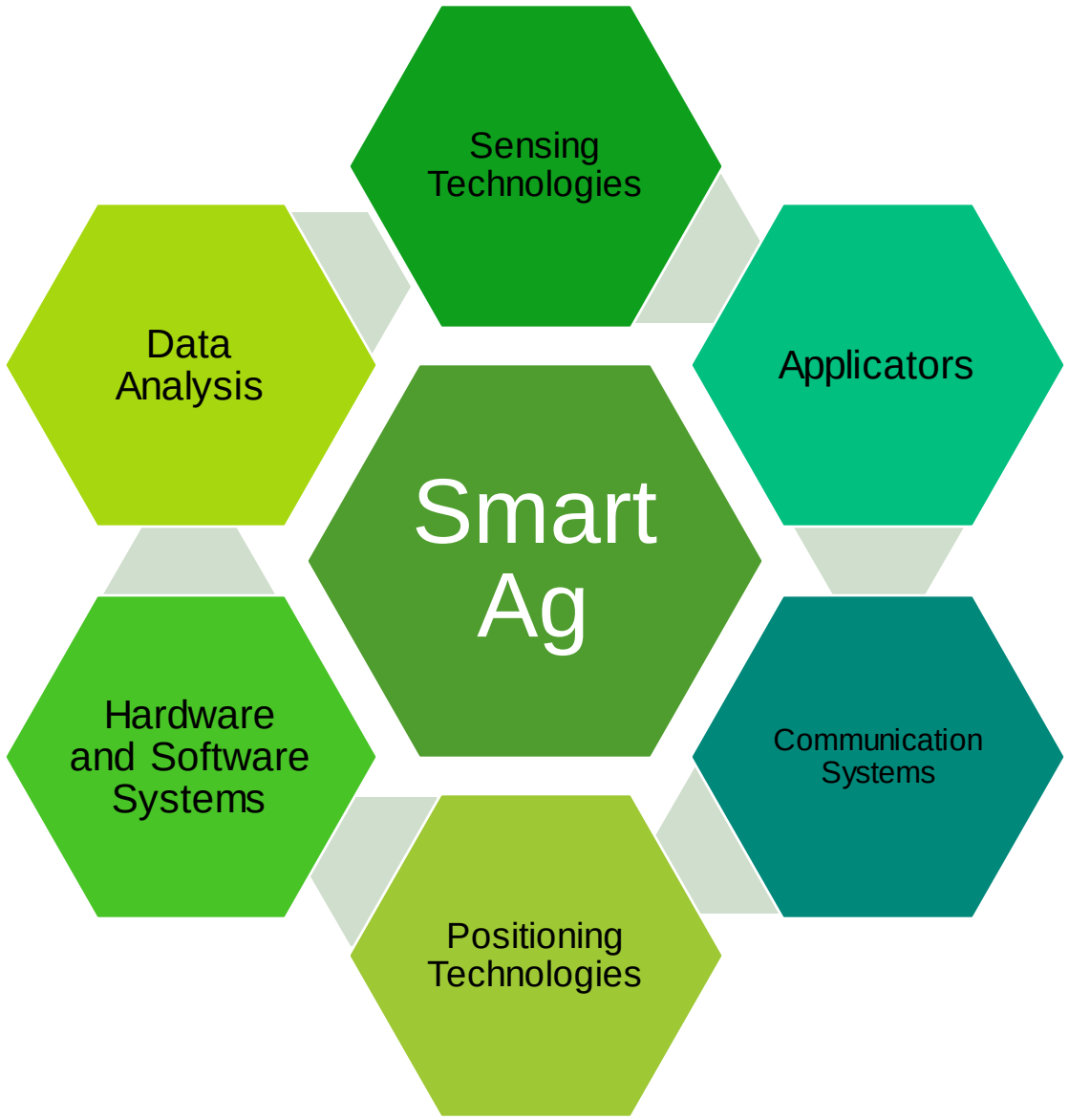
Tuesday, October 11th, 2022

Vol 13-16

PRESIDENT BIDEN SIGNS NSM-16 TO STRENGTHEN U.S. FOOD SAFETY, SECURITY; HIGHLIGHTS CLIMATE CHANGE, CYBERSECURITY

Cyber News

Smart Agriculture + Cyber Risk



IoT
As more devices are there is more opportunity for risk

Limited Patching
These systems often have limited patching or are neglected

Speed of Change
Adopting new tech needs to be done at a pace security can be ensured

Considerations for Protecting Key Networks

	IT	ICS/OT
		
Business Priority	Confidentiality	Safety, Availability
Major Focus	Data Integrity	Preventing Injuries and Production Downtime
Protection Targets	Windows Computers/Servers	Industrial Devices
Environmental Conditions	Controlled Environments – Air Conditioned, Stable	Harsh Environments – Extreme Temp, Vibrations

Attacks on ICS Systems can lead to real world impacts

Florida Water Treatment Plant

Attacker changed the chemical mix to extremely dangerous levels. Could have caused severe sickness and/or death in the community.

Middle East Oil Refinery

Rare and dangerous new form of malware (Triton) targets industrial safety control systems that protect human life.

Consolidated Grain & Barge Co.

Cyber criminals infected systems and rendered many facilities inoperable, forcing a system-wide shut down.

Colonial Pipelines

Colonial Pipelines suffered a ransomware attack to their payment systems. They shut off their pipeline in response and operations did not restore for 5 days

Key Takeaways

- Everyone is a target, from organizations, to personal accounts, attackers want it all
- There is no one stop shop that fixes all security risks, different technology needs to be secured differently
- Cyber attacks come in many forms targeting many kinds of systems; we might be most familiar with phishing emails but that is not all we need to be aware of

Thank you for listening

Security For AG Retail

Steve Griego

AGENDA

- Why security is a concern in Retail AG? Examples of real-world events
- CFATS Program Quick review
- Best Management Practices and security improvements
- Where to gain additional information

In 1995, a domestic terrorist killed 168 people and injured hundreds more when he used a fertilizer bomb to blow up a federal building in Oklahoma City.

The Department of Homeland Security has since stated that terrorists could target any of the tens of thousands of facilities throughout the United States that house hazardous chemicals—like the ammonium nitrate fertilizer used in that bombing.

CRITICAL INCIDENT NOTIFICATION
AgriBusiness

Describe what happened:
An SGS fumigation truck was staged in a growers field, when it was stolen at 9:30 at night.

What was the outcome:
The vehicle was utilized in criminal activity and left abandoned, and partially stuck in a trash pit

Where in the plant did it occur:
Truck was stolen from where it was staged off site in a growers field

What equipment was involved:
SGS fumigation truck

 |

CRITICAL INCIDENT NOTIFICATION
AgriBusiness

Initial Causal Findings:
Upon investigation, it was determined that the vehicle was left unattended in the field with the doors unlocked and the keys in the cab.

The vehicle had approximately 1,500 gallons of hazardous material in the tank. The valves on the tank were not secured as required by EPA regulation.

Immediate Corrective Actions:
Key lock boxes have been ordered and will be installed to allow the vehicle keys and tank valve lock keys to be placed in and secured.

Padlocks will be installed on valves on all pesticide/hazmat loads when unattended.

Theft

- Theft of Anhydrous Ammonia – an individual attempted to steal Anhydrous Ammonia using an insulated bucket. The individual was part of an undercover investigation on drug and meth manufacturing and ended up getting caught up in the effort.

Break Ins

- SGS Winnemucca Nevada
  - 7/19/2020 – Office window forced open. Cash box with approximately $300 in cash stolen
  - 9/18/2020 – Office broken into with cash box and approximately $150 in cash stolen
  - 11/02/2020 – Office window broken. No items taken (they attempted to take the safe but were unable).

Other incidents

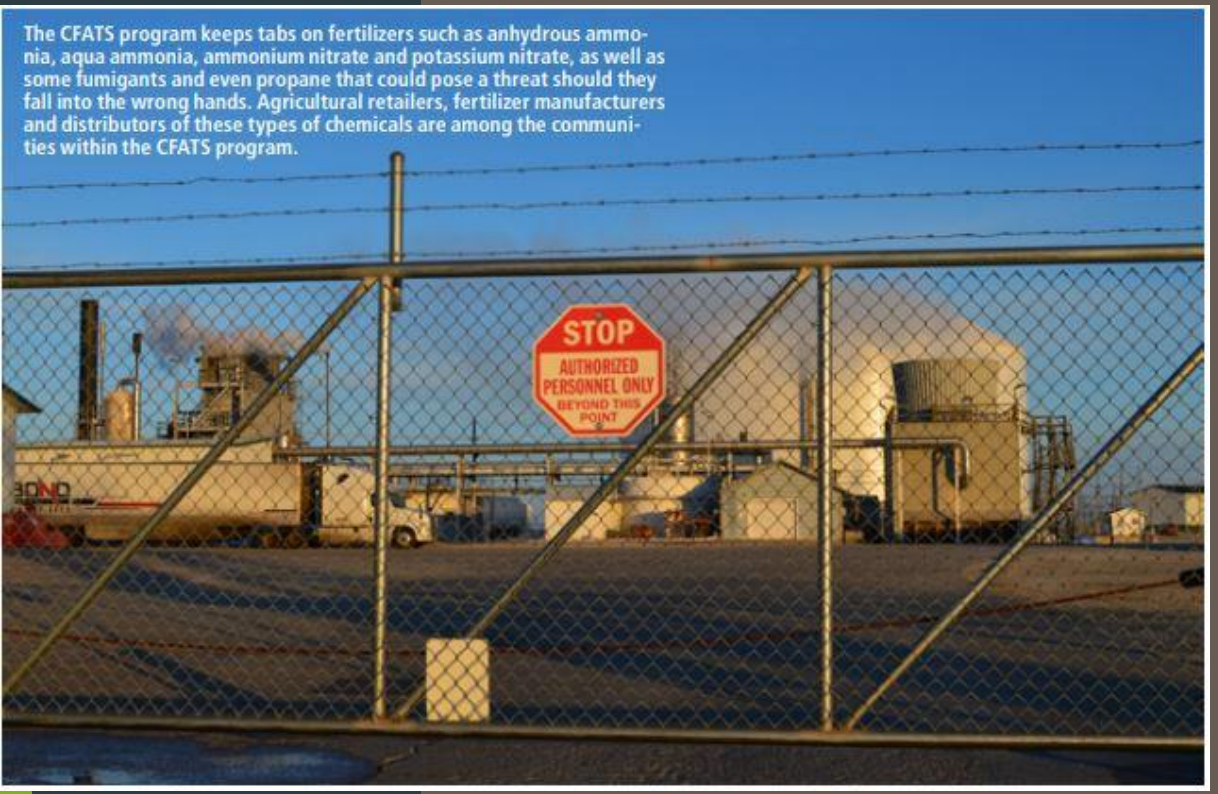
Suspicious Phone Calls – over the years, several of our facilities have received suspicious phone calls from out of state or out of country asking about purchase of high-risk products such as ammonium nitrate.

Video Taping – recently, we've had a number of groups stand outside our fence lines video taping our facilities and employee's; they are attempting to illicit a response from our people and create a scene or altercation; we instruct our employees to avoid these individuals and not engage regardless of what is said to them

Suspicious Public Complaint – in California, we had a member of the public contact the Corporate office and 3 local branches irate about a driver going too fast through his town; he was acting angry enough that we issued a security bulletin to all sites in that area and contacted local law enforcement for support/advice; we were able to find a photo of the individual via Facebook and sent that out to all locations

Cash Purchases / Unknown Customers – people of shown up to our sites with fistfuls of cash to buy bagged fertilizers; not necessarily high-risk fertilizer, but it's been assumed these individuals were using the fertilizer for marijuana growing operations (this was before a lot of it was legalized)

General Theft – warehouse break-ins where people have driven the forklift around

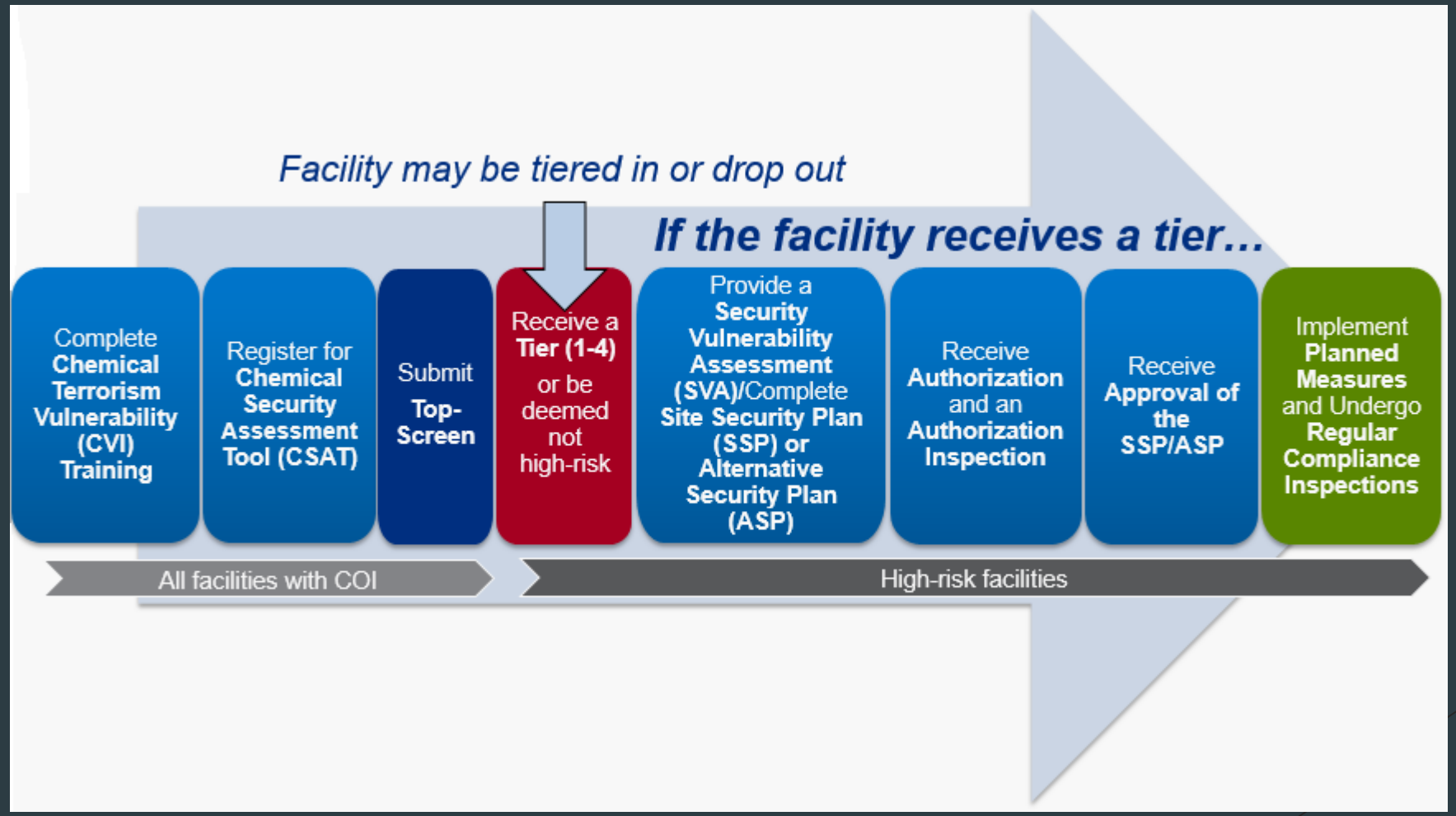


The CFATS program keeps tabs on fertilizers such as anhydrous ammonia, aqua ammonia, ammonium nitrate and potassium nitrate, as well as some fumigants and even propane that could pose a threat should they fall into the wrong hands. Agricultural retailers, fertilizer manufacturers and distributors of these types of chemicals are among the communities within the CFATS program.

CFATS Program in response

Congress authorized the U.S. Department of Homeland Security (DHS) to establish the Chemical Facility Anti-Terrorism Standards (CFATS) program in 2006. The program in its current form is authorized until 2023 and managed by the Cybersecurity and Infrastructure Security Agency (CISA).

A facility that meets or exceeds the specified concentrations and quantities for any COI is required to report possession of those chemicals by completing an online survey called a Top-Screen via the Chemical Security Assessment Tool (CSAT).



CFATS

Exclusions to CFATS

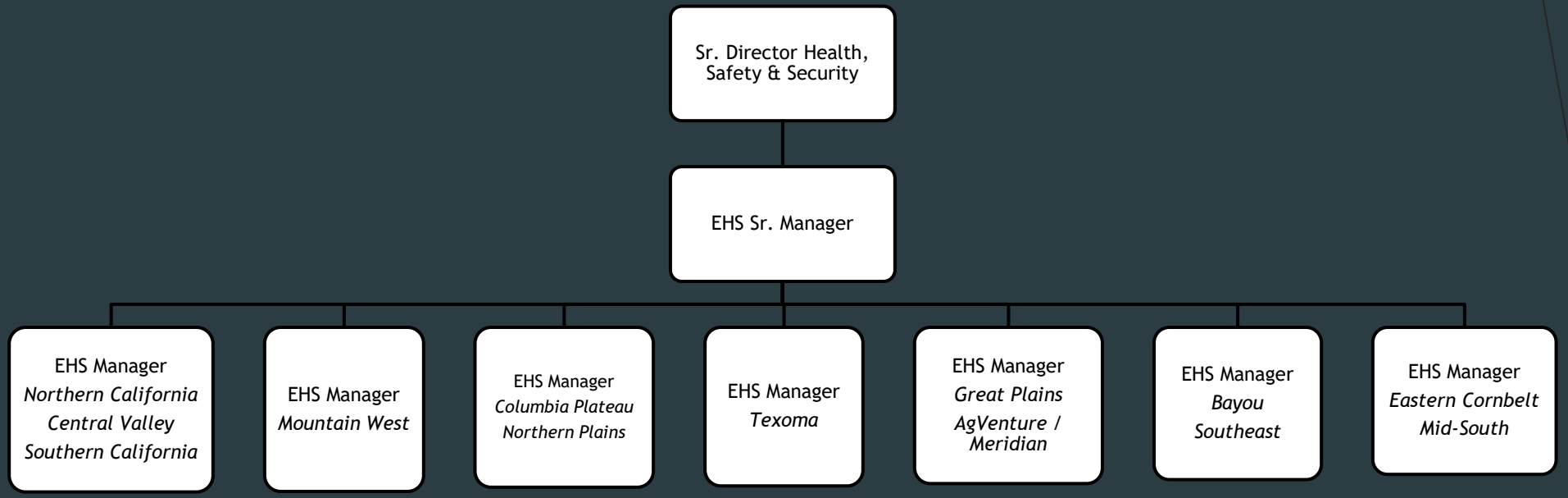
Most farmers and ranchers currently aren't subject to reporting if the chemicals are applied directly to their crops, feed, land, livestock or poultry.

CFATS

- What security improvements can be done for facilities who do not fall under CFATS?

Best Management Practices for Security

Retail EHS Support Structure

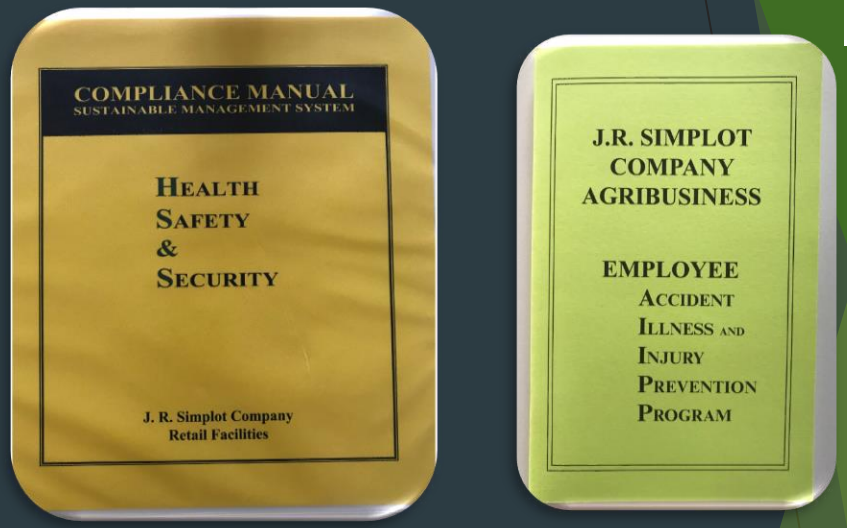


EHS Manager Responsibilities

- **Partners with Regional and Location Leadership and Employees to ensure compliance with Safety, Environmental, DOT and Security Requirements**
  - Research and Communicate new rules and existing rules and changes
- **Acts as a Liaison between the location and Regulatory Agencies such as OSHA, EPA, State DEQ and others**
  - Including written report generation or permit requirements
- **Locations notify their EHS Manager in the event of…**
  - Occupational Injury or Illness
  - Environmental Spill or Release
  - Vehicle Accident and/or Property Damage
  - Agency Inspection
  - Security issues
- **Schedule and conduct Audits according Responsible Ag and Internal protocols**
- **Develops and provides basic EHS training to employees.**

Establish Documented Uniformed Guidance

The Global Safety Philosophy reflects the Company's commitment and promotion of continuous improvement of safety processes.



The Compliance Manual and AIIPP Manual serve to guide the EHS processes within Retail. Each location will have a Yellow Book and each employee with have an AIIPP.

Establishment of Incident and Event Reporting

- Found in Sections **2.3 (Safety)** and **3.4 (Environmental)** of the Yellow Book

Health & Safety Incident Reporting

INCIDENT	DESCRIPTION	CONTACT/FORMS	TIME FRAME
WORKPLACE FATALITY	Employee injury resulting in: ✓ Fatality	1. Call 9-1-1 2. EHS Mgr. 3. Area Operations Mgr. 4. Safety Dir. Corporate 5. OSHA Office 6. Workers Comp Insurance	1. Call First! 2. Immediate! 3. Immediate! 4. Immediate! 5. **MUST BE DONE ASAP BUT NO LONGER THAN 8-HRS.** EHS Dept. will assist with this notification
		A. Incident Report Form B. Workers Comp Claim	A. Email to HS&S Dept. within 2 hrs. B. Notify Insurance Co. w/in 24-hrs.
SERIOUS INJURY – OTHER	An incident resulting in: A serious injury other than the above category ✓ Amputation ✓ loss of eye ✓ In patient Hospitalization	1. Call 9-1-1 2. EHS Mgr. 3. Area Operations Mgr. 4. OSHA office 5. Workers Comp Insurance	1. Call First! 2. Immediate! 3. Immediate! **4. MUST BE DONE ASAP BUT NO LONGER THAN 24-HRS.** 5. Notify ASAP but w/in 24 hrs.
		A. Incident Report Form B. Workers Comp Claim	A. Email to HS&S Dept. w/in 2-hrs. B. Notify Insurance Co. w/in 24-hrs.
RECORDABLE INJURY	Work-related injury or illness requiring medical treatment beyond basic first aid.	1. EHS Mgr. 2. Area Operations Mgr. 3. Workers Comp Insurance	1. Same day or next morning 2. Same day or next morning 3. Notify ASAP but w/in 24-hrs.
		A. Accident Report Form B. Workers Comp Claim	A. Email to HS&S Dept. w/in 2-hrs. B. Notify Insurance Co. w/in 24-hrs.

Facility Self Inspection Booklets

- Included site inspection booklets for the entire calendar year:
  - Annual Inspection Requirements
  - Monthly Inspection Requirements
- All Regulatory items included:
  - Fencing and security
  - Fire Extinguishers
  - Emergency Eyewash/Showers
  - Containment Structures
- Locations to maintain records onsite, no need to enter any systems

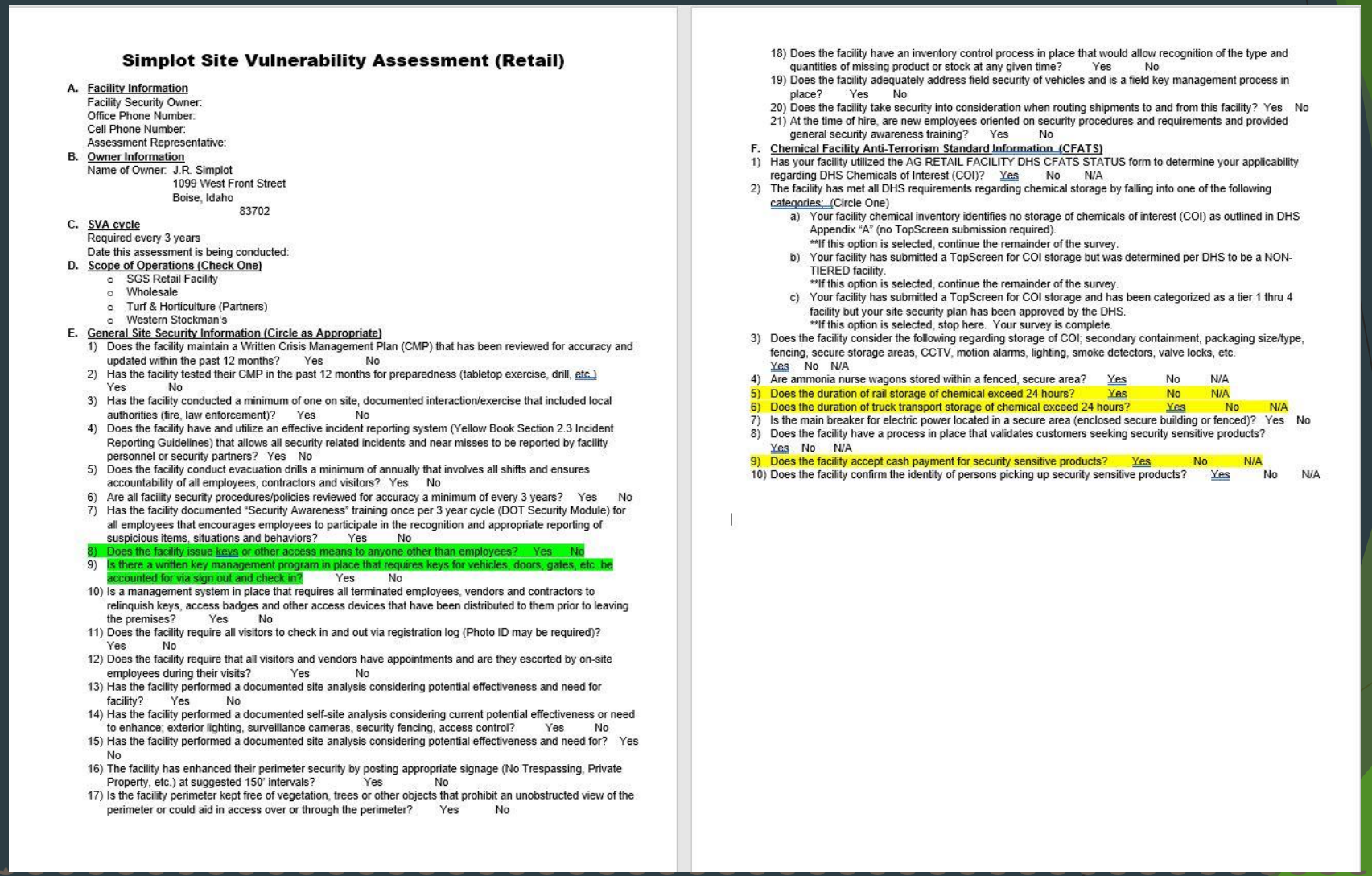
Responsible Ag

- Responsible Ag is an industry-led initiative committed to helping agribusinesses properly store and handle farm input supplies. The program helps members ensure they are compliant with environmental, health, safety and security regulations to keep employees, customers and our communities safe.

- 3 year certification cycle → goal to get every location certified

Conduct “in house” Security Assessments

Completed every 3 years



Simplot Site Vulnerability Assessment (Retail)

A. Facility Information
Facility Security Owner:
Office Phone Number:
Cell Phone Number:
Assessment Representative:

B. Owner Information
Name of Owner: J.R. Simplot
1099 West Front Street
Boise, Idaho
83702

C. SVA cycle
Required every 3 years
Date this assessment is being conducted:

D. Scope of Operations (Check One)
- SGS Retail Facility
- Wholesale
- Turf & Horticulture (Partners)
- Western Stockman’s

E. General Site Security Information (Circle as Appropriate)
1) Does the facility maintain a Written Crisis Management Plan (CMP) that has been reviewed for accuracy and updated within the past 12 months? Yes No
2) Has the facility tested their CMP in the past 12 months for preparedness (tabletop exercise, drill, etc.) Yes No
3) Has the facility conducted a minimum of one on site, documented interaction/exercise that included local authorities (fire, law enforcement)? Yes No
4) Does the facility have and utilize an effective incident reporting system (Yellow Book Section 2.3 Incident Reporting Guidelines) that allows all security related incidents and near misses to be reported by facility personnel or security partners? Yes No
5) Does the facility conduct evacuation drills a minimum of annually that involves all shifts and ensures accountability of all employees, contractors and visitors? Yes No
6) Are all facility security procedures/policies reviewed for accuracy a minimum of every 3 years? Yes No
7) Has the facility documented “Security Awareness” training once per 3 year cycle (DOT Security Module) for all employees that encourages employees to participate in the recognition and appropriate reporting of suspicious items, situations and behaviors? Yes No
8) Does the facility issue keys or other access means to anyone other than employees? Yes No
9) Is there a written key management program in place that requires keys for vehicles, doors, gates, etc. be accounted for via sign out and check in? Yes No
10) Is a management system in place that requires all terminated employees, vendors and contractors to relinquish keys, access badges and other access devices that have been distributed to them prior to leaving the premises? Yes No
11) Does the facility require all visitors to check in and out via registration log (Photo ID may be required)? Yes No
12) Does the facility require that all visitors and vendors have appointments and are they escorted by on-site employees during their visits? Yes No
13) Has the facility performed a documented site analysis considering potential effectiveness and need for facility? Yes No
14) Has the facility performed a documented self-site analysis considering current potential effectiveness or need to enhance; exterior lighting, surveillance cameras, security fencing, access control? Yes No
15) Has the facility performed a documented site analysis considering potential effectiveness and need for? Yes No
16) The facility has enhanced their perimeter security by posting appropriate signage (No Trespassing, Private Property, etc.) at suggested 150’ intervals? Yes No
17) Is the facility perimeter kept free of vegetation, trees or other objects that prohibit an unobstructed view of the perimeter or could aid in access over or through the perimeter? Yes No
18) Does the facility have an inventory control process in place that would allow recognition of the type and quantities of missing product or stock at any given time? Yes No
19) Does the facility adequately address field security of vehicles and is a field key management process in place? Yes No
20) Does the facility take security into consideration when routing shipments to and from this facility? Yes No
21) At the time of hire, are new employees oriented on security procedures and requirements and provided general security awareness training? Yes No

F. Chemical Facility Anti-Terrorism Standard Information (CFATS)
1) Has your facility utilized the AG RETAIL FACILITY DHS CFATS STATUS form to determine your applicability regarding DHS Chemicals of Interest (COI)? Yes No N/A
2) The facility has met all DHS requirements regarding chemical storage by falling into one of the following categories: (Circle One)
   a) Your facility chemical inventory identifies no storage of chemicals of interest (COI) as outlined in DHS Appendix “A” (no TopScreen submission required).
   **If this option is selected, continue the remainder of the survey.
   b) Your facility has submitted a TopScreen for COI storage but was determined per DHS to be a NON-TIERED facility.
   **If this option is selected, continue the remainder of the survey.
   c) Your facility has submitted a TopScreen for COI storage and has been categorized as a tier 1 thru 4 facility but your site security plan has been approved by the DHS.
   **If this option is selected, stop here. Your survey is complete.
3) Does the facility consider the following regarding storage of COI; secondary containment, packaging size/type, fencing, secure storage areas, CCTV, motion alarms, lighting, smoke detectors, valve locks, etc. Yes No N/A
4) Are ammonia nurse wagons stored within a fenced, secure area? Yes No N/A
5) Does the duration of rail storage of chemical exceed 24 hours? Yes No N/A
6) Does the duration of truck transport storage of chemical exceed 24 hours? Yes No N/A
7) Is the main breaker for electric power located in a secure area (enclosed secure building or fenced)? Yes No
8) Does the facility have a process in place that validates customers seeking security sensitive products? Yes No N/A
9) Does the facility accept cash payment for security sensitive products? Yes No N/A
10) Does the facility confirm the identity of persons picking up security sensitive products? Yes No N/A

Cameras and Security Systems

- Visible to be a deterrent
- IT spec'd to be firewall complaint and anti-Hack

Key Access and Controlled Access

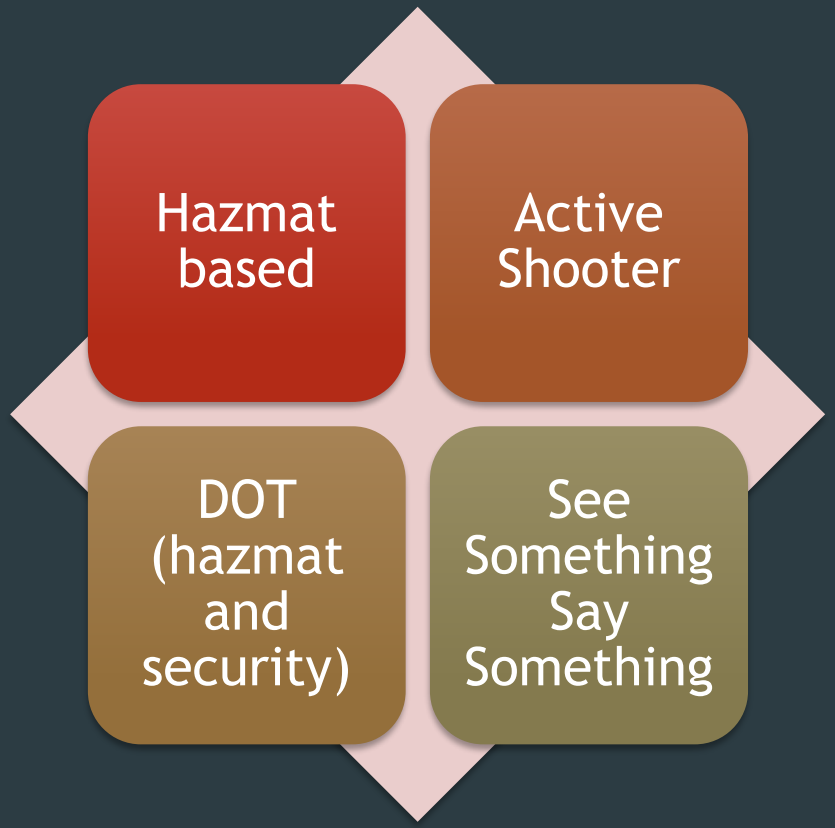
OFFICE

GROUNDS

VEHICLES

BULK TANKS (PRODUCTS AND FUEL)

Employee Trainings



Other Security Concerns

- Theft
- Bizarre Purchase Requests (esp. focused on high risk chemicals)
  - Cash Buyers
  - Non-Customer
  - Out of Country/State
- Disgruntled employees
- Homeless Encampments

Additional Informtation

- CFATS
- https://csat-help.dhs.gov/

- Responsible AG
- https://www.responsibleag.org/

- Steve Griego
- Steve.griego@simplot.com

Simplot®

2022 Fluid Technology Workshop

November 30th, 2022
The Blackhawk Marriot
Davenport, Iowa

2:10 PM

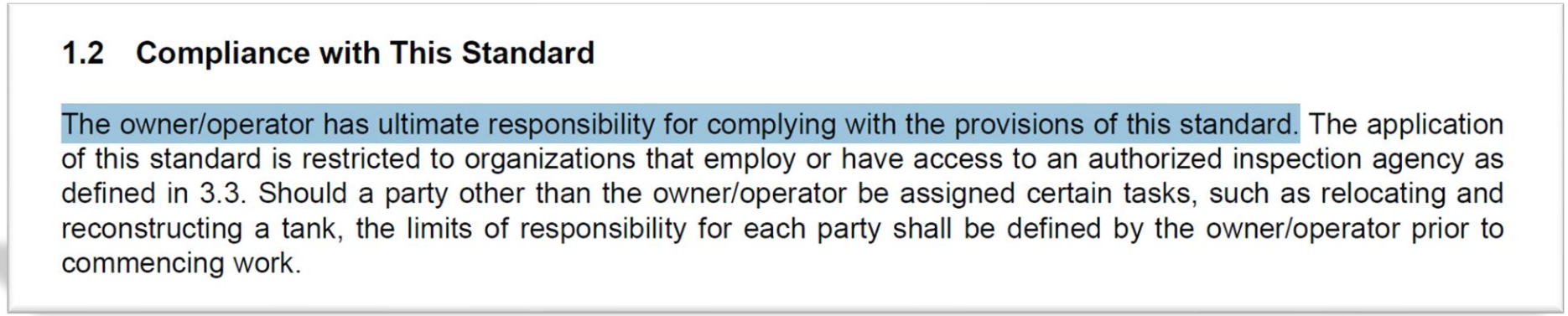
Liquid Storage Tank Safety Recommendations.
Is your fertilizer tank fit for service?

John Cornell, H.I.R. Technical Services

DRAKE WELL
MUSEUM AND PARK
Titusville, PA • 1859

The information in this presentation is 100% real situations that I have seen first hand.

- Numerical values and pictorial references have been changed as not to be vendor specific.
  - ✓ *Any similarities to inspection reports provided by others are not to be deemed as relating to any individual or specific party.*
  - ✓ *For training purposes only.*
  - ✓ *The tank owner can drive quality. <u>We must demand better reports!</u>*



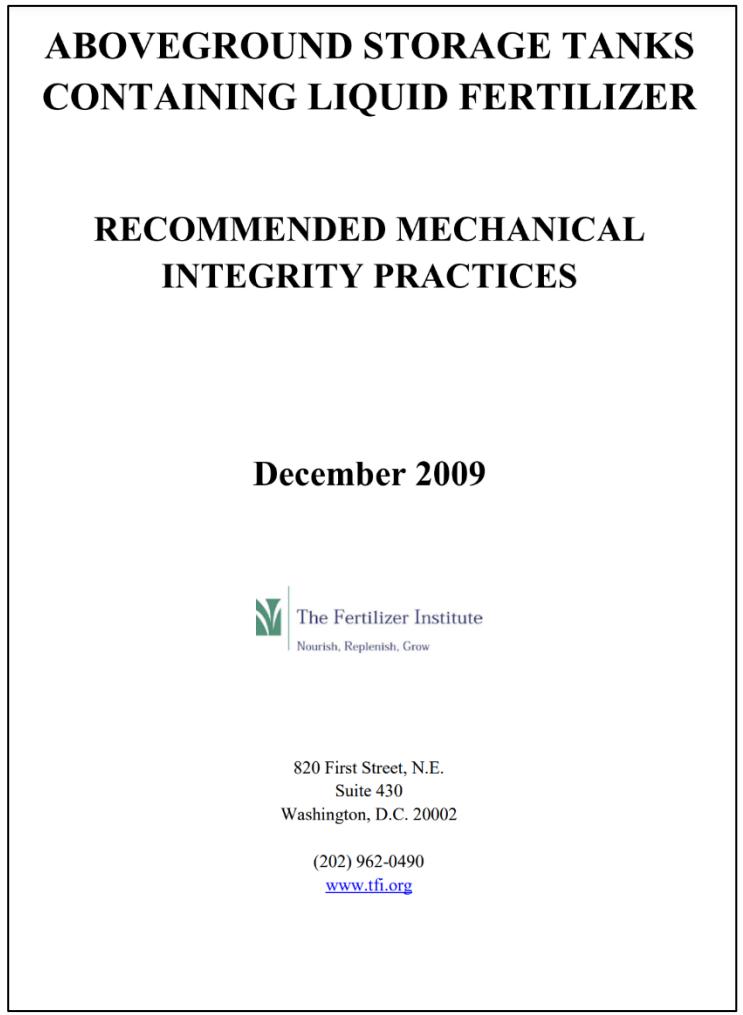
1.2 Compliance with This Standard

The owner/operator has ultimate responsibility for complying with the provisions of this standard. The application of this standard is restricted to organizations that employ or have access to an authorized inspection agency as defined in 3.3. Should a party other than the owner/operator be assigned certain tasks, such as relocating and reconstructing a tank, the limits of responsibility for each party shall be defined by the owner/operator prior to commencing work.

  - ✓ *<u>Remember, if former employees accepted shotty tank inspection reports, the onus is on the company to go back over the reports and to make sure they are in compliance.</u>*

Is there guidance for the construction, inspection, and repair of larger Liquid Fertilizer tanks.

Yes, The Fertilizer Institute.



ABOVEGROUND STORAGE TANKS CONTAINING LIQUID FERTILIZER

RECOMMENDED MECHANICAL INTEGRITY PRACTICES

December 2009

The Fertilizer Institute
Nourish, Replenish, Grow

820 First Street, N.E.
Suite 430
Washington, D.C. 20002

(202) 962-0490
www.tfi.org

*"In general, the Tank Integrity Work Group and the UAN Working Group recommend that all new tanks should be designed and built to American Petroleum Institute (API) Standard 650 and inspections of existing tanks **should** be based upon API Standard 653, but with modifications for the unique characteristics of a tank storing liquid fertilizer."*

"3.4 For ASTs used to store liquid fertilizer and of unknown design, or built to known criteria other than API 650, (perhaps AWWA D100 or 103). inspection criteria should be in accordance with the guidelines and recommendations of API 653 to the extent possible. An authorized inspector, or an authorized inspector in conjunction with an experienced storage tank engineer, may modify the inspection in consideration of original construction details that do not meet API 650 design criteria. The result of the inspection should be equivalent to the API 653. In addition, consideration should be given to other ancillary criteria as described in Sections 4, 5, 6 and 7 regarding fertilizer-specific issues."

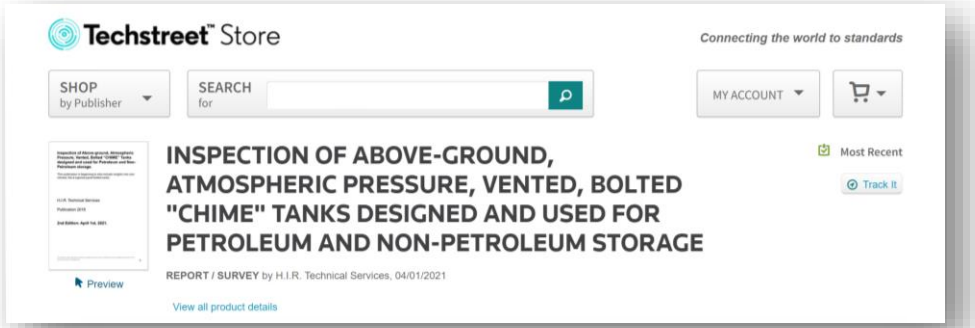
The reason for this presentation….

1) API 653 inspection reports must be complete “d”.

2) Fertilizer tanks are covered under the law. *Some say that a fertilizer tanks can be inspected to a lesser degree than a gasoline tank.*

3) Some say that any certified inspector can inspect any tank.

4) An Inspection report should be used to right the past.



Appendix C, Checklist, General rules regarding inspections.

79) Intentionally left blank.

80) Inspect the floor staves for topside coating failure and corrosion. Inspect the underside for corrosion. Coating failures **must** be addressed before the tank is returned to service.

81) Any nuts that do not appear to have as much thread engagement as the others in their proximity, should just be checked to see if they are loose by using only your fingers to see if you can easily tighten them. Only the owner should use a wrench to tighten any nuts that are found to be loose.

82) Check the vertical ladder, and the roof rafters for signs of corrosion or structural failure.

83) Intentionally left blank.

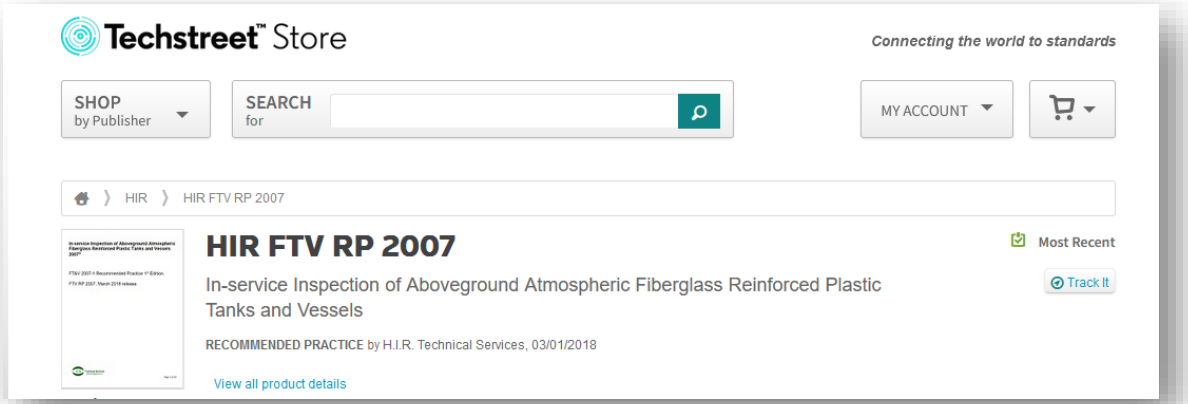
84) Take photos capturing all of the interior of the tank, so the tank owner can clearly see the condition of the internal coating. Take close-ups of all areas exhibiting a higher rate of corrosion than the remaining portion of the tank's interior. One common cause of metal loss could be related to abrasion caused by movement of suspended solids.

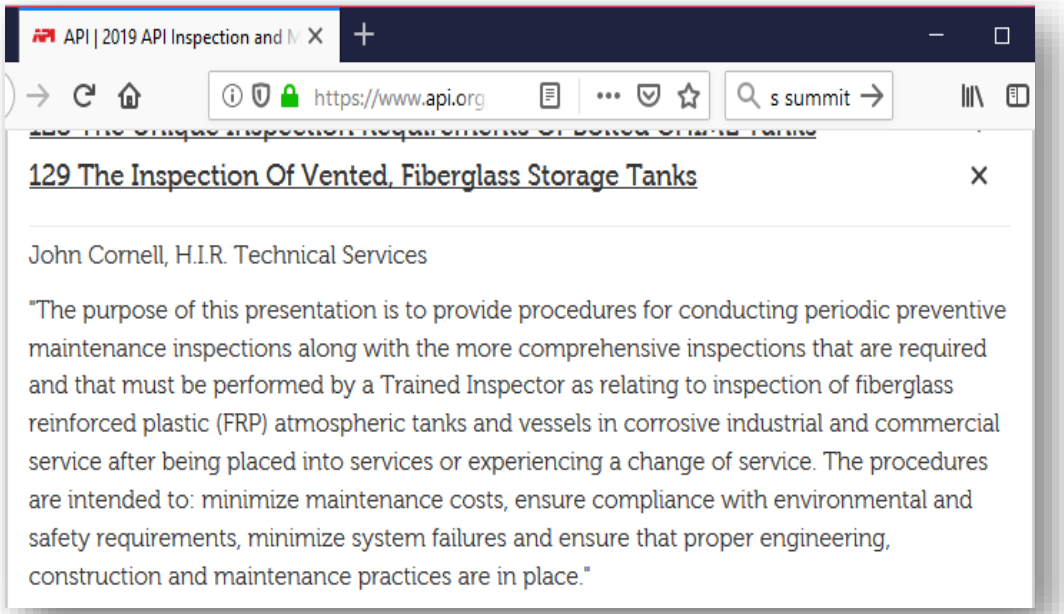
85) Use a pit gage* to record the depth of isolated pits. Afterwards, create a drawing showing the exact locations of all active corrosion and pits found on the inside of the shell. This will allow the owner to visually monitor these areas for possible through wall corrosion that may eventually occur.

86) Intentionally left blank.

87) Intentionally left blank.

*What a pit gage is and how it is used? Turn to 14.025 of this publication.





One tank inspection website states:

"For liquid fertilizer tanks, no federal requirements exist as to how often an API 650 tank must be inspected."

Citation 312927429/01001

Inspection	Reporting ID	Open Date	SIC	Establishment Name
312927429	0626700	04/01/2011	2869	

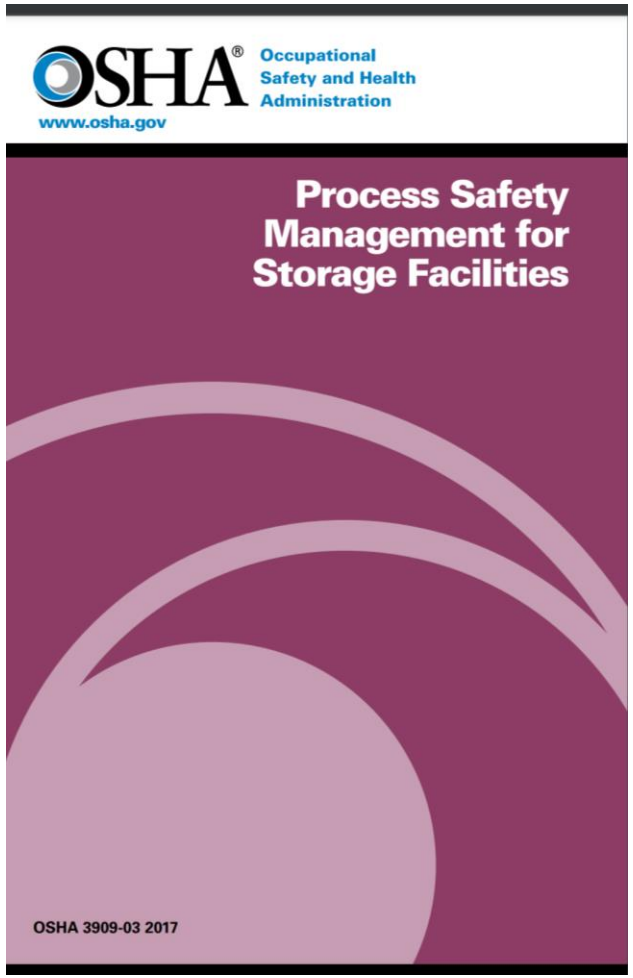
Citation	Issuance Date	Hazard Category
01001	09/23/2011	Chemical

Section 5(a)(1) of the Occupational Safety and Health Act of 1970: The employer did not furnish employment and a place of employment which were free from recognized hazards that were causing or likely to cause death or serious physical harm to employees in that: Employees were exposed to inhalation of toxic chemicals, fire and thermal burn, and struck-by hazards caused by the rupture of aboveground atmospheric storage tank containing flammable and combustible products. The employer failed to perform inspections and test on atmospheric storage tanks in accordance with Recognized and Generally Accepted Good engineering Practices (RAGAGEP), exposing employees to serious fire, explosion and toxic release hazards in the event a leak or rupture were to occur as a result of corrosion and or wall thinning. The employer did not develop and implement an inspection plan or procedure to perform internal and external inspection to ensure the ongoing integrity of any of the facilities atmospheric storage tanks and charge tanks. Feasible means of abatement, among others, include the following: 1) Adhere to the tank manufacturers instructions (2 Adhere API RP 575, section 6.1 FREQUENCY OF INSPECTION - Tanks covered by API Std 653 should be checked at least monthly. These routine in-service inspections should include checking for corrosion, leaks, settlement, distortion, and determining the condition of the foundation, insulation systems, and paint systems. The value of the API Std 653 informal monthly inspection is to detect changes. Personnel experienced in the tanks operation usually perform the monthly inspection. Observations, especially changed conditions, should be reported to a tank specialist for further assessment and evaluation. (3 Adhere API Std 653, section 6.4.2 INSPECTION INTERVALS - The interval from initial service until the initial internal inspection shall not exceed 10 years.

One tank inspection website states:

No federal requirements exist as to how often an API 650 liquid fertilizer tanks must be inspected.

I say that false statements like the one aforementioned could lead to more tank failures with the liquid fertilizer industry.



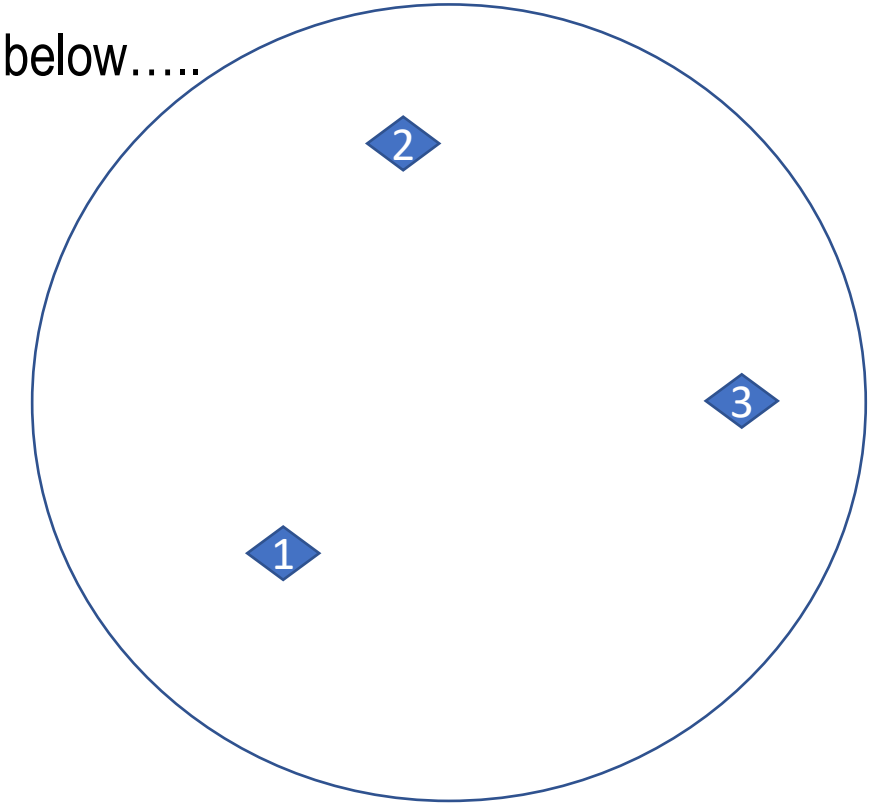
- A starting point for creating a mechanical integrity program is listing all equipment and etc..
- Recommendations from the manufacturer.
- Employers should look for applicable codes/standards or industry best practices.
- Inspections and tests must follow Recognized and Generally Accepted Good Engineering Practices (RAGAGEP).
- Inspection and test frequency must be consistent with manufacturer's recommendations and good engineering practices.

Sited therein:

- In 2008, a nearly 90-year-old liquid fertilizer storage tank catastrophically failed.
- Seriously injured two employees.
- Further, some tank inspection and testing activities did not follow recognized and generally accepted good engineering practices.

#1, API 653 Inspection Reports must be complete w/ very little guessing.

We took 3 Ultrasonic thickness readings on the roof as illustrated below…..



a. Do you believe this is complete or acceptable.

b. How many times have you walked on a tank roof and would you feel comfortable knowing this was the limit of the last inspection?

Roof plates as measured: .186”, .184”, and .182”

Average roof plate thickness as calculated…. = .184”

#1, API 653 Inspection Reports must be complete w/ very little guessing.

We took 3 Ultrasonic thickness readings on the roof as illustrated below…..

TANK ROOF EVALUATION

Any area or roof plates with any holes through the roof plate shall be repaired or replaced.

Minimum "t" thickness for a existing steel roof plate.

4.2 TANK ROOF EVALUATION

4.2.1 General

4.2.1.1 The structural integrity of the roof and roo
verified.

4.2.1.2 Roof plates corroded to an average thickness of less than 0.09 inches in any 100 inch area or roof plates with any holes through the roof plate shall be repaired or replaced.

#1, API 653 Inspection Reports must be complete w/ very little guessing.

This tank was inspected using API 653 as the basis…..

But….. This tank is only 7) years old and a settlement survey is not provided....

4.4 Tank Bottom Evaluation

Excessive foundation settlement of storage tanks can affect the integrity of tank shells and bottoms. Therefore, monitoring the settlement behavior of tanks is a recognized practice to assess the integrity of tank bottoms. See Annex B for techniques for evaluating tank bottom settlement.

B.3.4.5 In general, settlement occurs slowly, and for most existing tanks, the majority of settlement is presumed to have occurred in the first few years of service. Significant additional settlement will not be expected after the initial inspections.

And also, “Check for settlement” is found in Annex “C” twice.

#1, API 653 Inspection Reports must be complete w/ very little guessing.

$$t_{\min} = \frac{2.6\,(H-1)DG}{SE}$$

Sometime they do this…….. $\dfrac{2.6 \quad 28 \quad 47 \quad 1.00}{21000 \quad 1.0} = \dfrac{3421.6}{21000} = 0.163$

Fertilizer

This is what they should have done……. $\dfrac{2.6 \quad 28 \quad 47 \quad 1.35}{21000 \quad 1.00} = \dfrac{4619.16}{21000} = 0.220$

#2, What is required for a report to contain and does it change in relationship to the product being stored? Some say that a fertilizer can be inspected to a lesser degree than a gasoline tank?

Notes:

- Tanks usually don't fail due to the product type, but instead to stress and corrosion.

- To say you are going to perform a complete 653 inspection sort of makes everyone think that you are going to perform a complete 653 inspection.

- Truth be told, owners of more hazardous product tanks (gasoline) have more regulators involved so they must cross the "t"s and dot the "i"s. Some tank like fertilizer tanks are more remote and who's really paying attention.

- And yes, there are more issues for the owners of PHMSA and EPA regulated tanks and the owners know what to look for and don't fall for the low-bidders sales pitch, "you don't need to do that because it's not required for your type of product" or "API 653 is just a guide"

#3, Some say that any certified inspector can inspect any tank.

Notes:

- This is just not true.

- Inspectors start out with a basic understanding of tank design and then compare what is currently standing right in front of them to what they are convinced to have been there many, many years ago.

- An inspector that only has experience with inspecting small, Annex “J” (shop-fabricated) tanks would be hard-pressed to inspect a 200’-0 diameter PHMSA regulated gasoline storage tank, having a modern full-surface contact floating roof having a wiper seal around the perimeter, a foam system and a beautiful geodesic dome on top. Don’t send this person to my refinery. I as the tank owner can say no. I as the owner am responsible for my tank’s inspection.

- Are they sending API 653 Certified Inspectors out to inspect your given tank? Sometimes, NO.

- API 653, Section 12.1.1.2, Personnel performing NDE shall be qualified in accordance with API 650, Section 8, and any supplemental requirements given herein.

#4, An Inspection report should be used to right the past.

Assumptions can hurt the client….

* Original roof thickness assumed to be 12ga. (.104).

This was NOT a bolted tank with a baked-on coating or galvanized coating.

How was this derived?

Wrong!!

Individual spot UT reading taken on roof plates.

Maximum reading .102”

Minimum Current minimum thickness: .096”

CR = (.104-.096) / 38 years =.00021” per year.

R_L = (.096 -.090) / or .006 / .00021= 28.5 years.

Individual spot UT reading taken on roof plates.

Maximum reading .102”

Minimum Current minimum thickness: .096”

CR = (.~.188-.096) / 38 years =.0024” per year.

R_L = (.096 -.090) / or .006 / .0024 = 2.5 years

Closer!!

When the inspector assumes that one part of the tank was not built in accordance with API 650, all other variables within the required calculations need to be investigated.

In closing I would like to once again thank the management team here at NISTM for this continued opportunity.

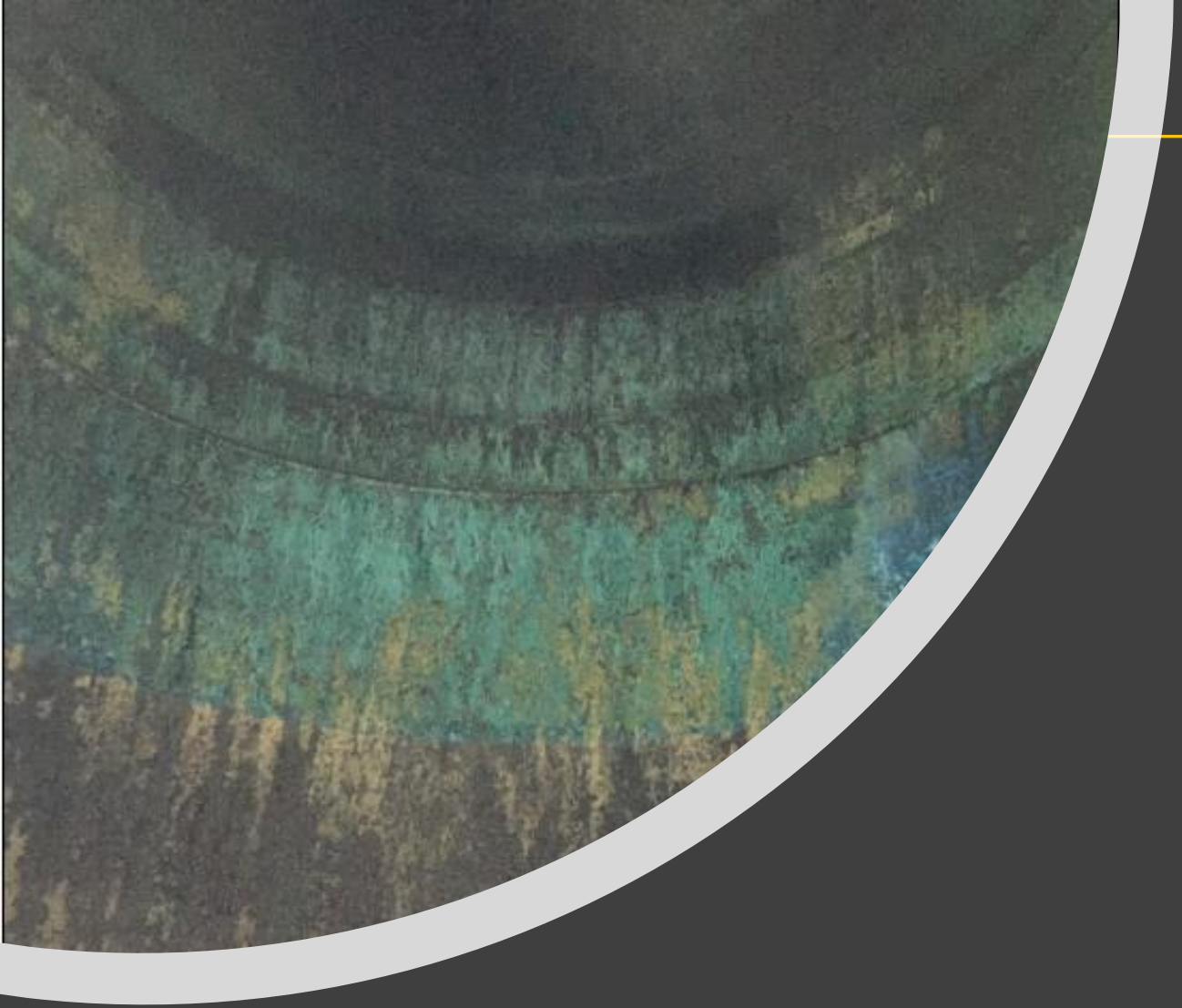
I would like to open the floor for any questions regarding today's presentation.

Afterwards, feel free to track me down for any generic tank questions that you may have.

Thank you.

John Cornell, Sr. Storage Tank Specialist
H.I.R. Technical Services

LinkedIn: https://www.linkedin.com/in/john-cornell-3a2b8346/
Twitter: https://twitter.com/TankTrainer1
Bizfluence: https://bizfluenceapp.com/hubs/storage-tanks



Product Stability and Compatibility

"Quality is not what happens when what you do matches your intentions. It is what happens when what you do matches your customers' expectations." Guaspari

Presented by Jesse Voss

Quality Assurance - Specialty Liquids

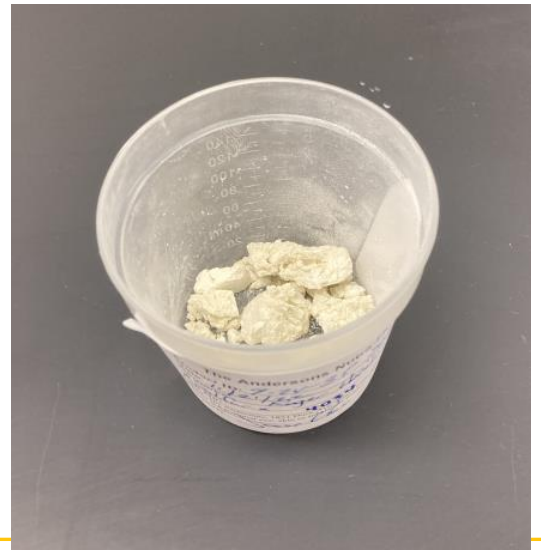
The Andersons

Product Stability and Compatibility

- Stability
  - Major issues affecting stability - Extremes
    - Hot Summer Storage
    - Freezing Cold Winter Storage
  - Formulate the problem out
  - Reduce inventory of vulnerable products during extreme periods
    - 10-34-0 in Summer
    - 6-24-6 D in Winter
  - Ship vulnerable products closer to time of use
  - Understand the effects of extreme storage conditions on received product
- Compatibility
  - If done right, compatibility can be formulated out
  - Jar test is always recommended

Compatibility

- Differentiation – Makes formulation tricky
  - Stringent process for product developement
- Reduced passes - Humic Acid compatibility with Capture LFR
- SRN (triazone) compatibility with Polyphosphate
- Non chelated micronutrient compatibility with Ortho and Pyrophosphate



Compatibility

	Compatible
	Limited Compatibility
	Incompatable
Color	Might change final color

Product last in the trailer

Product to be loaded	Gold Start Fertilizer 20% Polys	Premium Fertilizer 50% Polys	Conventional 10-34-0 70% Polys	Diamond Fertilizer 100% Ortho	X-0-X zero Phosphate grades	Aqua Ammonia	Urea Solution	Ammonium Nitrate Solution	Urea Ammonium Nitrate Solution	Ammonium Sulfate solution	Ammonium Thiosulfate Solution ATS	Potassium Thiosulfate Solution KTS	Potassium Carbonate Solution	Super 72 SRN 28-0-0	Water	Nulex 10%,15%& 20% Zn	Citrate, EDTA 10% Zn (10XL)	Chelate 6 Zn	Chelate 9 Zn	Chelate Mn 6	10% B MEA	4.5 % Fe EDTA	7.5% Cu EDTA	MS Corn Mix	MS Soy Mix	MS Wheat Mix
Gold Start Fertilizer 20% Polys																						Color	Color	Color	Color	Color
Premium Fertilizer 50% Polys																						Color	Color	Color	Color	Color
Conventional 10-34-0 70% Polys																						Color	Color	Color	Color	Color
Diamond Fertilizer 100% Ortho																						Color	Color	Color	Color	Color
X-0-X zero Phosphate grades																										
Aqua Ammonia																	Color					Color	Color	Color	Color	Color
Urea Solution																						Color	Color	Color	Color	Color
Ammonium Nitrate Solution																	Color					Color	Color	Color	Color	Color
Urea Ammonium Nitrate Solution																	Color					Color	Color	Color	Color	Color
Ammonium Sulfate solution																						Color	Color	Color	Color	Color
Ammonium Thiosulfate Solution ATS																						Color	Color	Color	Color	Color
Potassium Thiosulfate Solution KTS																						Color	Color	Color	Color	Color
Potassium Carbonate Solution																						Color	Color	Color	Color	Color
Super 72 SRN 28-0-0																						Color	Color	Color	Color	Color
Water																	Color									
Nulex 10%,15%& 20% Zn																	Color			Color		Color	Color	Color	Color	Color
Citrate, EDTA 10% Zn (10XL)																				Color		Color	Color	Color	Color	Color
Chelate 6 Zn																	Color			Color		Color	Color	Color	Color	Color
Chelate 9 Zn																	Color			Color		Color	Color	Color	Color	Color
Chelate Mn 6																						Color	Color	Color	Color	Color
10% B MEA																										
4.5 % Fe EDTA																							Color	Color	Color	Color
7.5% Cu EDTA																						Color				Color
MS Corn Mix																										Color
MS Soy Mix																										Color
MS Wheat Mix																										

Compatibility

The Andersons Ag Specialty Compatability Chart

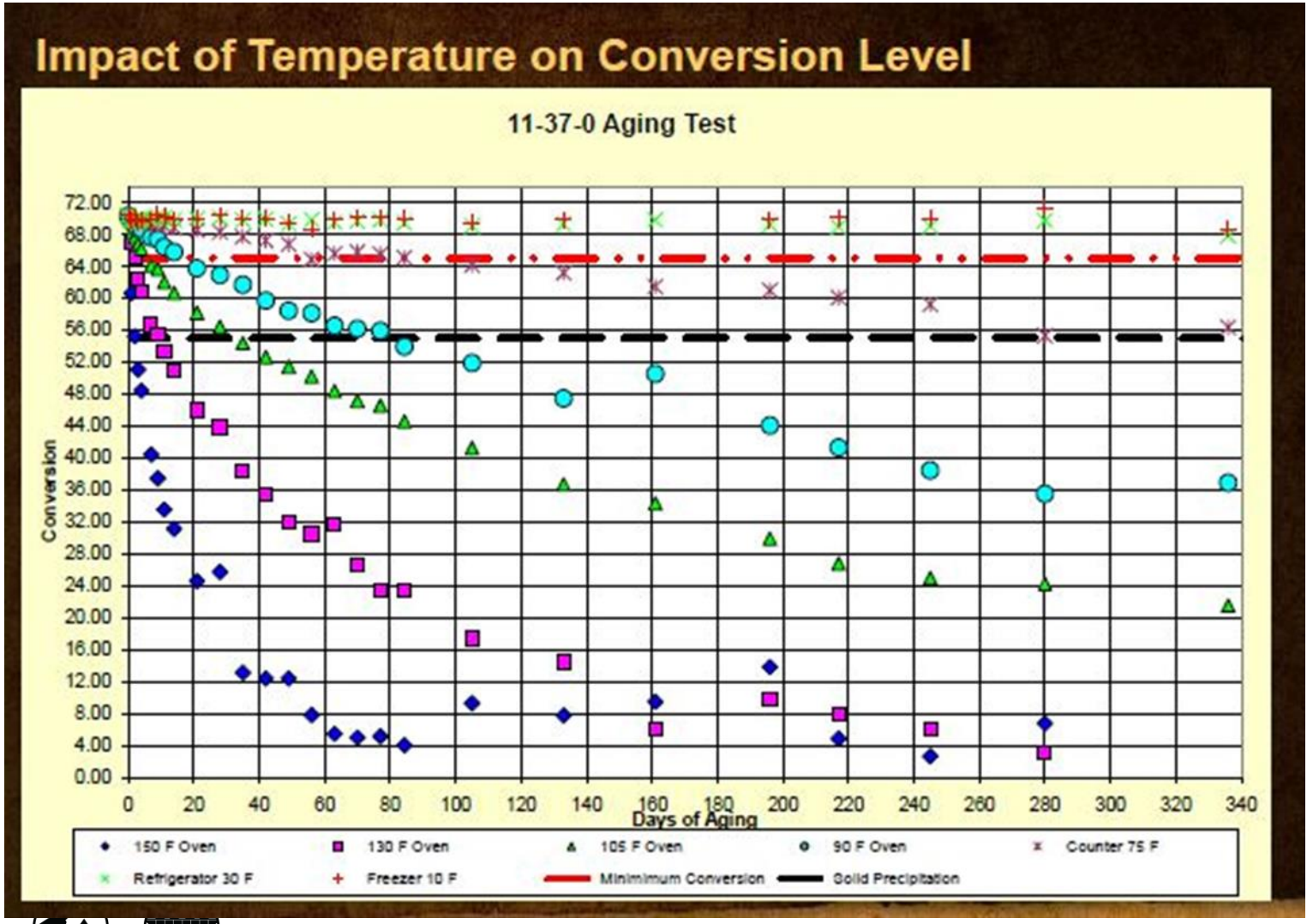
PRODUCTS	TRIPLE CROWN	EEZY MAN	BORON 10%	APP CORN MIX	MICRO CARB ZMB	PHOS FIX	SWEET N' EEZY	EZG CA 3%	EZG CU 7.5%	EZG FE 4.5%	EZG MG 2.5%	EZG MN 6%	EZG ZN 9%	EZG ZINC MAN	EZG BEAN BLEND	EZG CORN MIX	EZG WHEAT BLEND	EEZY CAL 10%	EEZY CAL-B	EEZY CAL-K	LIQUID CALCIUM NITRATE	SEASON PASS	100% ORTHO	POLY BLENDS	OVERPASS SF	OVERPASS CF	FOLIAR K	BEAN MAKER	MICRO NOURISH	ULTRA MATE SG	UAN	GLYPHO SATE
EZG ZINCMAN																																
EZG BEAN BLEND																																
EZG CORN MIX																																
EZG WHEAT BLEND																																
EEZY CAL 10%																																
EEZY CAL-B																																
EEZY CAL-K																																
LIQUID CALCIUM NITRATE																																
SEASON PASS																																
100% ORTHO																																
POLY BLENDS																																
OVERPASS SF																																
OVERPASS CF																																
FOLIAR K																																
BEANMAKER																																
MICRONOURISH																																
ULTRAMATE SG																																
UAN																																
GLYPHOSATE																																

Color Chart

- Compatible
- Splash N' Go
- Do Not Mix

The Andersons

Extreme Heat

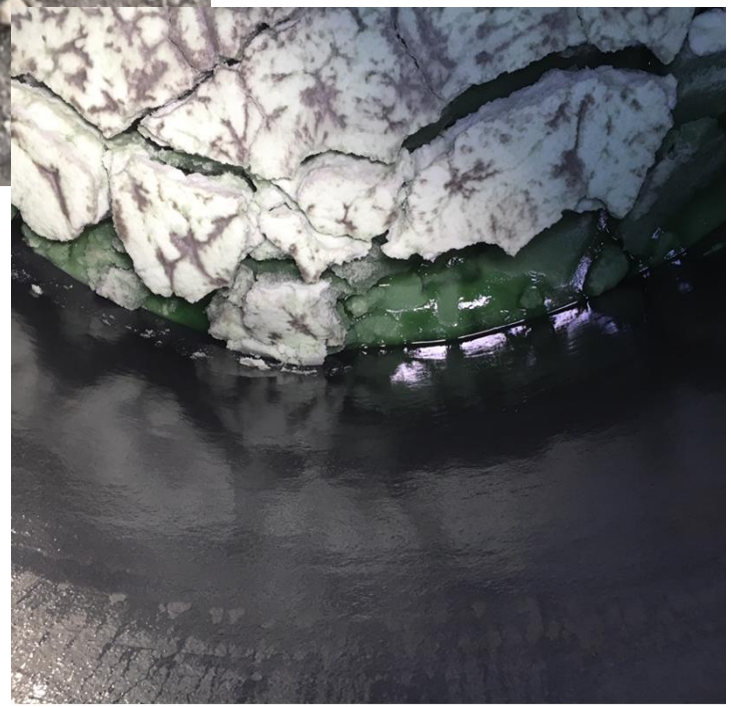


Johnny Walkers

Extreme Cold

- Seeing increased gallons shipped in the fall to be stored over winter
  - Market driven
- 80/20 and 100% Ortho products are most vulnerable
- Extreme Cold weather
  - Storage – Steel Tank
  - Shipment – Stainless Trailer

Salt out Material

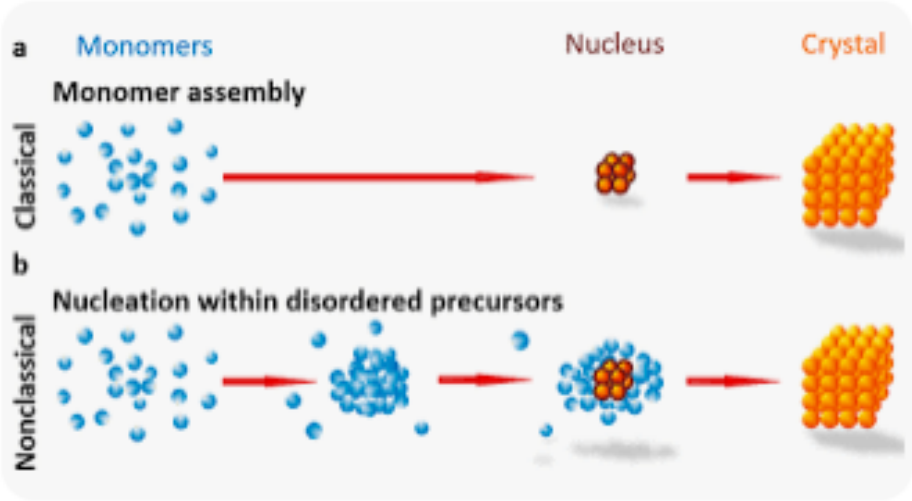


Product Analysis

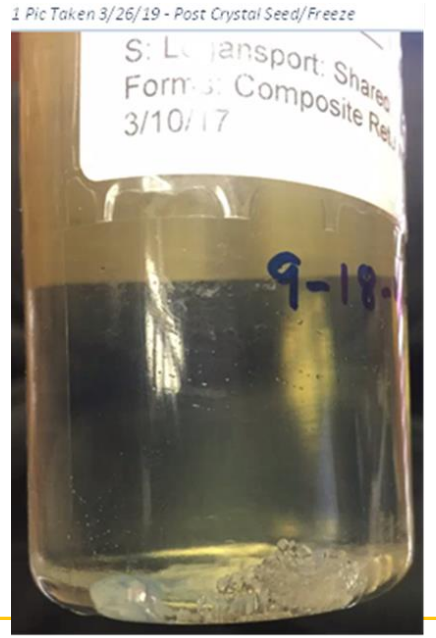
- As-is analysis
  - N = 13.68%
  - P205 = 42.64%
  - K20 = 1.85%
    - Boron = 0.006%
    - Copper = 0.0142%
    - Iron = 0.211%
    - Manganese = 0.0354%
    - Zinc = 0.225%
- DAP Analysis
  - 18-46-0 (dry)

Nucleation

- Product can seem to be stable in cold extremes in very clean containers
- Presence of crystals in a tank can cause nucleation
- Reduces the stability of the overall product
- Clean tanks are extremely important for product stability



ACS Publications - American Chemical Society

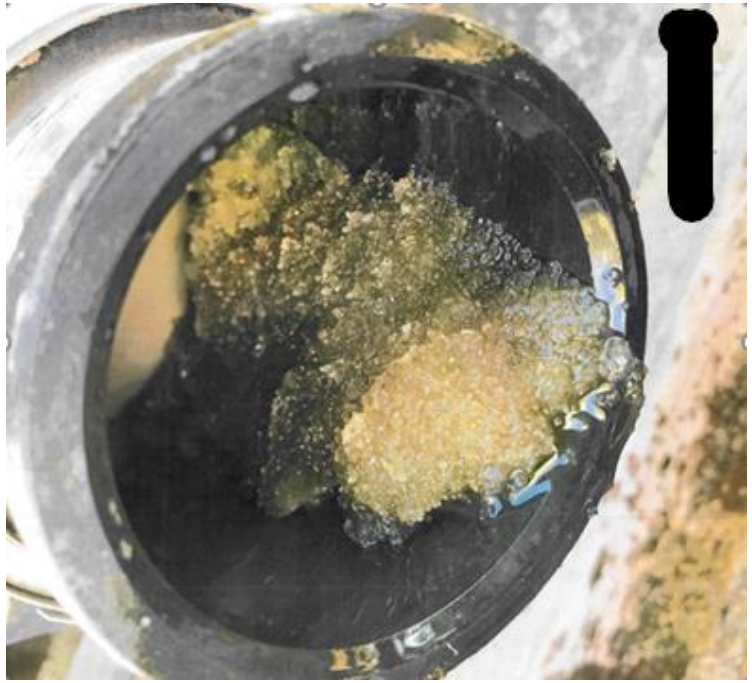


Phase Separation

- Water freezes and rises to the top
- Salt solution concentrates
- Sometimes crystals can then form in the concentrated salt solution and fall to the bottom

Product Handling

- Handling product at temps below the SOT (salt out temperature)
  - Does not allow crystals to go back into solution
  - Aggressive agitation and heat are required



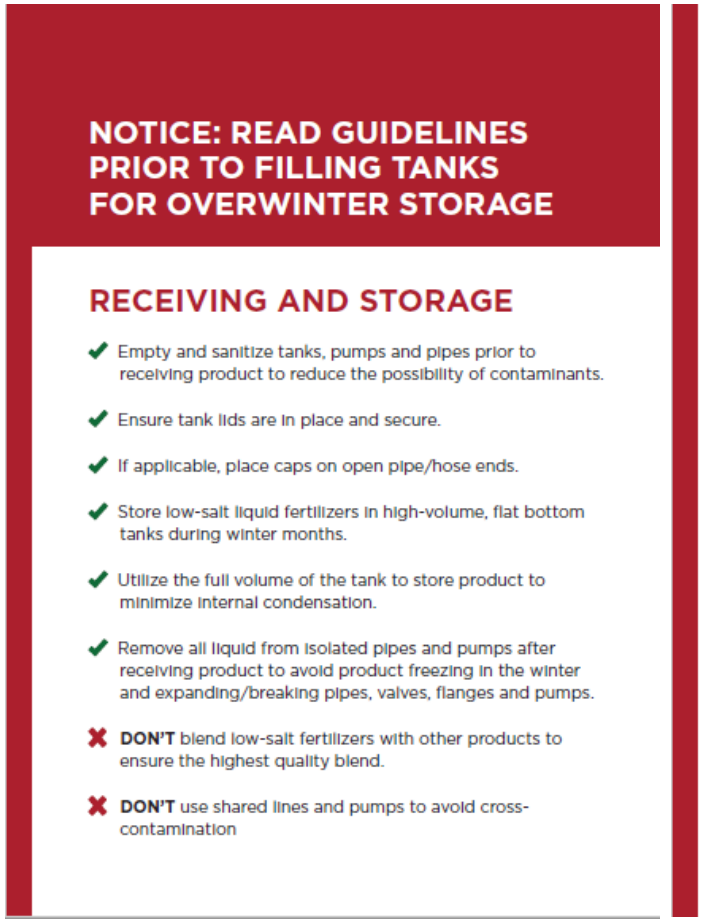
Production Correction

- Monopotassium Phosphate (MKP) formation at Low pH

New Challenges…Mold

- Increased carbon additives
  - Fulvic
  - Humic
- Product Carryover
  - Water condensation in tank tops leads to a thin water layer on top of product.
  - Prime environment for mold growth.

Product Handling and Storage Guidelines



NOTICE: READ GUIDELINES PRIOR TO FILLING TANKS FOR OVERWINTER STORAGE

RECEIVING AND STORAGE

- ✔ Empty and sanitize tanks, pumps and pipes prior to receiving product to reduce the possibility of contaminants.
- ✔ Ensure tank lids are in place and secure.
- ✔ If applicable, place caps on open pipe/hose ends.
- ✔ Store low-salt liquid fertilizers in high-volume, flat bottom tanks during winter months.
- ✔ Utilize the full volume of the tank to store product to minimize internal condensation.
- ✔ Remove all liquid from isolated pipes and pumps after receiving product to avoid product freezing in the winter and expanding/breaking pipes, valves, flanges and pumps.
- ✖ **DON'T** blend low-salt fertilizers with other products to ensure the highest quality blend.
- ✖ **DON'T** use shared lines and pumps to avoid cross-contamination

SPRING HANDLING: RECIRCULATION & FILTRATION

- ✔ Aggressive recirculation/agitation must be completed prior to removing product from tank.
- ✔ Recirculation/agitation can be initiated when product temperature is above the labeled salt-out temperature. 30 minutes is recommended for every 500 gallons of product. In all instances, longer is better.

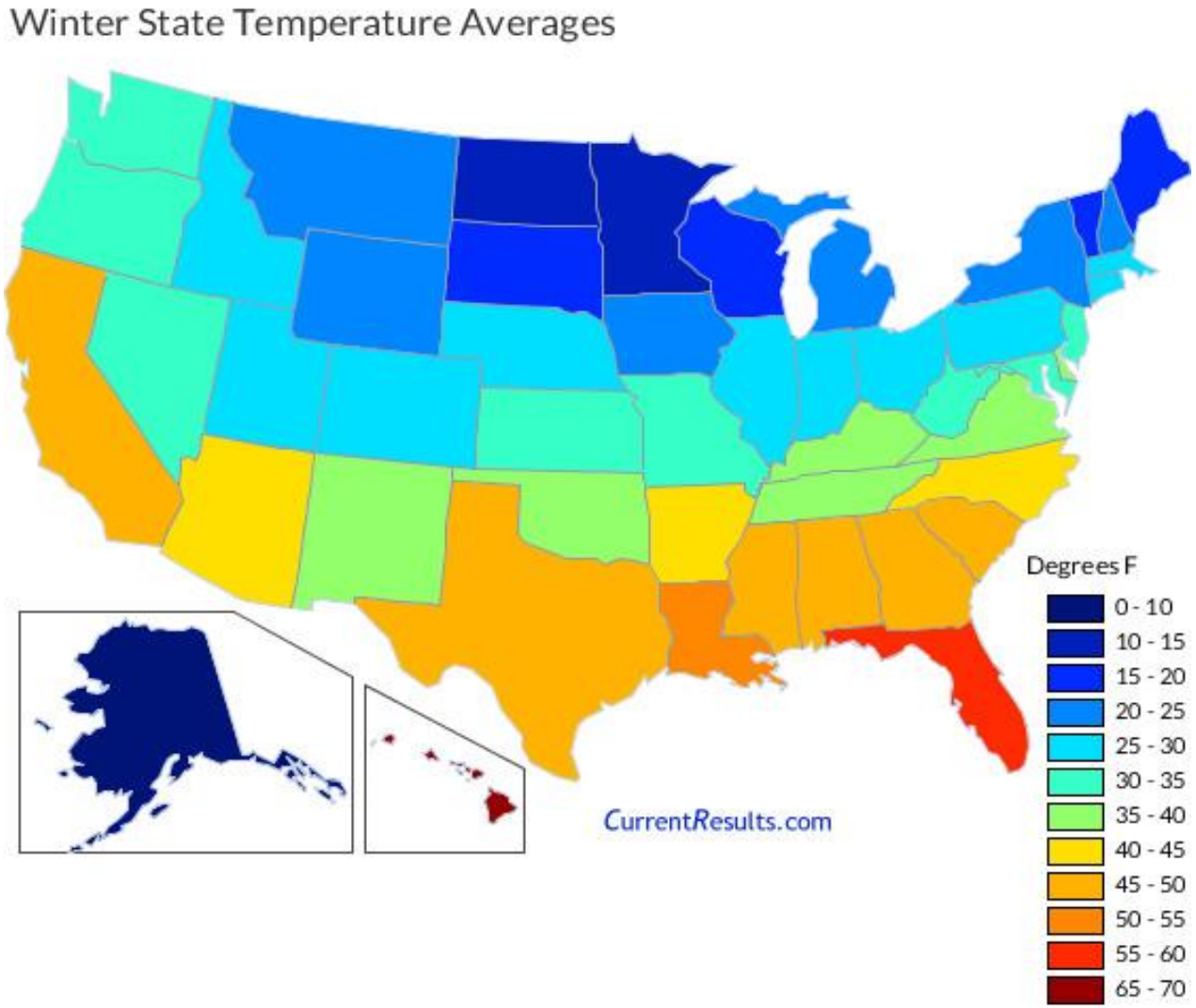
  An ice plug may be present at the top of the tank at the time of recirculation where water has come out of solution and froze. Aggressive recirculation/agitation will aid in reconstituting the water and any salt-out material back into solution.
- ✔ Filter product prior to use.

- In-depth guidelines available
  - https://andersonsplantnutrient.com/agriculture/resources/tank-guidelines

Winter Salt Out & Freezing issues

Presented by Terry Robinson
Scientist, Plant Nutrient Group
The Andersons

Winter State Temperature Averages supplied by NOAA National Climatic Data Center



What to do when winter arrives?

Masks were worn so we

didn’t catch whatever the

geese caught.

Probably tetanus.

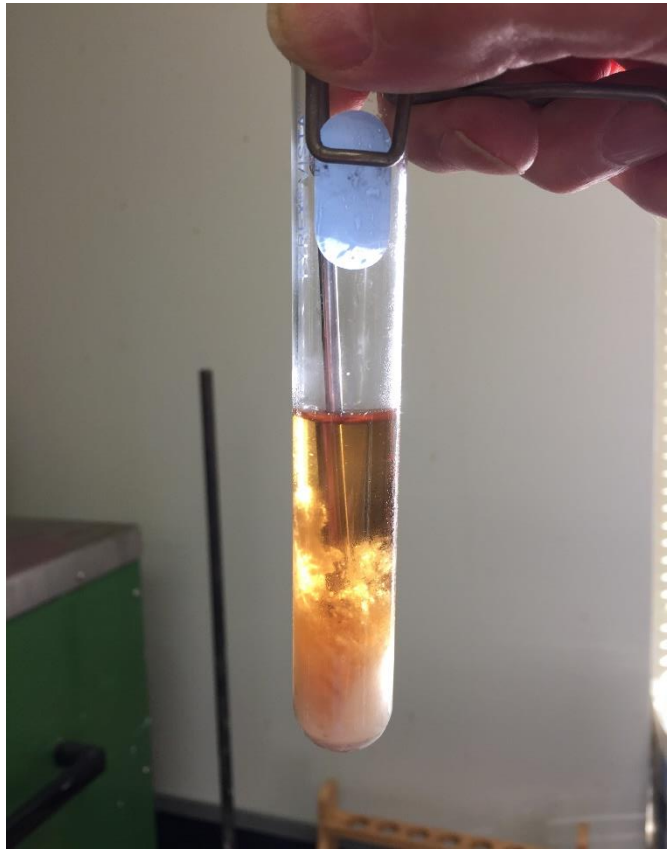
Methods of Determining Salt out Temperatures

New ISO/DIS 23381 Determination of Salt Out (Crystallization) Temperature of Liquid Fertilizers

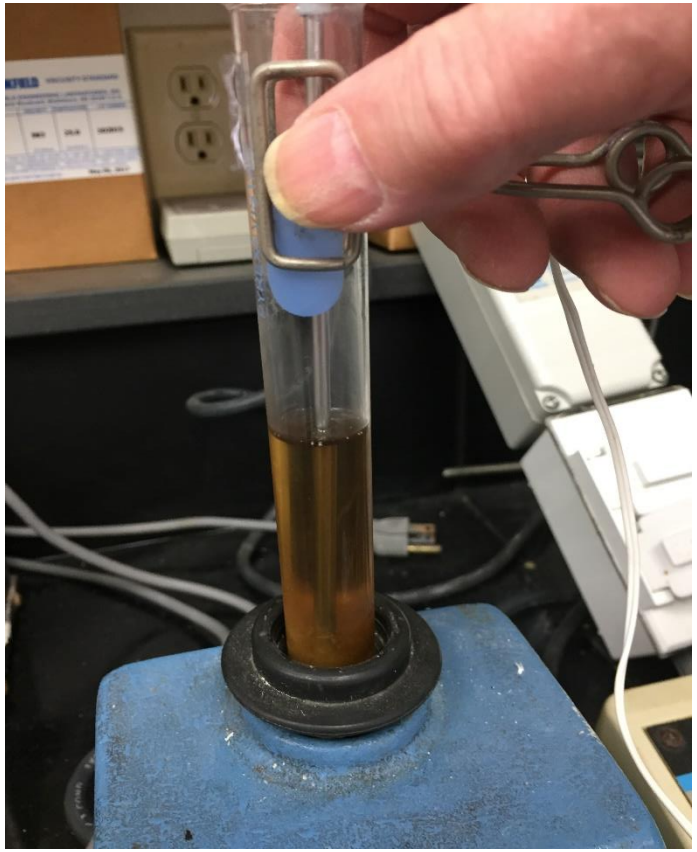
Adopted Andersons Methods for determining Salt out temperatures

1) **Quick Chiller Method**: Maintain Chiller at about -24 F. Expose sample to chiller via clear test tube and record temperature and type of solids that form. Remove sample from chiller and stir vigorously with test tube stirrer at room temperature. Record temp when solution is clear and free of solids. Repeat if needed. This is the salt out temperature reported. This is a quick test and since you are using the temperature when the sample warms up to clear, This value represents the ISO/DIS 23381
2) **Slow Cooling/thawing method**: Subject samples to slow incremental temperature decreases and record temperature and type of solids that form. Then slow incremental increases to temperature until samples is clear. Repeat 3 cycles. Record this temperature when sample is clear as the Salt out temperature. We have seen some salt out temperatures increase by 15-20 F because of freeze thaw concentration effects.

Salt Out Determination Chiller Method



Sample exposed to -25 ºF until solids start to appear & temperature recorded as start temperature. Then exposed another 2-3 minutes longer.

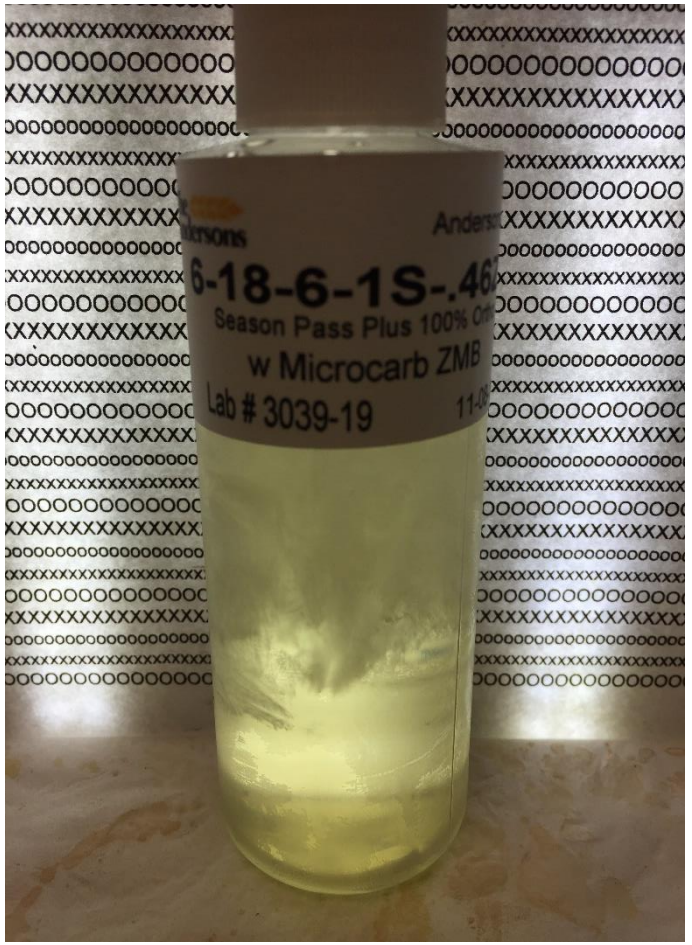


Sample is then stirred with test tube stirrer and temperature probe. Solids are observed as they slowly re dissolve.

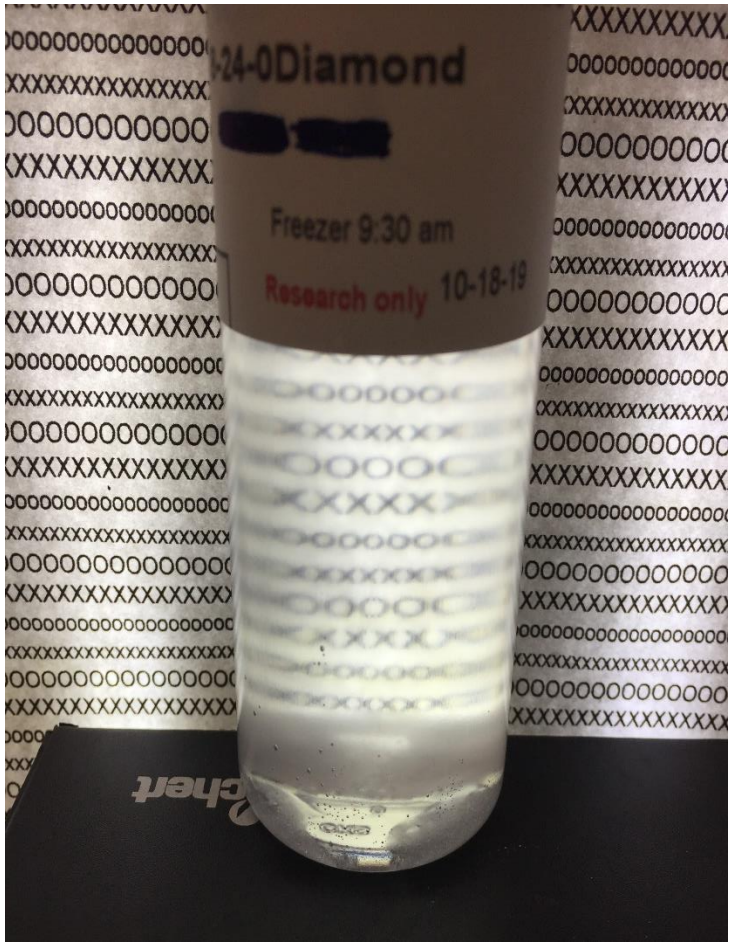
Sample right before the salt out temperature is recorded. You can see a small amount of ice phase still present.

100% Ortho Phosphate fertilizers exposed to freezer 4 ºF

Ice phase on top and MAP & DAP on the bottom.



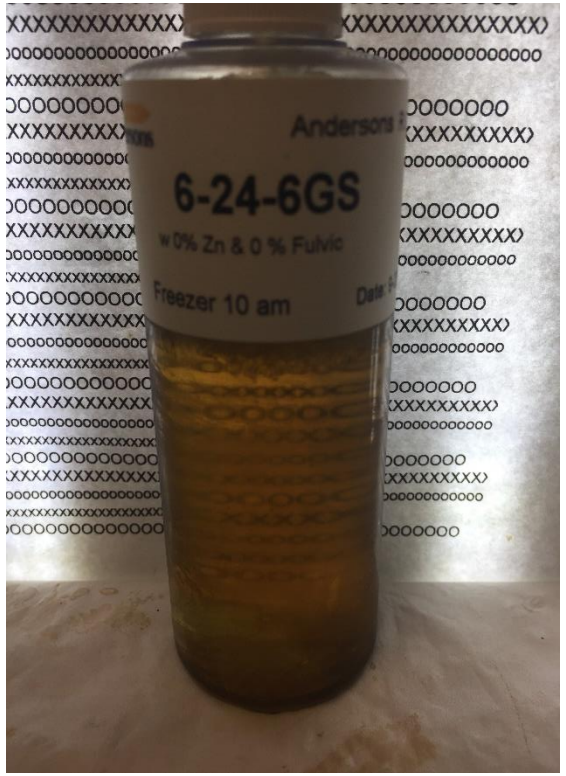
Ice phase that floated to the top



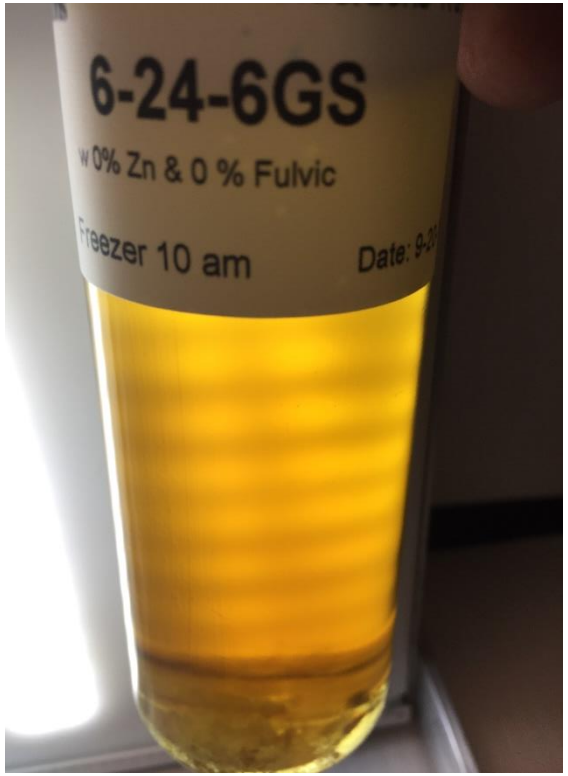
Sample was in freezer 5 days then sat idle (68 ºF) 5 days. MAP & DAP crystals still not dissolved.

80% Ortho Phosphate fertilizers exposed to freezer 4 ºF

6-24-6 80% Ortho Phosphate
In freezer 4 ºF for 2 weeks. Note the ice on top and MAP & DAP crystals on the bottom.



Same sample as on the left. Clear liquid in the middle with ice on top and crystals on the bottom



Same sample as on the left. Exposed to 68 ºF for 10 days no agitation. Note the MAP & DAP crystals still on the bottom.

Observations when Fertilizer Salts Out

- Ice phase usually forms first and floats to the top. Since the ice is primarily water, this process concentrates the other components in the fertilizer thus changing the physical characteristics of the system.

- With this increase in concentration of the liquid portion, the formation of MAP & DAP crystals becomes more possible. You now have a product that is non-homogeneous and will behave differently than before it salted out.

- **Solution after Salt out:** Heat of some kind is necessary to re-dissolve the MAP & DAP crystals as well as the Ice. With heat alone, the process will take an extended amount of time and the final product will be stratified with low concentration fertilizer on the top and high concentration fertilizer on the bottom, leaving the solution susceptible to further salt out episodes.

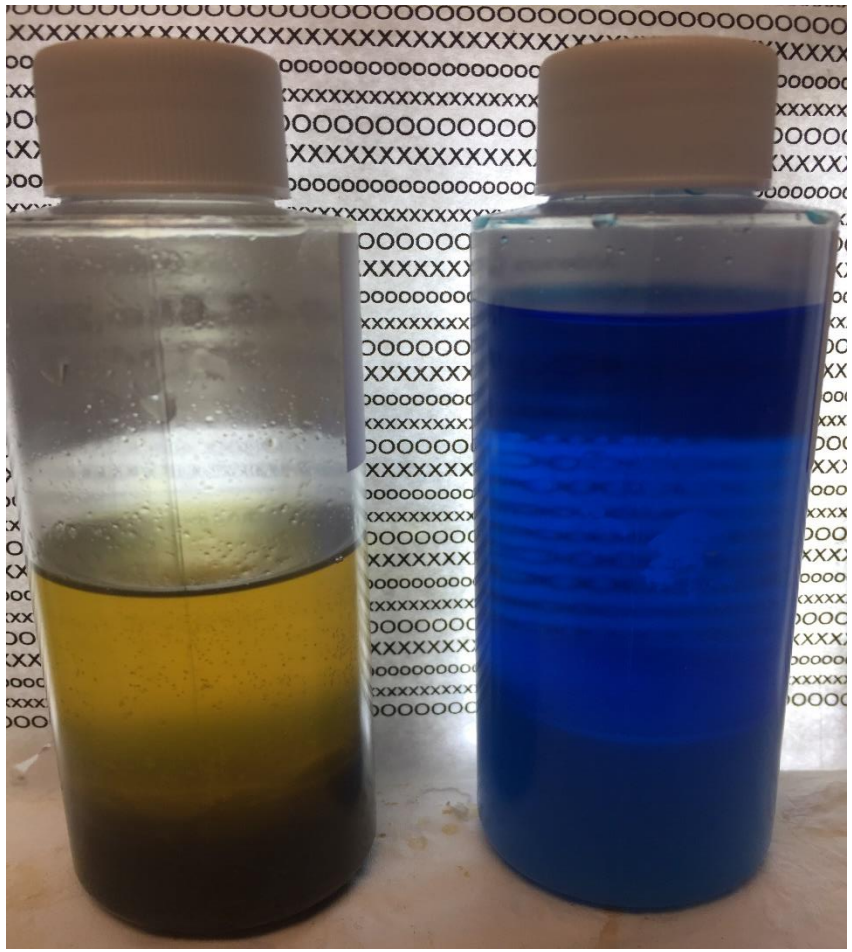
- Along with heat, one must also introduce some type of agitation/re-circulation. This helps the fertilizer return to the original concentration throughout the vessel before the salt out occurred.

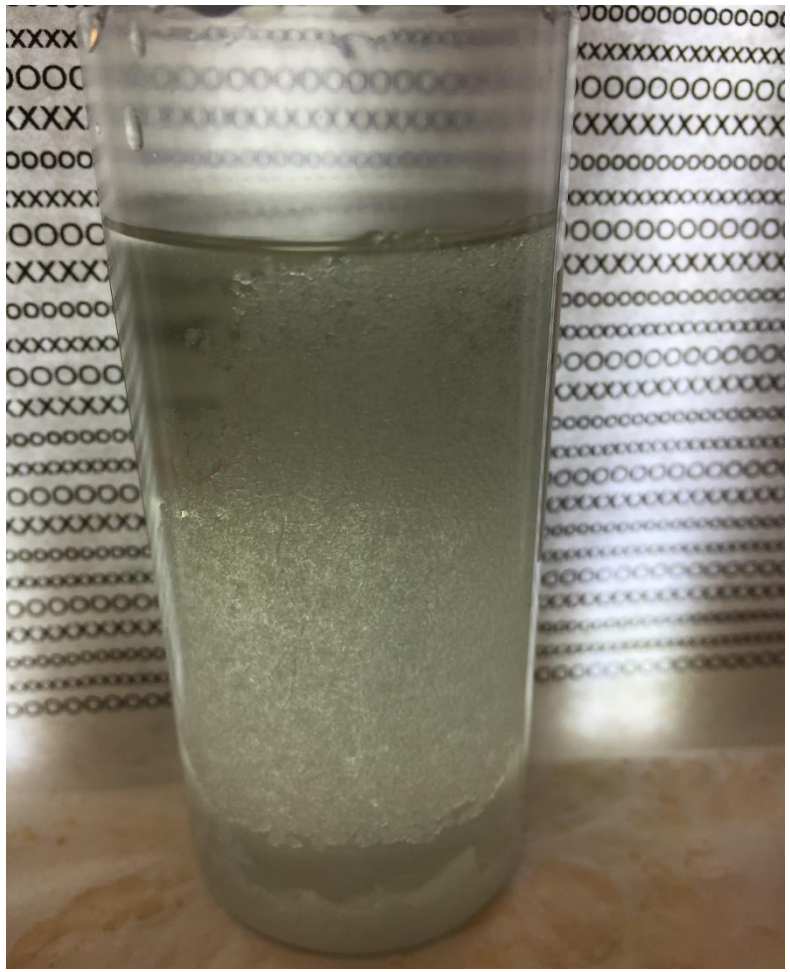
Salt Out vs Precipitation

- Salt out : When a liquid fertilizer is exposed to low temperatures for an extended time. These temperatures vary and the results can be ice or ice and crystalline salt complexes. Usually re dissolve with heat and agitation.

- Precipitation: Solids that form from incompatible mixing of products, pH change, hydrolysis of polyphosphates releasing insoluble metals. To mention a few causes. These solids typically don’t re dissolve. Identification of the precipitate and possible cause of precipitate can lead to a solution of further prevention.

Salt out vs Precipitation



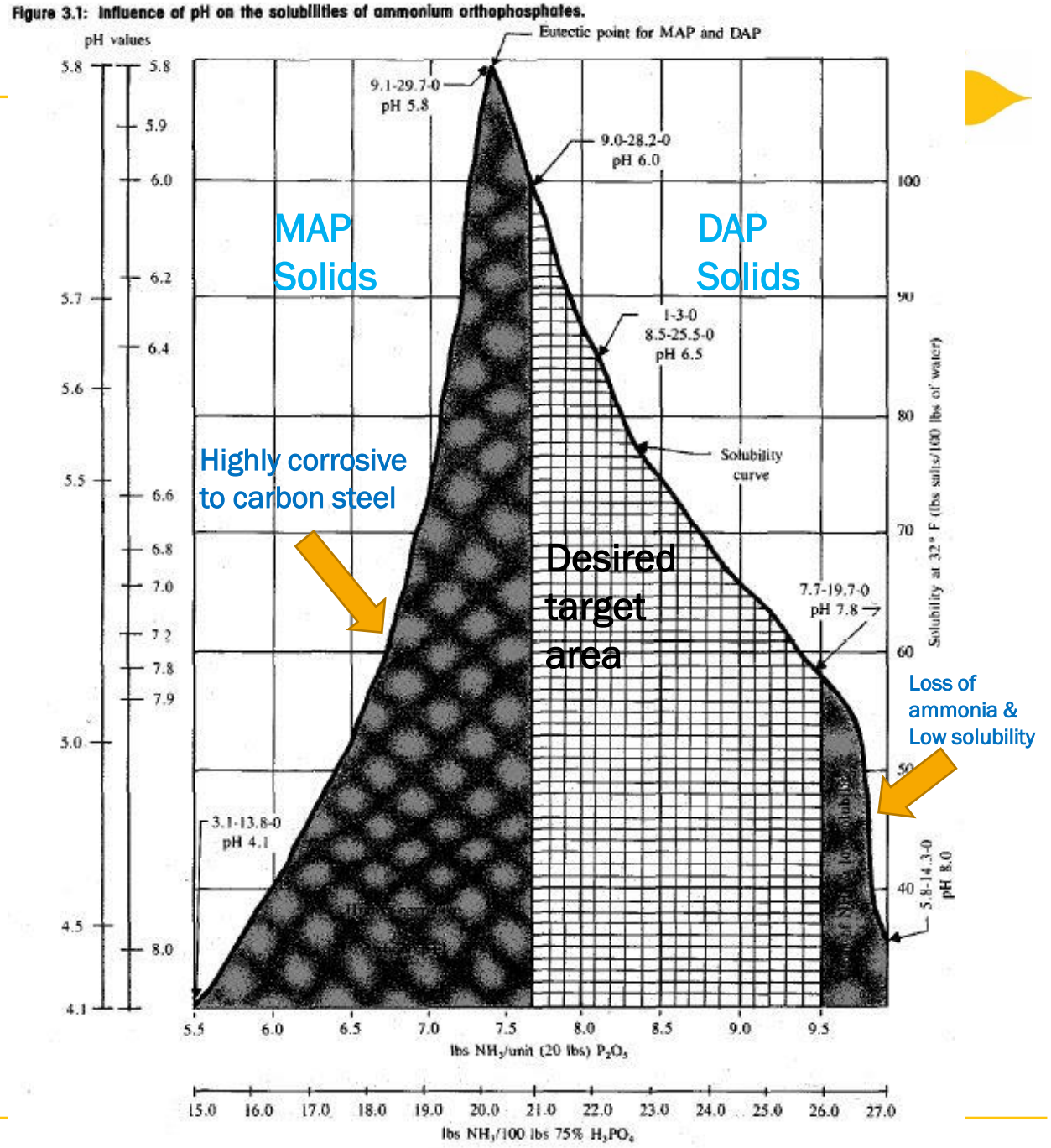


These samples precipitated at room temperature and will not re dissolve unless the chemistry is changed. Prime examples of precipitation failures.

Solubility of Ammonium Ortho Phosphates

The diagram located on the right has been in circulation for many years after being developed by TVA. The scale on the right is related to the total concentration (Solubility of Ammonium Phosphates 100% Ortho Salt lbs/100 lbs Water)

The scale on the left is related to the pH. 5.8 to 8.0 relates to the cross hatched section with the “Desired target area” of the diagram on the right hand side. The scale to the left pH 5.8 to 4.1 relates to the left side of the diagram. This area also has a lower pH and products that fall into this area can be corrosive to steel storage tanks.



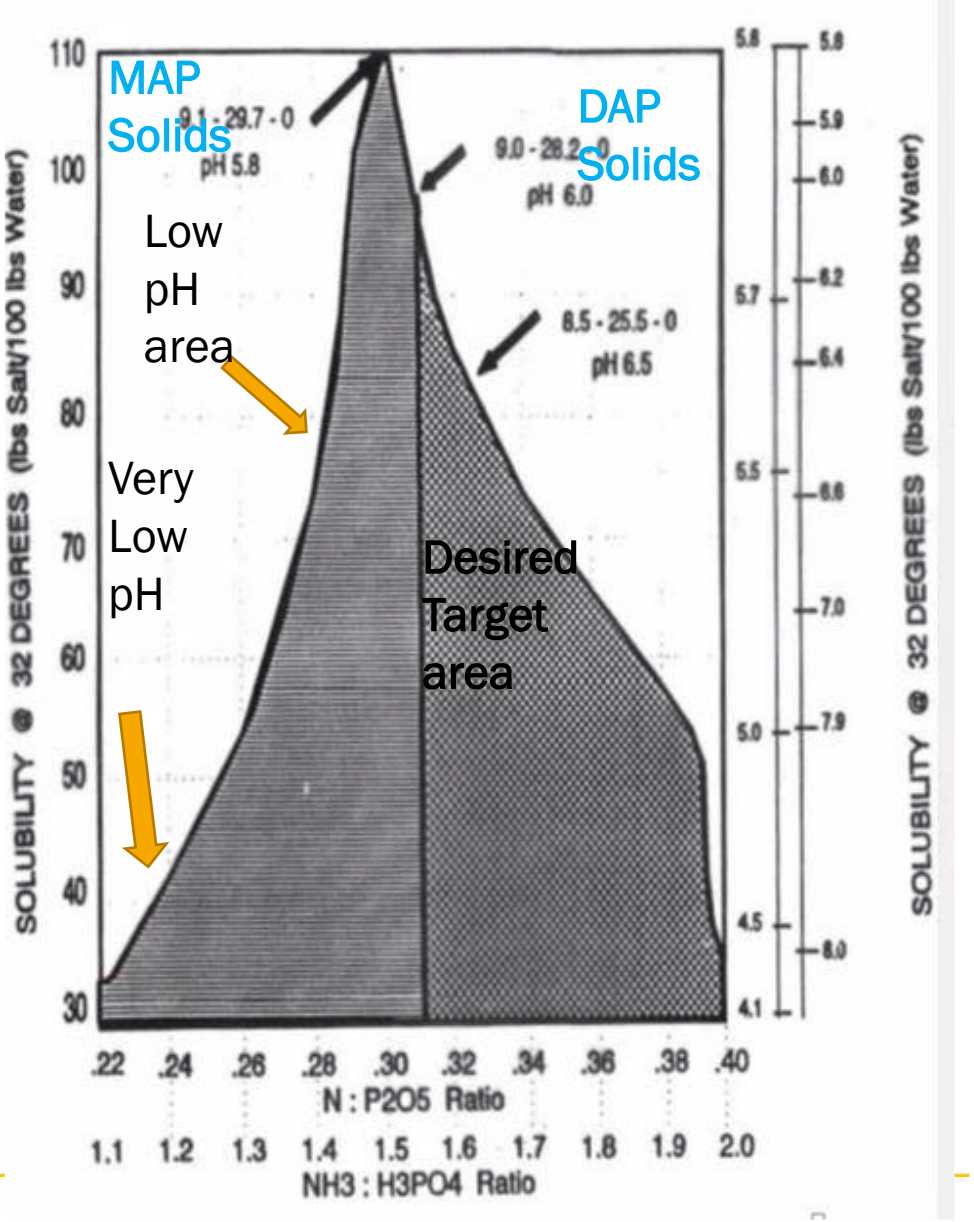
Solubility of Ammonium Ortho Phosphates

Same diagram as previous but with N:P2O5 ratio shown on the bottom scale of the diagram. This converted scale is much easier to work with when developing formulas. The key scale is the N:P2O5 Ratio. The N value is only counted for non neutralized N components ie: Aqua ammonia or Anhydrous ammonia.

The P2O5 value is only counted for Non neutralized P2O5 sources ie: Ortho phosphoric acid.

This diagram can also be used with some success with NPK systems that include (KOH). Accounting for the K2O from KOH, by subtracting that K2O value from the P2O5 then using that new P2O5 value to obtain the N:P2O5 ratio.

Ammonia and KOH are both bases and neutralize phosphoric acid but when KOH is in the system instead of KCl higher pH values can be obtained with lower salt out characteristics.

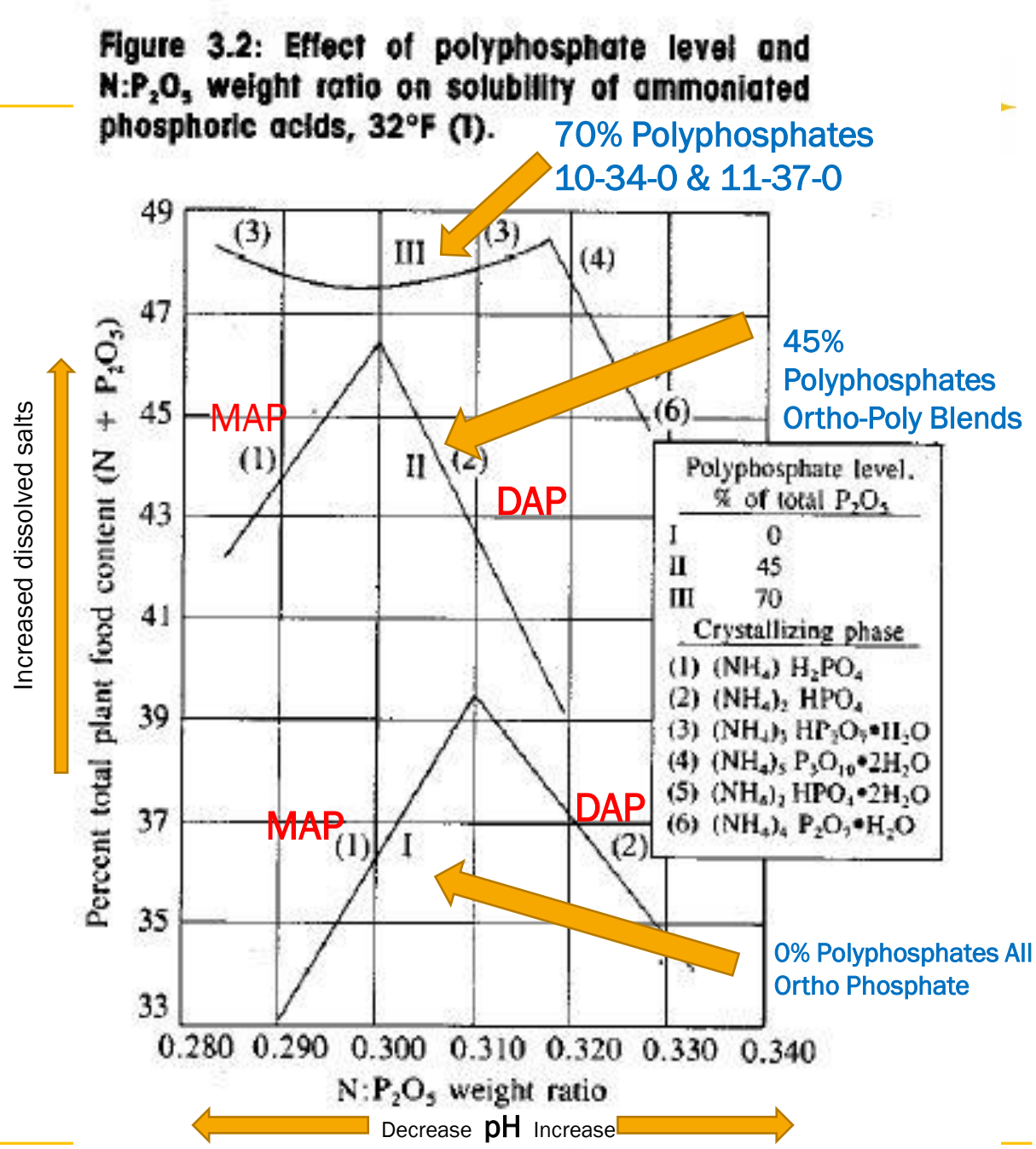


Effect of Polyphosphates on solubility of Ammonium Phosphate solutions

Scale from bottom to top shows an increase of dissolved salts NH4 & P205
Scale at bottom shows increase in N:P205 weight ratio (pH increase to the right)

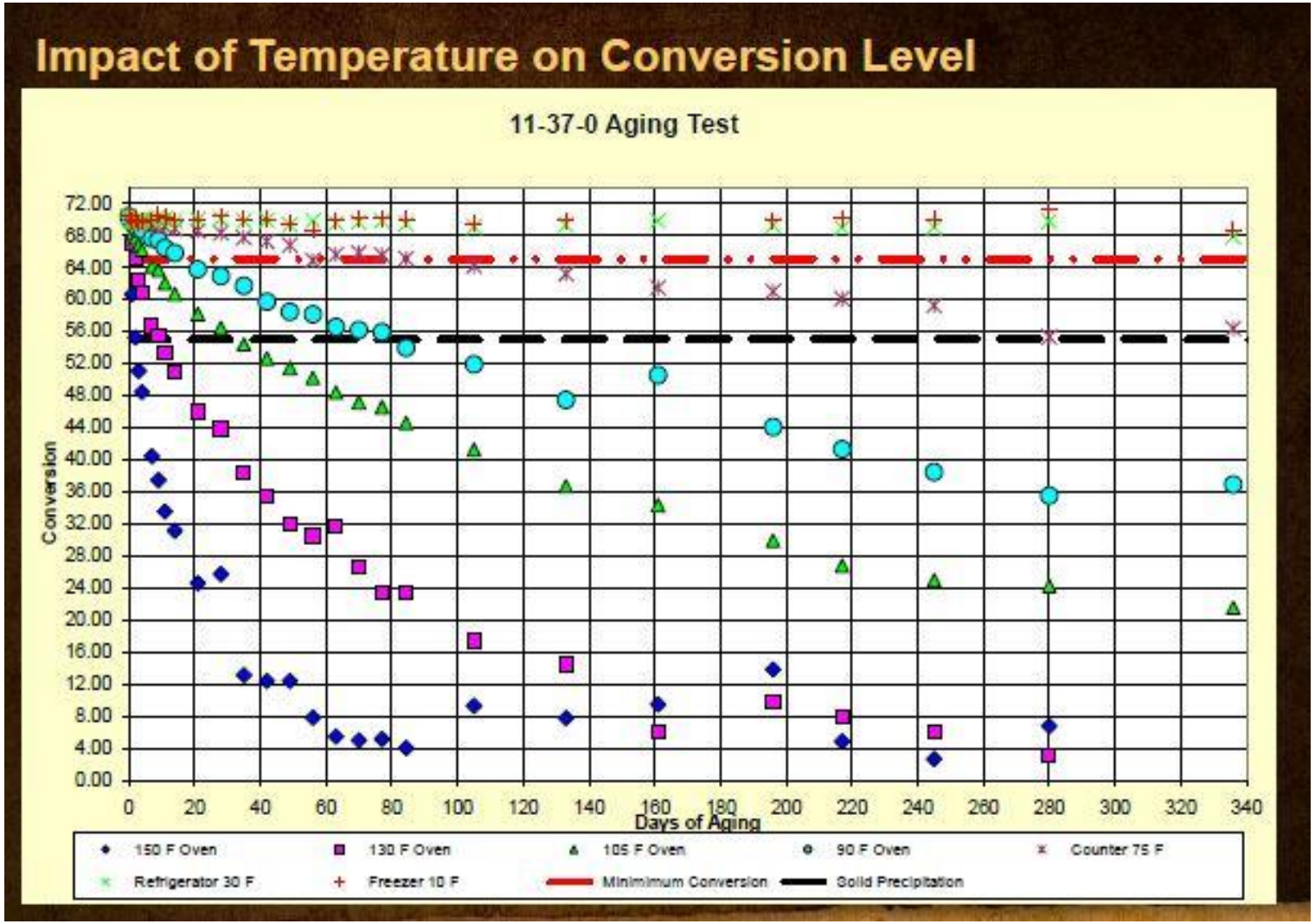
This chart can give you a relative comparison of the solubility of ammonium polyphosphates versus Ortho phosphate. As you can see the higher polyphosphate are much more soluble and not so pH dependent. Notice the peak of the 45% Polyphosphate is representative of a 9-30-0 grade. The peak of the all ortho phosphate is representative of 7.5-24-0

Some work has been done to determine Potassium Phosphate solubility of 100% ortho products. Typically 0-20-23 will have a salt out of 20 F. Add a little ammonia in place of the K20, 1.4-20-20 and you will see a salt out of 0 F. We have found that pH plays a critical role in determining salt out values. TVA has limited data with NPK fertilizers containing KOH.



Temperature effects on conversion of 11-37-0
John Walker from Potash Corp

Left scale is conversion, or % Polyphosphates. The bottom scale is days of aging. The minimum conversion is shown at about 65%. This will be slightly different depending on the tramp metal content of the wet process acid used.
Obviously temperatures above 90 F have a detrimental effect on the % Polyphosphate content.



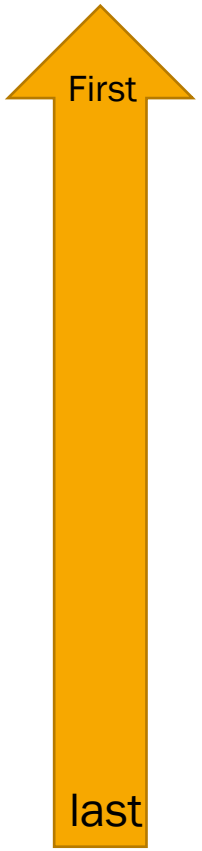
Compatibility of Micronutrients: Fully Chelated vs Sequestered

Fully Chelated metals are determined by the ability of the metal to remain in solution (dissolved) for the life of the product it is dissolved in. Our verification is determined by the ability of the chelated metal solution to be added to a 100% Orthophosphate solution and remain dissolved, with no precipitate, for an extended period of time.

Chelated/Sequestered: There are many molecules that hold metals in solution. Some of the most popular are EDTA (Ethylenediaminetetraacetic acid), Di Sodium EDTA, HEDTA, MEA (Monoethanolamine), TEA (Triethanolmine), Glucoheptonate, Ammonium, Citrate, Acetate,Formate, Polyamino acids and polyphosphates etc.....

We prefer to work with the EDTA groups which we find have the strongest chelating capability for most metals.
When working with solutions containing tramp metals it is important to keep the Metal Chelate Selectivity (Displacement) series in mind. This chart on the right shows the preference of EDTA chelation based on the metals. Similar to the Noble Metals chart. Ex: Fe $^{+}3$ must be chelated before attempting to chelate Cu $^{+}2$ etc when both are present in an unchelated or sequestered form.

V $^{+}3$	Vanadium
Fe $^{+}3$	Iron (Ferric)
Hg $^{+}3$	Mercury
Ti $^{+}3$	Titanium
Cu $^{+}2$	Copper
VO $^{+}2$	Vanadium Oxide
Ni $^{+}2$	Nickel
Pb$^{+}2$	Lead
TiO $^{+}2$	Titanium Oxide
Zn $^{+}2$	Zinc
Cd $^{+}2$	Cadminum
Co $^{+}2$	Cobalt
Al $^{+}3$	Aluminum
Fe $^{+}2$	Iron (Ferrous)
Mn$^{+}2$	Manganese
V $^{+}2$	Vanadium
Ca $^{+}2$	Calcium
Mg $^{+}2$	Magnesium
Ba $^{+}2$	Barium



Adding non EDTA metal micronutrients to poly phosphates

10-34-0 & 11-37-0 blends with a minimum of 70% polyphosphates can keep most metals in solution , up to about 1.5% wt total of the metals. This value is based on ignoring the tramps Mg, Al, Fe,& S contained in the wet process acid.

We found that non EDTA metals can be added to 50% polyphosphates and stay in solution, totaling about 0.5 to 0.75% depending on the metals

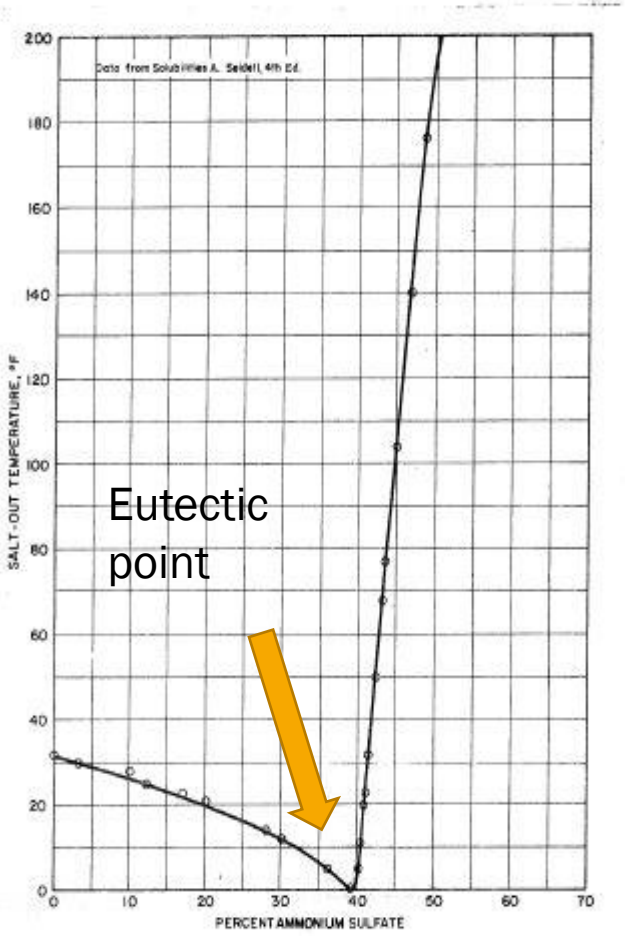
We have also found that non EDTA metals can be added to 20% polyphosphates and stay in solution, totaling 0.2 to 0.25% depending on the metals.

Those metals sequestered by acetate, citrate, nitrate, ammonium, etc will vary to the amount and length of stability in the above solutions. Stability tests can be performed to verify.

Some Nutrient Incompatibilities

- Sulfate, Nitrate, and Chloride based metals have very limited solubility's in low polyphosphate fertilizers.
- Low value phosphate fertilizers IE: 8-1-8 do not mix well with hard water. Phosphates will precipitate.
- We have found some solubility inconsistencies with the mixtures of Manganese EDTA and Boron MEA.
- Iron EDTA and Copper EDTA have been found to degrade in the presence of sunlight/UV light. The EDTA bond is broken/destroyed and Iron will take the place of copper leaving it to precipitate as a solid.
- Potassium mixed with UAN can cause the precipitation of potassium nitrate crystals at certain concentrations.
- Potassium mixed with Sulfur in the form of sulfate can cause potassium sulfate to precipitate.
- I am sure you know of other incompatible mixtures.

Aqua Ammonia & Ammonium Salts



Ammonium Sulfate Salt out diagram. Typical 8-0-0-9S solution falls in the eutectic point.

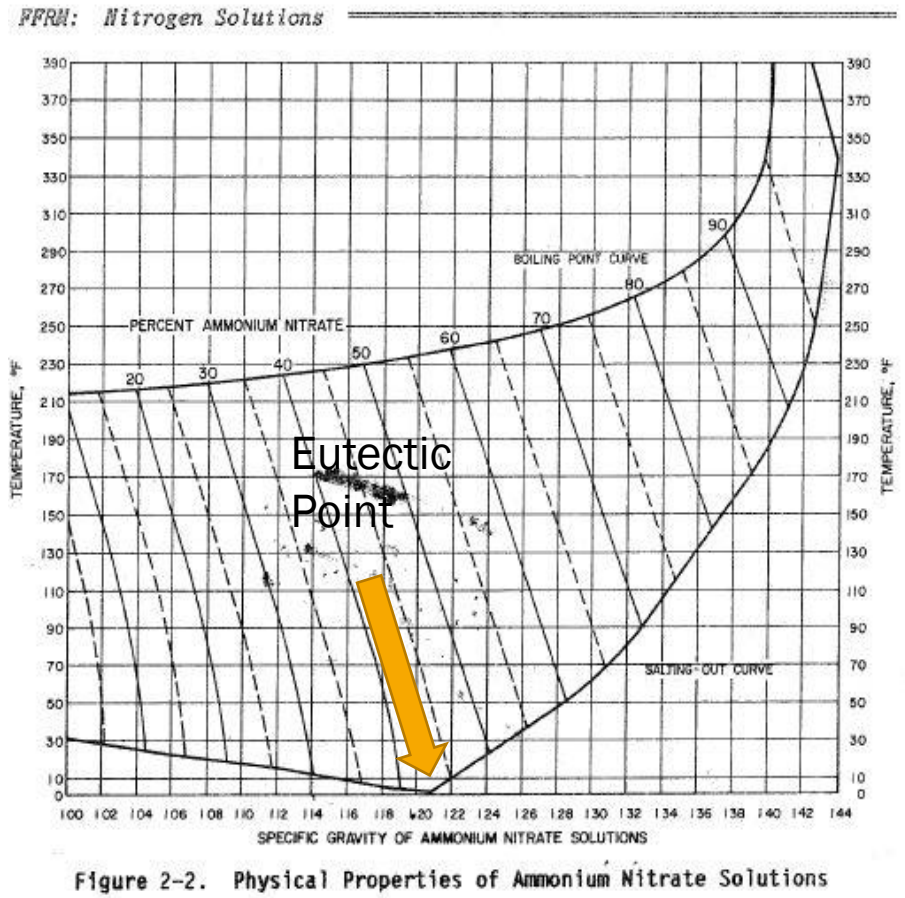


Figure 2-2. Physical Properties of Ammonium Nitrate Solutions

Ammonium Nitrate Salt out and boiling point curve. 45% Solution falls in the eutectic point.

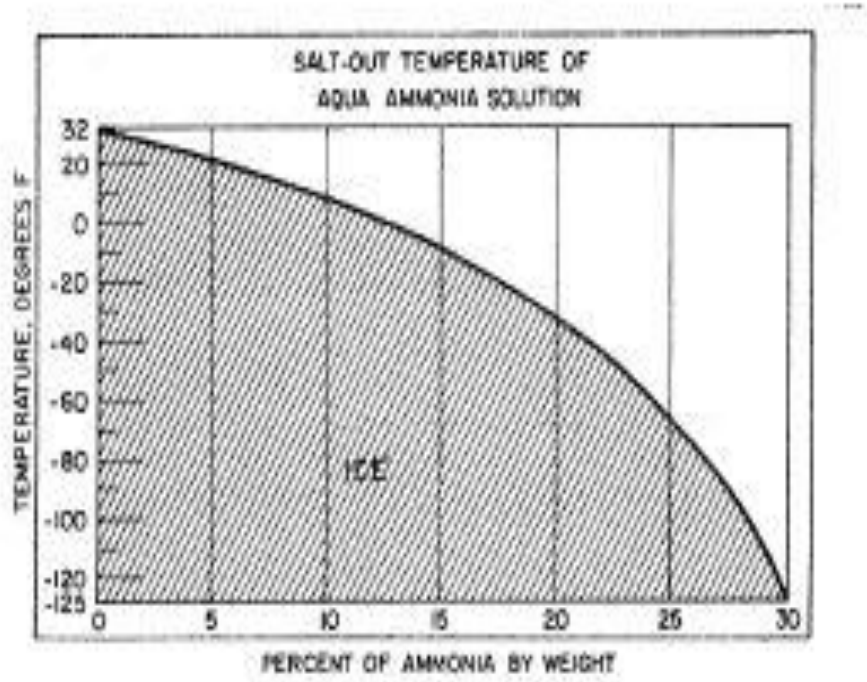
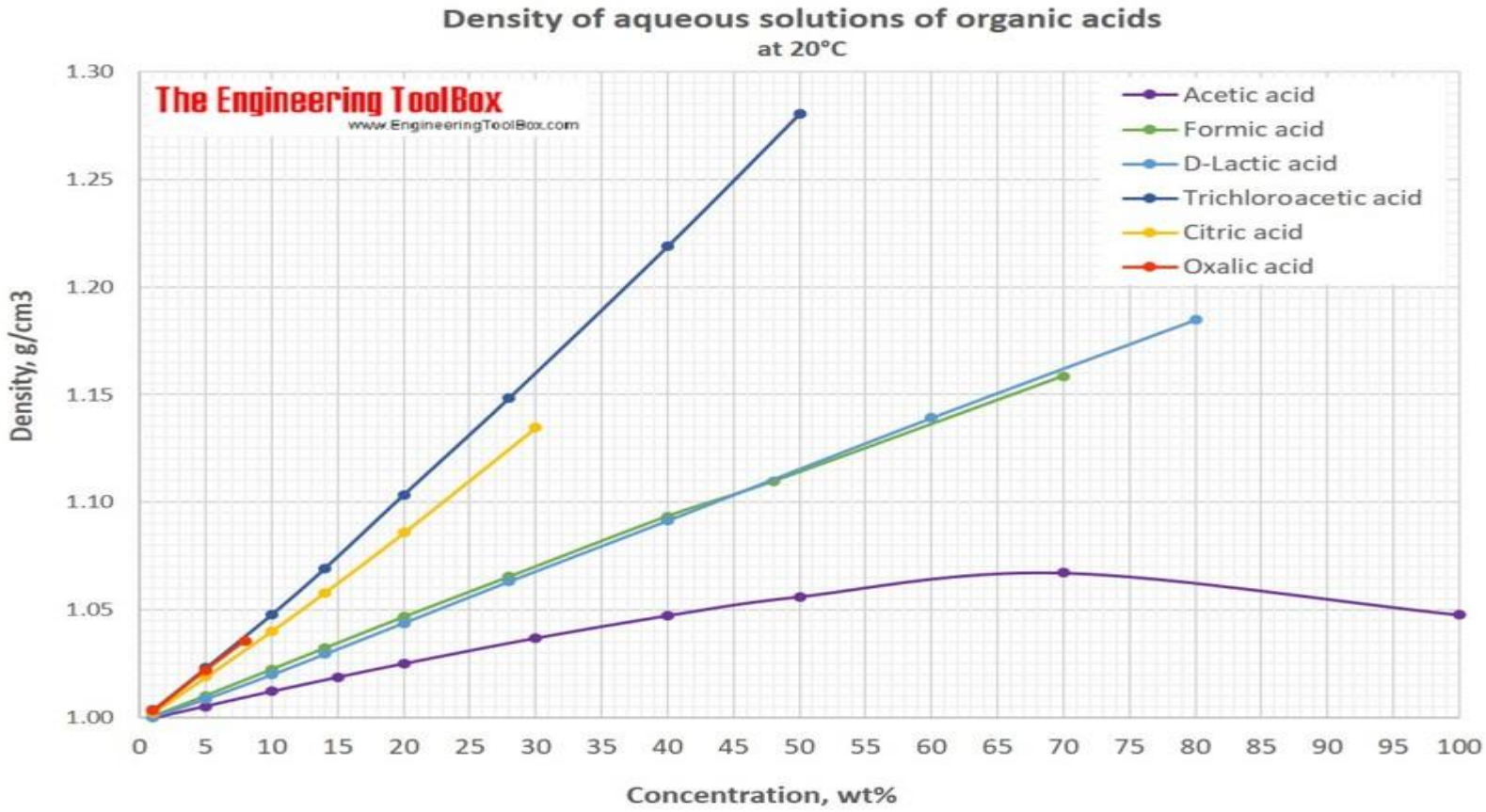


Figure 2-6. Salt-Out Temperature of Aqua Ammonia Solutions

Typical Salt out diagram for Aqua Ammonia.

Acetic acid 45% or 100%?

The concentration curve for acetic acid (purple line) is another example of the reason for verification. The density is the very close to the same for 45% & 100%



Ammonium Sulfate pH curve

Data is not always what we expect. That is why we need to verify!!

So when you expect the ammonium sulfate solution to have a pH of 7.0 don't be surprised if the meter shows a value of 4.0 or 5.0. All the same ..

pH

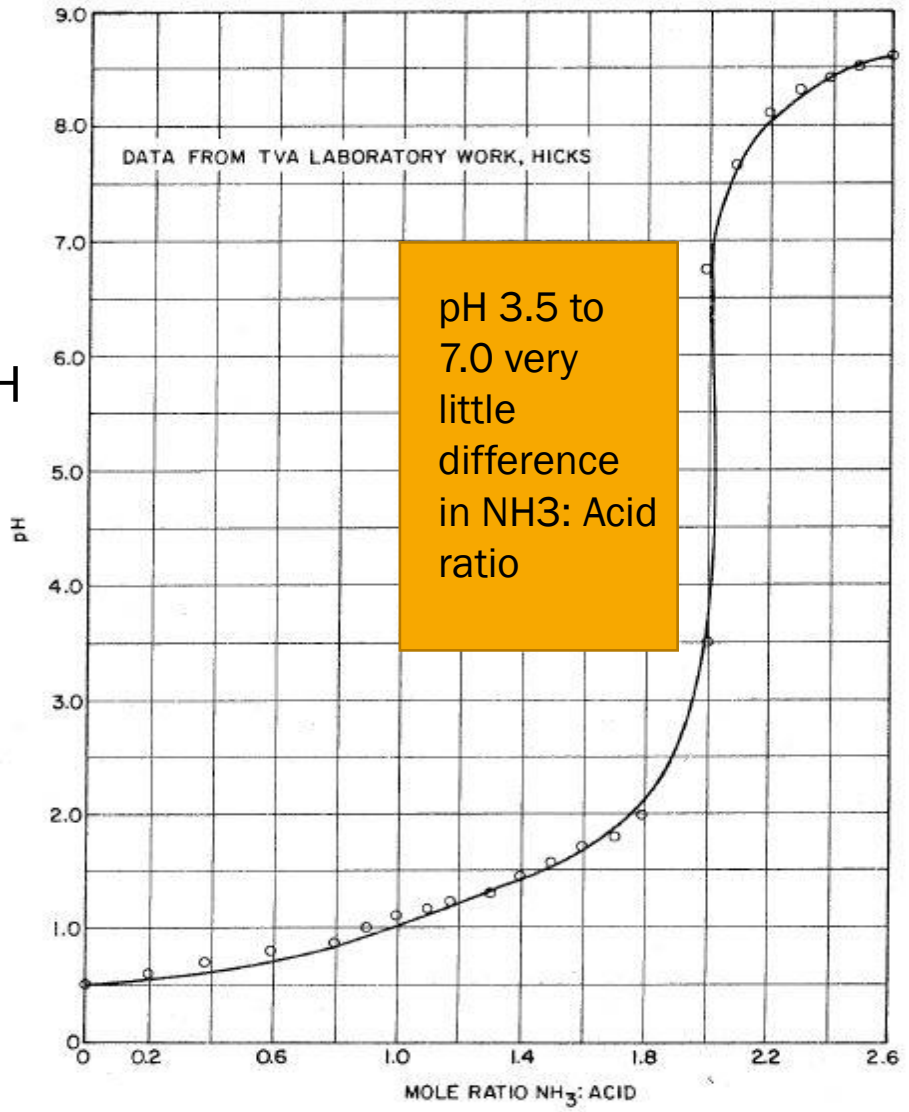


Figure 2-4. Effect of Adding Ammonia to Sulfuric Acid

Storage & Compatibility Properties of different formulations

- Know and/or verify salt out values for products to be stored. Internet can be a useful tool or a trap sometimes.
- If salt out value is undesirable then look at changing the chemistry, the location, or time of year, to obtain successful storage.
- One must also recognize that hot temperatures can be just as damaging to high polyphosphate products.

Questions? Comments ?

Increased Phosphate Fertilizer Efficiency with Crystal Green® Granular Fertilizer and a Liquid Starter

Dr. Galen Mooso PhD, CPAg, CCA
Ostara Technical Field Agronomist

Scott Kluesner, CCA
Ostara Regional Sales Manager (IA, IL, WI)

November 30, 2022

OSTARA

Importance of Using a Phosphate Starter Fertilizer

- Phosphorus nutrition is very important for early root development and plant growth.
- Proper P nutrition is required for:
  - cell division and enlargement
  - energy transfer in biological work - photosynthesis
  - reproduction and transfer of heredity traits
  - timely plant maturity
  - high yielding crops
- No other element can substitute for P in plant nutrition
- P nutrition can be a challenge in cold soils – not very available

OSTARA

Liquid phosphate fertilizer is a perfect start for your crop

OSTARA

But what happens to phosphate the rest of the season?

OSTARA

The Phosphate Challenge

- **Up to 90% of conventional applied phosphate is not available to crops during the growing season.**
  - Soil Fixation/Antagonistic Cations
  - Soil Erosion/Runoff removes P
  - Leaching

- **Inefficient phosphates lead to excess nutrient loss and cause harmful environmental degradation.**

Conventional phosphate fertilizers are very inefficient

OSTARA

Inefficient phosphate sources are preventing yield potential and impacting the environment.

OSTARA

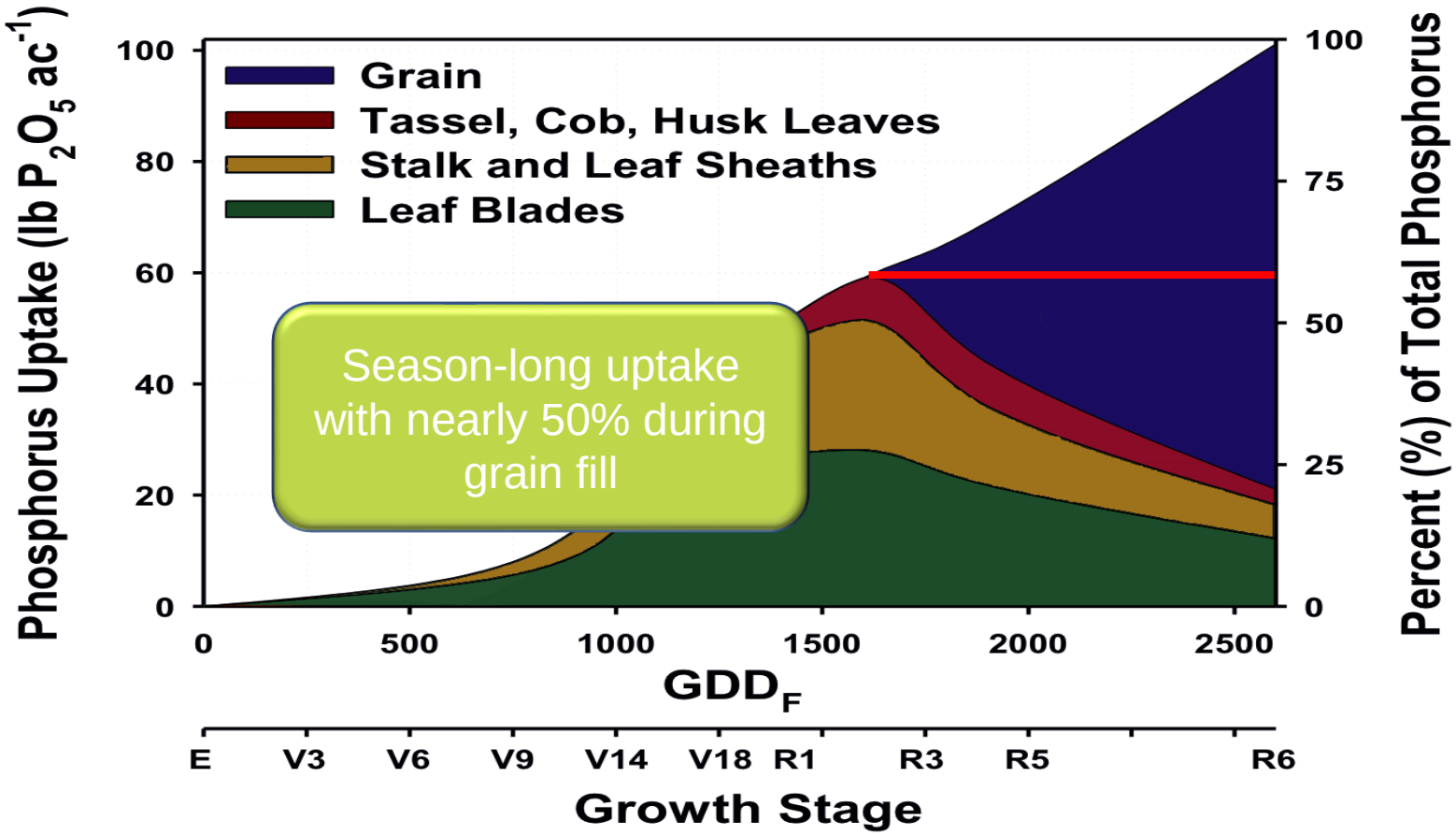
Why Focus on Phosphate for Higher Crop Yields?

- **Increasing plant populations results in plants with smaller root systems.**
- **Soil test values might not be calibrated for the yield potential of modern hybrids.**
- **Soil P availability is low, while crops require season-long availability.**
- **Improving P efficiency/reduce environmental losses.**

OSTARA

P Availability is Critical for High Yielding Corn

P Uptake & Partitioning for 230 Bushel Corn

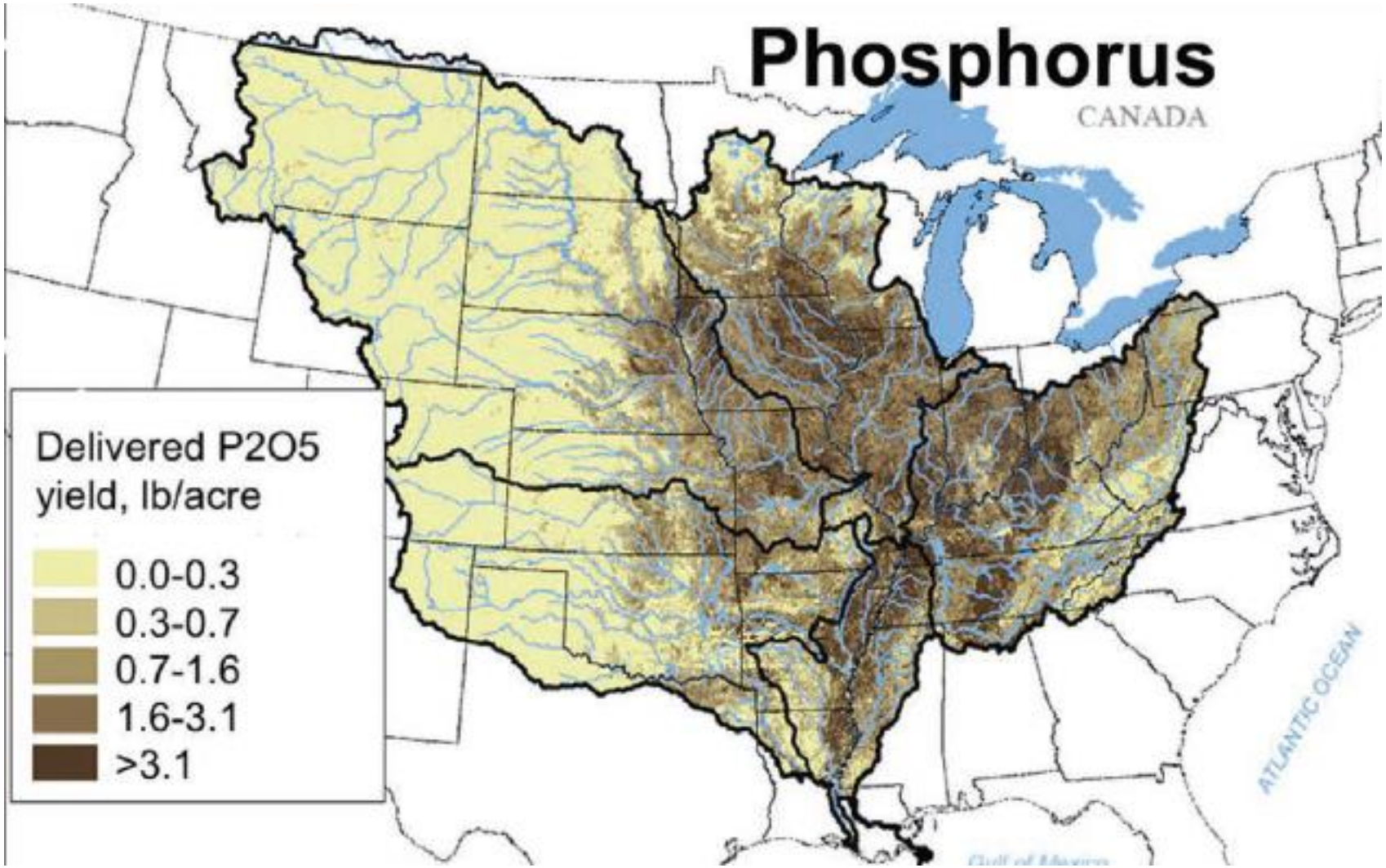


Average of 6 hybrids in Champaign and DeKalb IL in 2010

Agron. J. 105:161-170 (2013)

OSTARA

Delivered Phosphorus yield per acre to the Mississippi Watershed



Bruulsema, 2022

OSTARA

Table 2. Total annual phosphorus load and yields, delivered to the Gulf of Mexico, for the four states contributing the largest loads and the entire Mississippi River watershed. Percentage attributed to each source by the SPARROW model calibrated for 2012 inputs and loads (Robertson & Saad, 2021)

Area	Delivered P load	Delivered yield	Source distribution			
			Urban	Fertilizers	Manures	Natural losses
	thousand tons P_2O_5 equivalent	lb P_2O_5 per watershed acre	%			
Illinois	61	4.2	32	46	7	16
Kentucky	52	5.1	14	29	15	42
Iowa	50	3.5	13	47	25	16
Missouri	46	2.6	20	41	24	16
Mississippi River watershed	490	1.6	21	38	18	23

Bruulsema, 2022

OSTARA

Table 2. Total annual phosphorus load and yields, delivered to the Gulf of Mexico, for the four states contributing the largest loads and the entire Mississippi River watershed. Percentage attributed to each source by the SPARROW model calibrated for 2012 inputs and loads (Robertson & Saad, 2021)

Area	Delivered P load	Delivered yield	Source distribution			
			Urban	Fertilizers	Manures	Natural losses
	thousand tons P_2O_5 equivalent	lb P_2O_5 per watershed acre	%			
Illinois	61	4.2	32	46	7	16
Kentucky	52	5.1	14	29	15	42
Iowa	50	3.5	13	47	25	16
Missouri	46	2.6	20	41	24	16
Mississippi River watershed	490	1.6	21	38	18	23

Over 50% of the P_2O_5 load is from agriculture!

Bruulsema, 2022

OSTARA

The need for a more efficient phosphate is critical for the future of agriculture and the environment.

OSTARA

Introducing Crystal Green® Phosphate Fertilizers

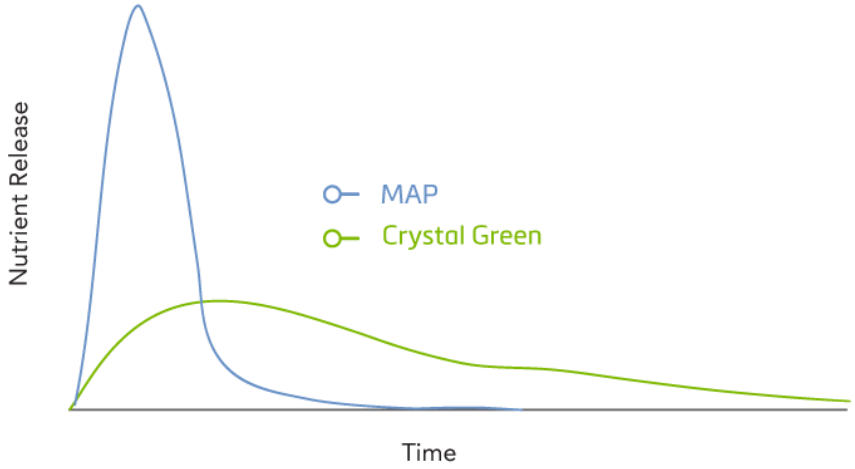
- Maximize Phosphate Efficiency
- Remains Plant Available All Season
- Reduced environmental loss to soil fixation, runoff and leaching.
- Soil incorporation keeps it from moving off-site but still plant available
- Stay where you put it-be there when you need it
- Compatible with other crop nutrients
- Recognized by the 4R Nutrient Stewardship program

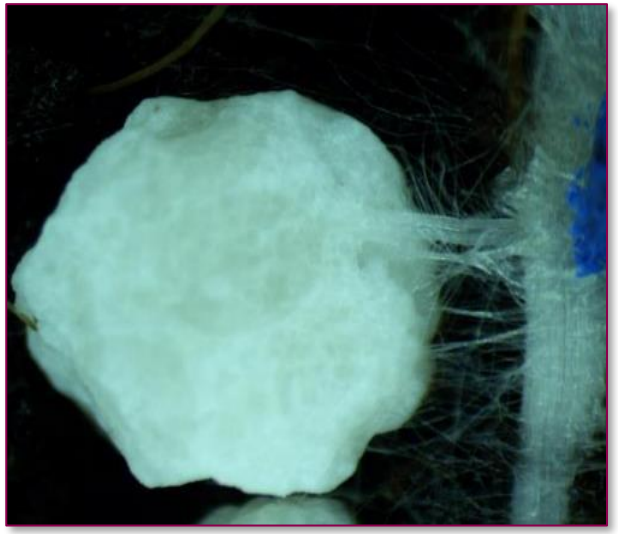
Crystal Green	Crystal Green Synchro™ 50
5-28-0 with 10% Mg	8-40-0 with 5% Mg
The most efficient granular phosphate fertilizer on the market. Can be blended in various ratios with ammonium phosphate or applied directly	A fully homogeneous granular phosphate fertilizer containing Crystal Green that eliminates the need for blending with ammonium phosphate fertilizer.

OSTARA

How Crystal Green Works

- Crystal Green phosphate granules solubilize as roots exude organic acids.
- Roots take up nutrients as they need them to promote crop growth and development.
- Remains available all season to meet crop demand.

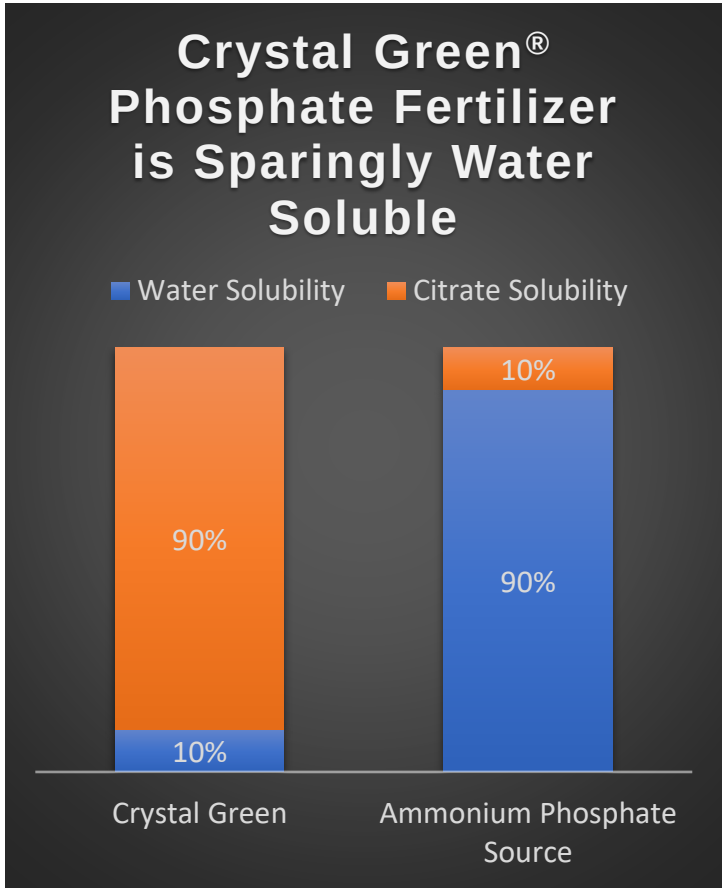




Roots Mining a Crystal Green Granule

OSTARA

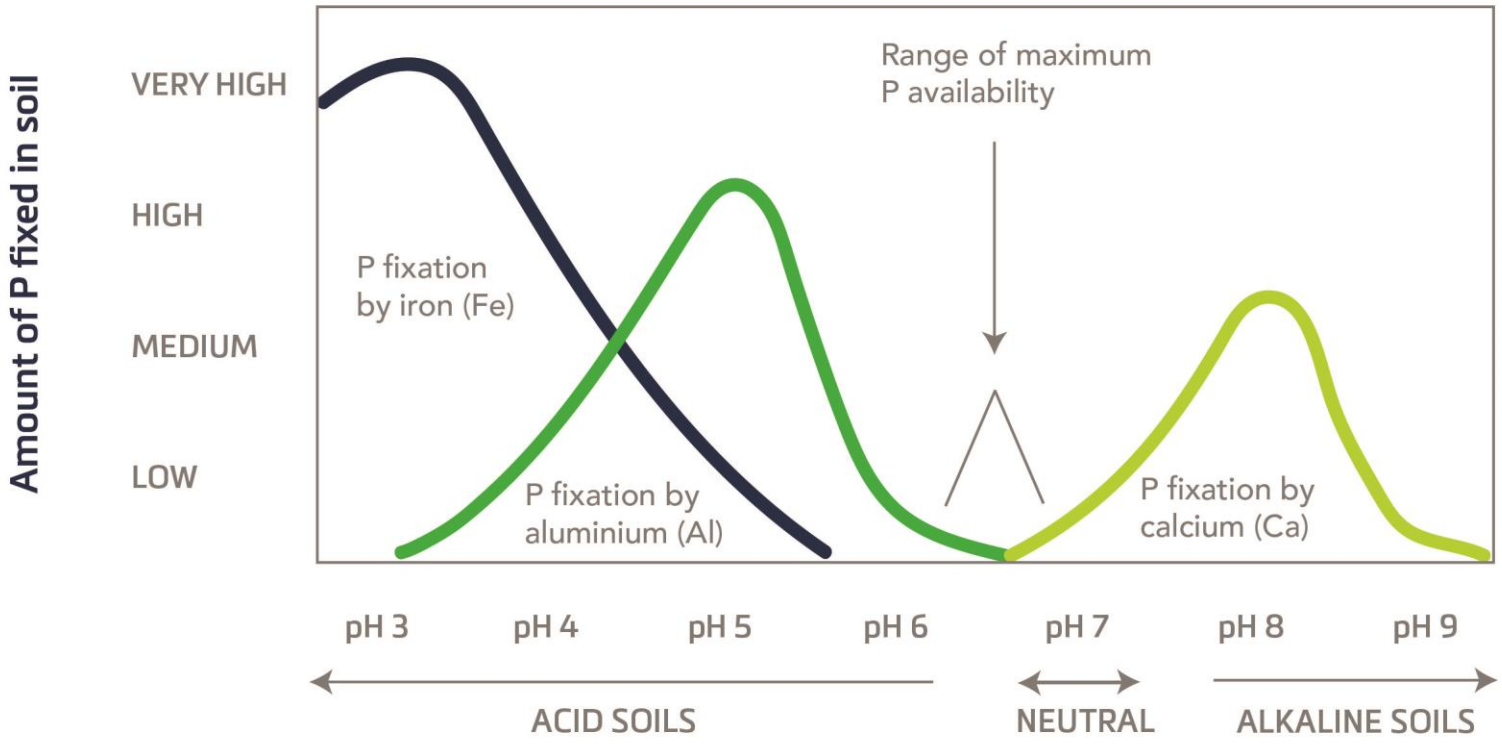
The Solubility of Crystal Green



OSTARA

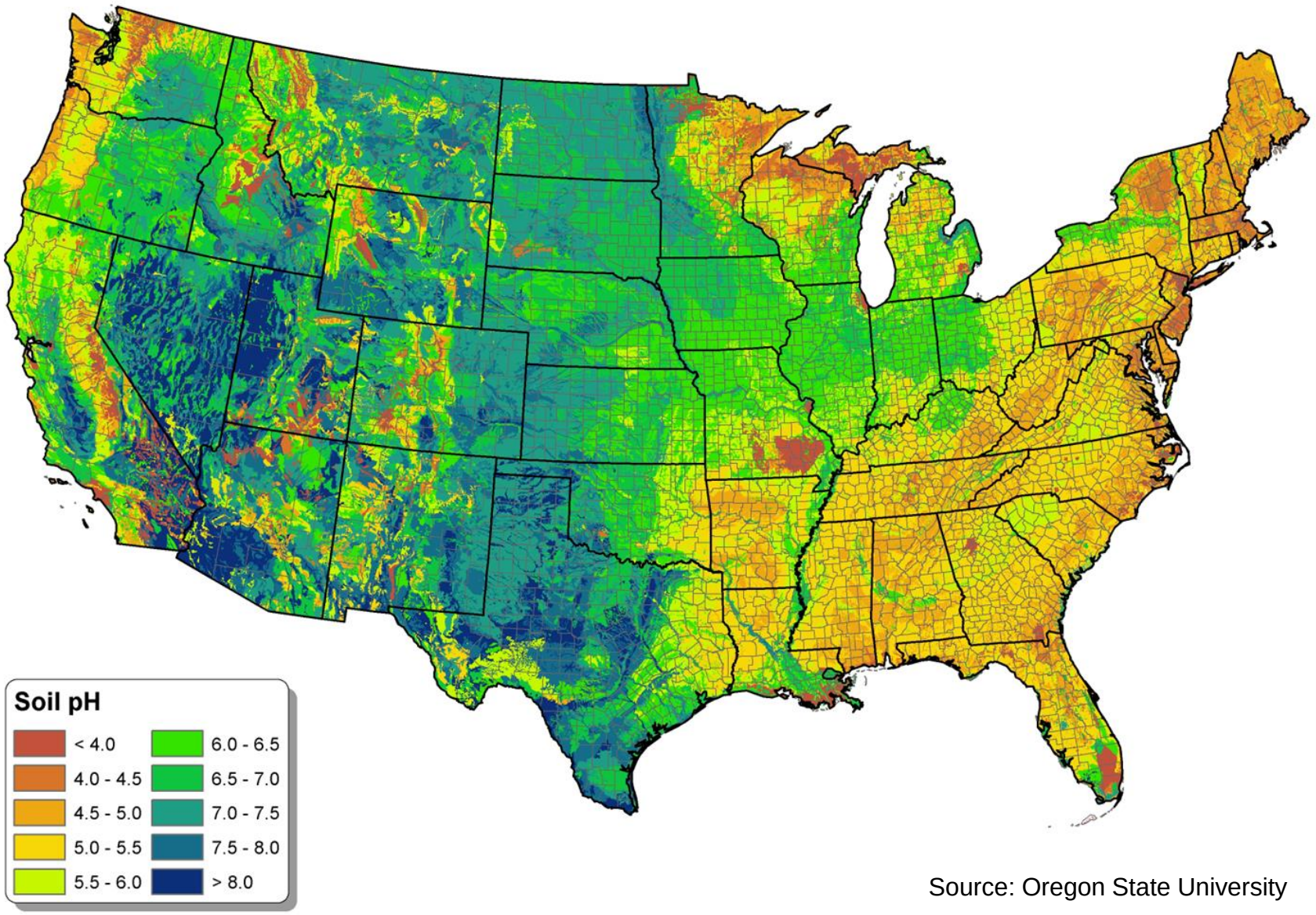
Prevent Soil P Tie-Up

Crystal Green remains plant available in all pH ranges.



OSTARA

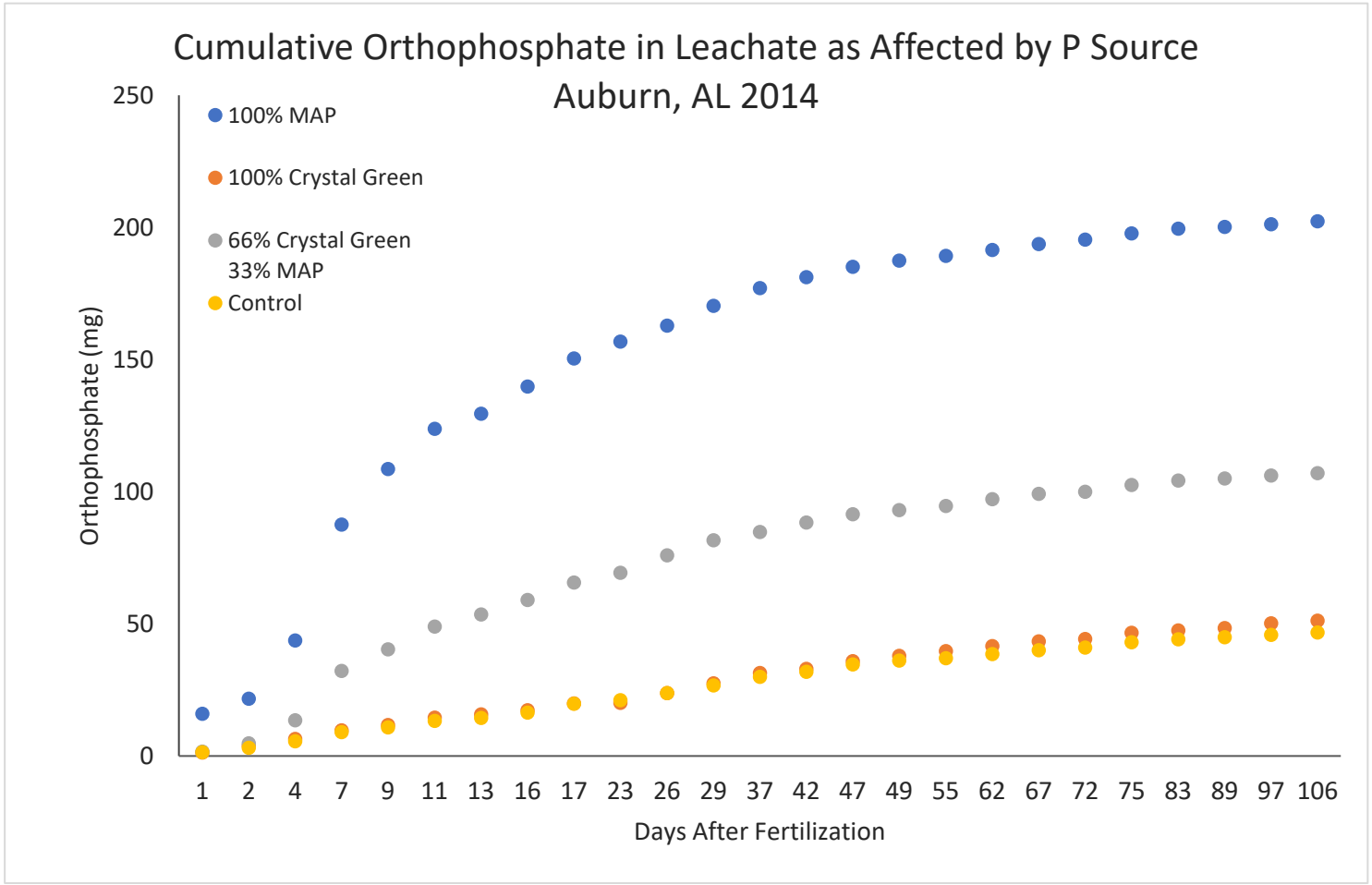
Surface pH is Affected by Geography



Source: Oregon State University

OSTARA

Avoid Runoff & Leaching

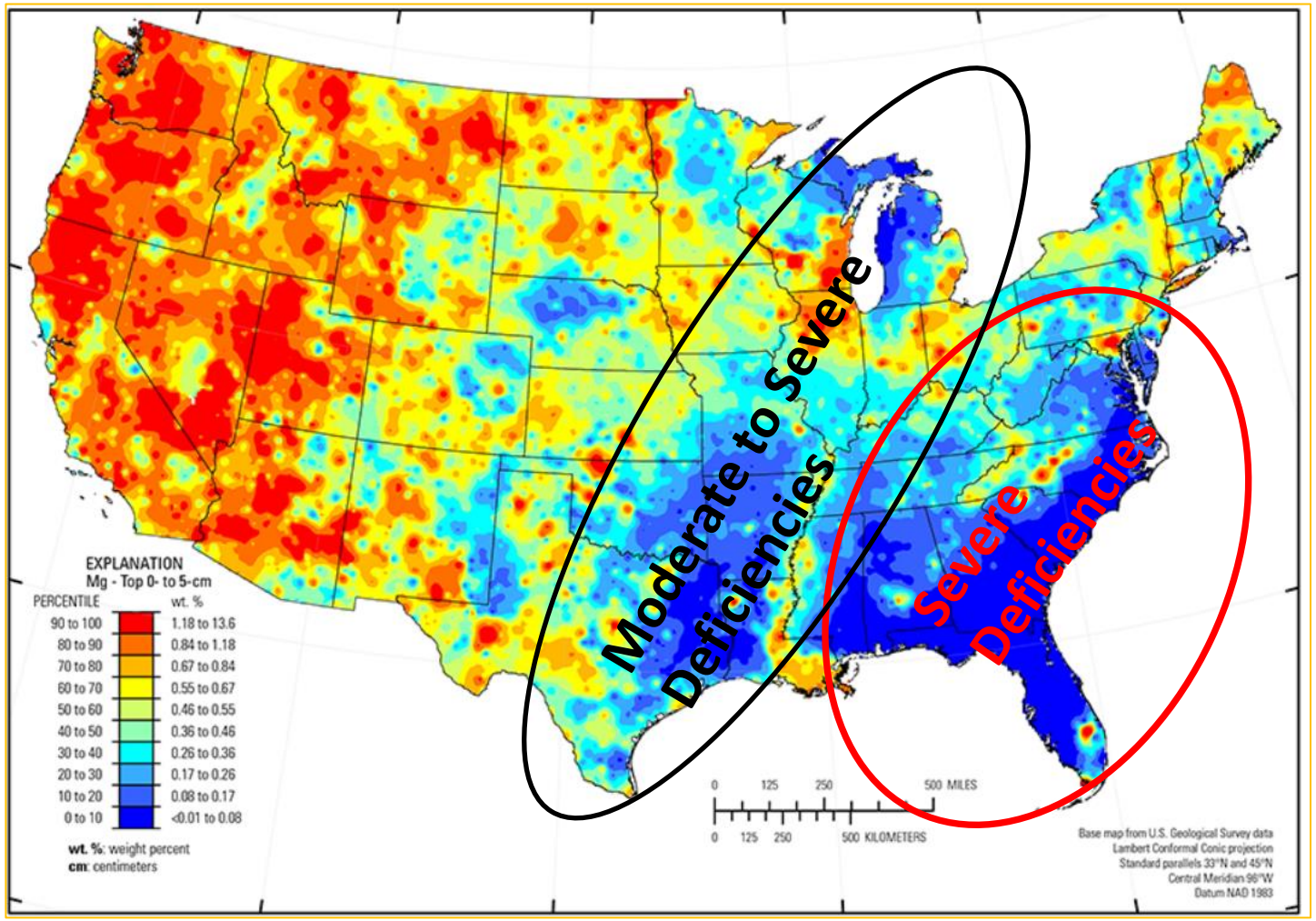


By using Crystal Green, leaching or runoff from phosphate fertilizer is significantly reduced.

Research conducted by Auburn University using turf lysimeters, showed Crystal Green phosphate leachates equal to untreated controls. Yet, turf color and quality of establishing bermudagrass was equal to or better than standard practice.

OSTARA

Remember the Magnesium



Mg is required for chlorophyll synthesis and photosynthesis

Current market price for granular magnesium sulfate 9.8% is ranging from $600-$800 per ton

Crystal Green is 5-28-0-**10Mg** in one nutrient-packed granule.

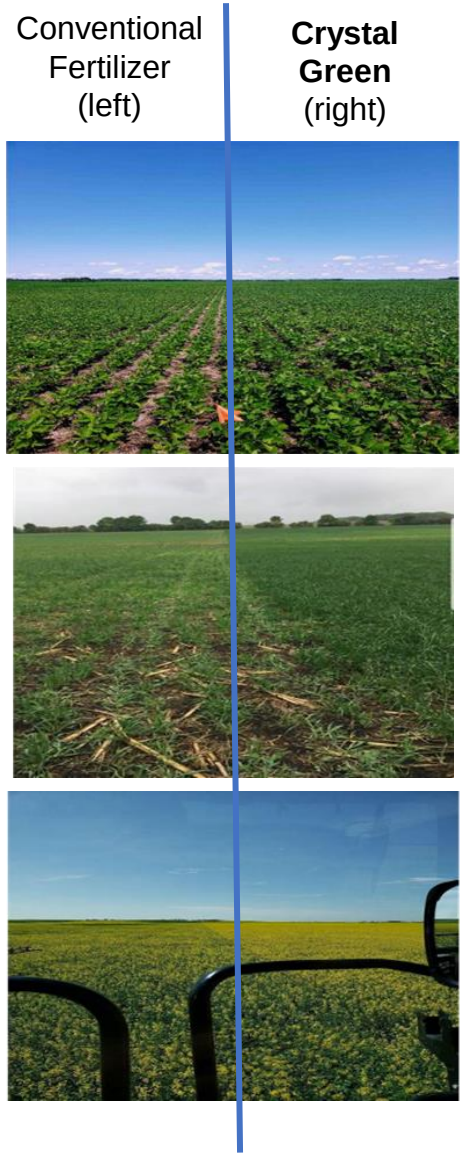
Corn, potato, sugarcane and sugar beet are among the highest Mg-demanding crops in North America.

OSTARA

A Fit For Every Crop

Crop	Average Yield Increase
Corn	9 bu/acre
Soybean*	2 bu/acre
Wheat	4.8 bu/acre
Canola	2.6 bu/acre
Potato	26 cwt/acre
Sugar beets	810 Lb. CRS/acre
Tomato	80 box/acre

Continuous research at accredited universities shows Crystal Green is well suited among a variety of different crops and soil types.



*Crystal Green applied at a 50% reduced rate of fertilizer application vs grower standard practice

OSTARA

Crystal Green paired with a liquid starter is a great combination for high-yielding production practices.

OSTARA

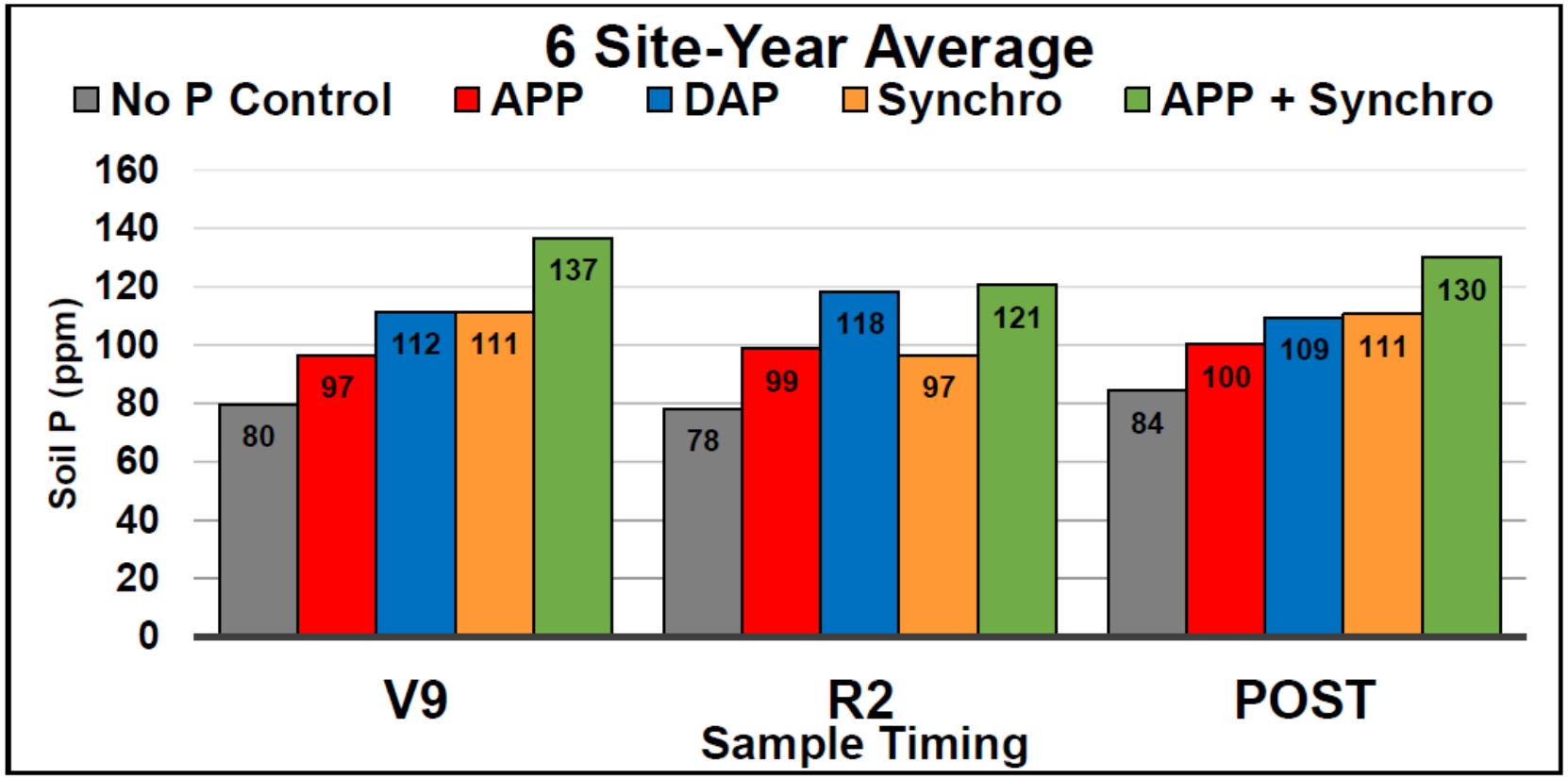
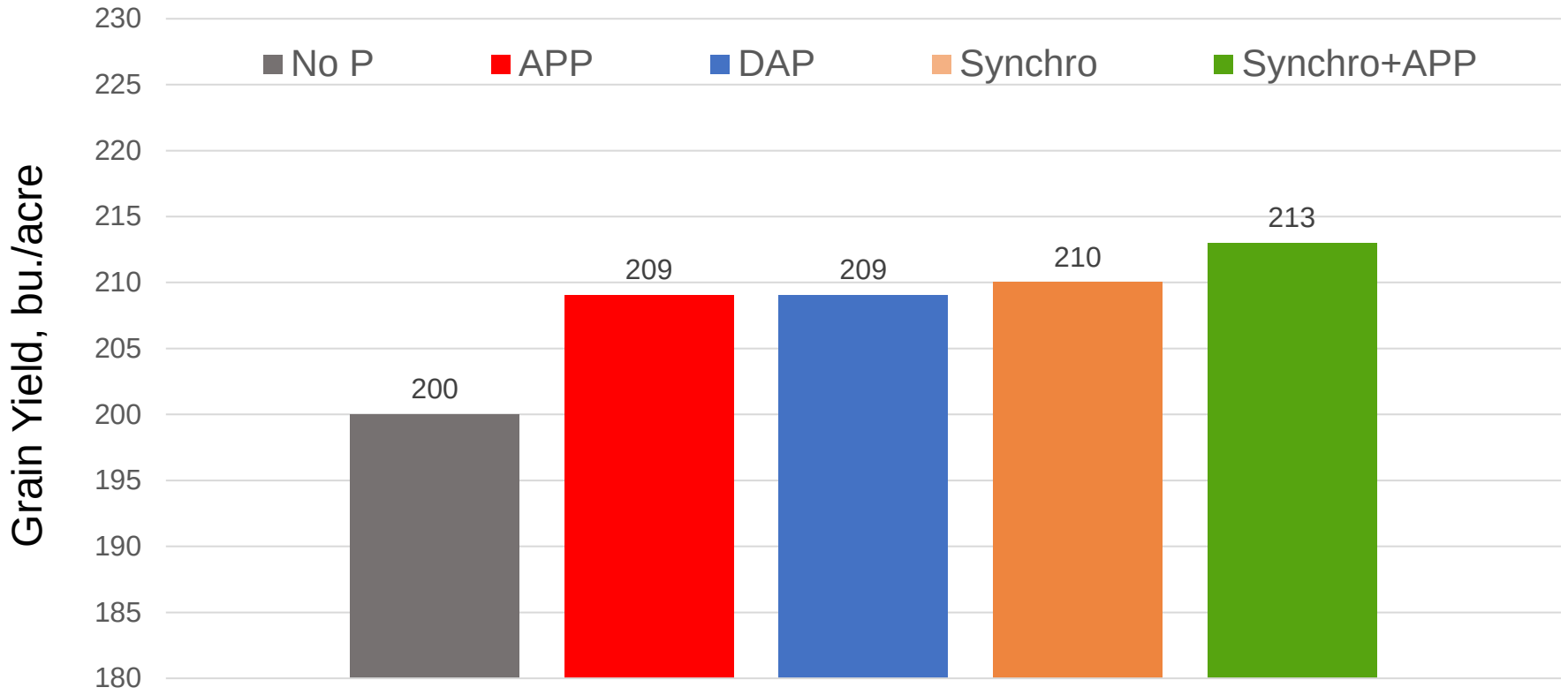


Figure 2.7. Seasonal soil P availability, measured at three corn growth stages (V9, R2, and postharvest [POST]), as affected by P fertilization treatments averaged over six site-years across Illinois. Synchro 73 and Synchro 83 data were averaged together.
LSD ($\alpha = 0.10$): within V9 = 9; R2 = 12; Post = 10.
LSD ($\alpha = 0.10$): P Treatment *x* Time = 11.

Foxhoven, Univ. of IL

OSTARA

Effect of P Fertilization Treatment on Three Grain Yield Sites 2019



APP- 20 lb. P_2O_5/acre
DAP-100 lb. P_2O_5/acre
Synchro-100 lb. P_2O_5/acre
Synchro- 80 lb. P_2O_5/acre + APP 20 lb.P_2O_5/acre

Foxhoven, Univ. of IL

OSTARA

Crystal Green applied fall 2022 via strip-till with anhydrous ammonia is ready for spring planting with a starter fertilizer to provide season-long P nutrition.

OSTARA

Crystal Green + P starter fertilizer will:

- Increase phosphate use efficiency
- Provide season-long P availability
- Significantly reduce phosphate losses

That’s a win for yield and a win for the environment.

OSTARA

Thank You!

Contact us to learn more.

info@ostara.com

www.ostara.com

OSTARA

Developing Liquid Starters for Corn Production in the Midwest

Jeffrey Vetsch, Researcher 4

Univ. of MN Southern Research and Outreach Center

2022 Fluid Technology Workshop December 1, 2022, Davenport, Iowa

UNIVERSITY OF MINNESOTA
Driven to Discover®

https://nutrientstewardship.org/4rs/

4RS
4R Principles
Benefits of Using the 4Rs
Implementation
Sustainability

RESOURCES
4R Pocket Guide
4Rs of Nutrient Stewardship
4R Farmers & The Lake
4R Micronutrient Webinars

What are the 4Rs

RIGHT SOURCE
Matches fertilizer type to crop needs.

RIGHT RATE
Matches amount of fertilizer type crop needs.

RIGHT TIME
Makes nutrients available when crops needs them.

RIGHT PLACE
Keep nutrients where crops can use them.

Where do liquid starters fit in 4R management?

- Crops: corn, small grains, soybean, sugar beets
- Nutrients applied: N, P, K, S, Zn, other micros
  - Crop response can be affected by placement, nutrient and rate
- Tillage system: no-till, reduced till, strip-till (band method)
- Crop rotation: corn after corn or small grains vs soybean
- Soil characteristics: poorly drained, well drained, pH
- Broadcast P rates affect starter response to N, P & S
- Soil test P levels: low, medium/optimum or very high

Liquid starter fertilizer placement options

Liquid starter placement at Waseca (2004-06)

Fluid NPKS Placement[1/]	3-Yr Avg. Corn Yield
	bu/ac
Control	186
2×0	196
2×2	195
LSD (0.10) =	7

[1/] Averaged across 4 NPKS rates of application (Waseca, 2004-2006).

- **Corn after soybean (2 yr) or corn silage (1 yr)**
- High to very high Bray P1
- Surface dribble as good as stream injected behind coulter
- Yield response to NPKS
- N&P in pop-up also increased yield in this study (data not shown)
- Randall and Vetsch. 2006. Fluid Journal
- FFF funding

Liquid starter placement at Waseca (2007-09)

Starter Treatment			Grain	
Placement	APP	UAN	Yield	Moisture
	gal/A	lb N/A	bu/A	%
control	0	0	184	24.2
In-furrow	5	0	190	24.1
2 × 0	5	0	186	24.2
“	5	15	192	23.8
“	5	30	190	23.8
“	5	45	187	23.5
LSD (0.10):			*4*	*NS*

- **Corn after corn (3-yr)**
- Very high Bray P1
- Surface dribble with extra N as good as popup
- N&P in pop-up also increased yield
- Randall and Vetsch. 2010. Fluid Journal
- FFF funding

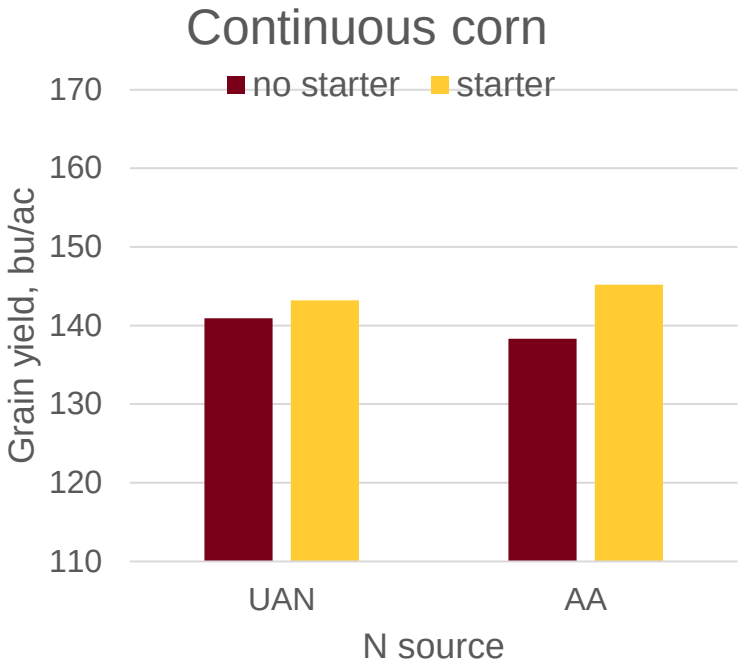
Liquid starter placement by nutrient (N-P-S-Zn)

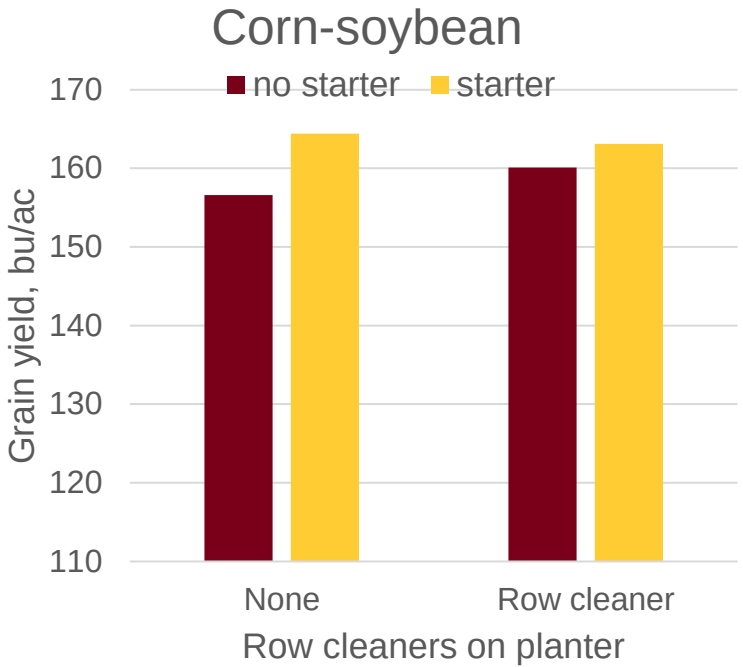
Starter Treatment			Grain
Placement	Products	Rate	Yield
			bu/ac
control	None	None	196
In-furrow	APP	5 gal	200
In-furrow	APP+Zn	5+¼ lb	199
In-furrow	APP+Zn	5+½ lb	197
Surf. Band	APP+ATS	5+2 gal	205
Surf. Band	APP+ATS+Zn	5+2+¼	201
9-site average		*LSD (0.10):*	*3*

- **Corn after beans**
- 8 of 9 sites very high Bray P1
- DTPA Zn ranged 0.4–1.8 ppm
  - 3 of 9 sites had DTPA Zn=0.4 ppm
- 2 of 9 + yield response to Zn
- 1 of 9 – yield response to Zn
- 2 of 9 + yield response to APP
- 3 of 9 + yield response to APP+ATS, compared to APP alone
- 5 of 9 + yield response to APP+ATS, compared to control

Vetsch 2010 AFREC (MN) funding

In-furrow starter interactions with N source and management of no-till corn (Vetsch and Randall. 2000. Agron, J).



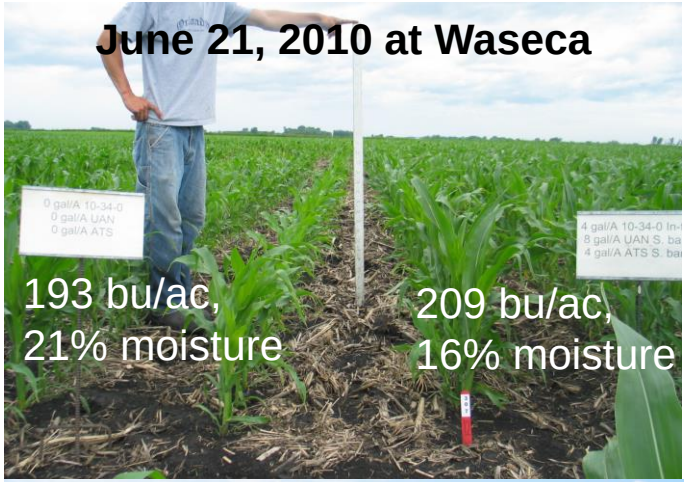


Corn yield as affected by N management in strip-till at Waseca.

Time of application, N source, inhibitors and N rate (lb/ac)				Yield
Fall AA	Preplant†	Planting UAN	Sidedress UAN	(bu/A)
None	None	None	None	111
w/N-Serve				161
Without				161
	AA			**168**
	Urea w/NBPT			**166**
	Urea w/NBPT	Dribble, 20		**172**
			Coulter Inj.	**166**
		Dribble, 20	Coulter, 80	**170**
		Coulter, 20	Coulter, 80	**170**
		Dribble, 40	Coulter, 60	160
		Coulter, 40	Coulter, 60	163
		Broadcast, 40	Coulter, 60	**174**
† w/NBPT as Agrotain			LSD (0.10):	8

Effects of liquid starter fertilizer on V6 continuous corn.

Starter Fertilizer Rate				Dry matter yield, V6	
APP	UAN	ATS		2012	2013
---------- gal/acre ----------					%
0	0	0		100	100
0	0	2		107	117
0	0	4		131	117
0	8	0		145	165
0	8	2		184	175
0	8	4		184	180
4	0	0		144	161
4	0	2		151	170
4	0	4		153	167
4	8	0		193	184
4	8	2		187	187
4	8	4		200	207



Funding provided by the
Fluid Fertilizer Foundation

AFREC
Agricultural Fertilizer Research & Education Council

Effects of liquid starters on corn grain moisture and yield, plant height and height CV at Waseca (clay loam, poorly drained).

Effects of starters	Grain H_2O	Grain Yield	Plant height	CV of height
	%	bu/A	inch	%
APP (10-34-0) in-furrow				
None	17.8 a	209 a	31.4 b	7.9 a
4 gal/A	17.3 b	210 a	34.0 a	6.8 b
UAN (28-0-0) surface dribble band				
None	17.7 a	209 a	31.3 b	**8.3 a**
8 gal/A	17.3 a	210 a	34.1 a	**6.4 b**
ATS (12-0-0-26) surface dribble band				
None	17.8 a	207 b	31.9 c	7.4 a
2 gal/A	17.4 a	211 a	32.7 b	7.6 a
4 gal/A	17.4 a	211 a	33.6 a	7.0 a

- APP in-furrow
  - did not affect grain yield (very high STP sites, not high pH).
  - reduced grain moisture in 3 of 4 yr and for the 4–yr avg.
- UAN as a surface band
  - reduced grain moisture in 2 of 4 yr.
  - reduced CV of plant height (4-yr avg)
- ATS in a surface band
  - reduced grain moisture in 2 of 4 yr
  - increased grain yield in 1 of 4 yr (4 bu/A avg. across yr)

Funding provided by the Fluid Fertilizer Foundation

Effects of liquid starters on corn grain moisture and yield, plant height and height CV at Rochester (silt loam, well drained).

Effects of starters	Grain H_2O	Grain Yield	Plant height	CV of height
	%	bu/A	inch	%
APP (10-34-0) in-furrow				
None	19.1 a	219 a	31.1 b	6.6 a
4 gal/A	18.5 a	219 a	33.4 a	6.2 a
UAN (28-0-0) surface dribble band				
None	19.0 a	218 a	31.7 b	6.5 a
8 gal/A	18.6 a	220 a	32.7 a	6.2 a
ATS (12-0-0-26) surface dribble band				
None	19.0 a	218 a	31.9 a	6.7 a
2 gal/A	18.7 b	219 a	32.3 a	6.2 a
4 gal/A	18.7 b	220 a	32.5 a	6.2 a

- APP in-furrow
  - Increased grain yield 1 of 4 yr and decreased 1 of 4 yr (high STP sites, not high pH).
  - reduced grain moisture in 2 of 4 yr
- UAN as a surface band
  - reduced grain moisture in 2 of 4 yr.
  - Increased corn grain yield in 1 of 4 yr
- ATS in a surface band
  - reduced grain moisture (4-yr avg.)
  - increased grain yield in 1 of 4 yr

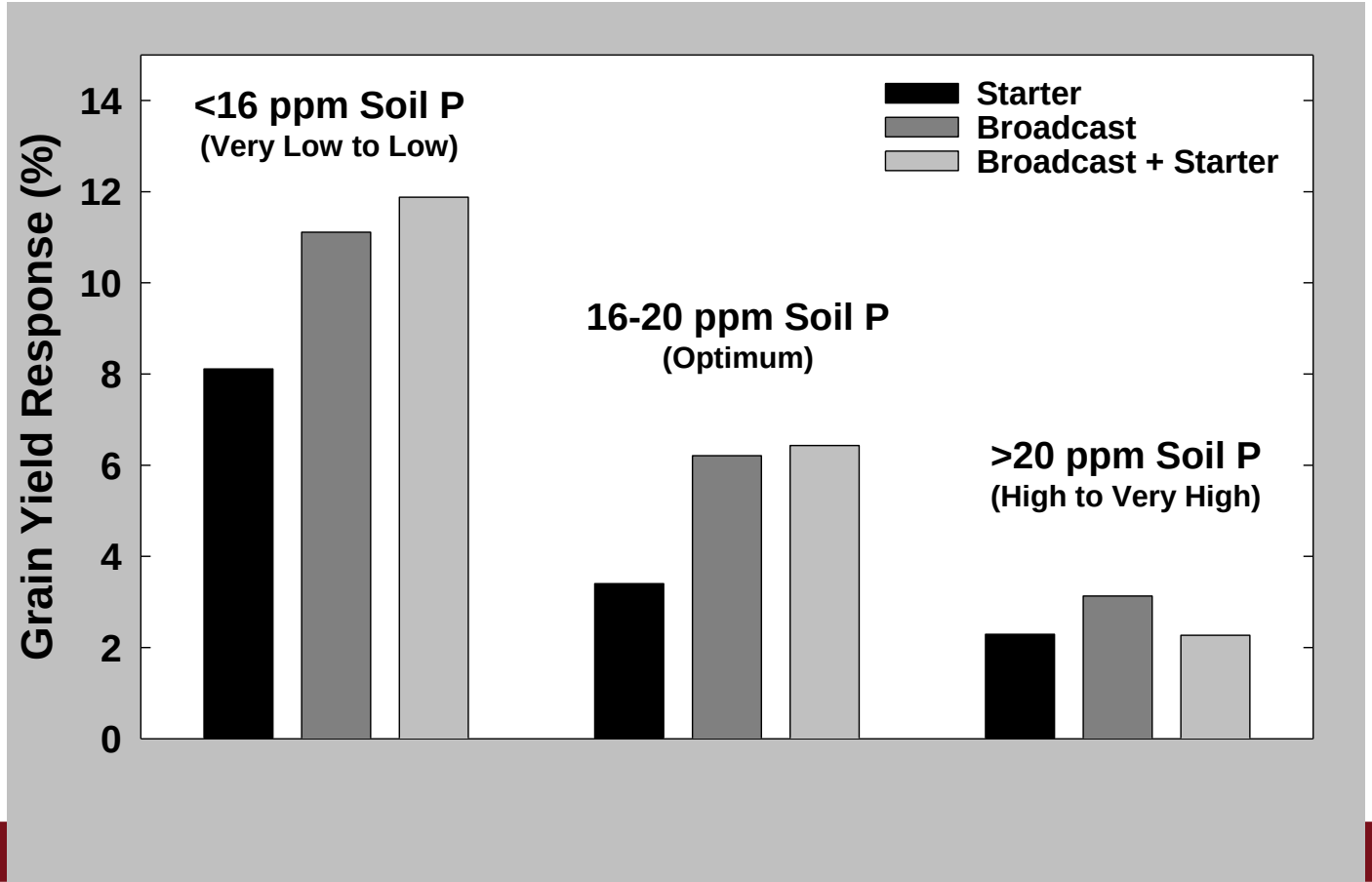
Funding provided by the Fluid Fertilizer Foundation

Summary of liquid starters in continuous corn

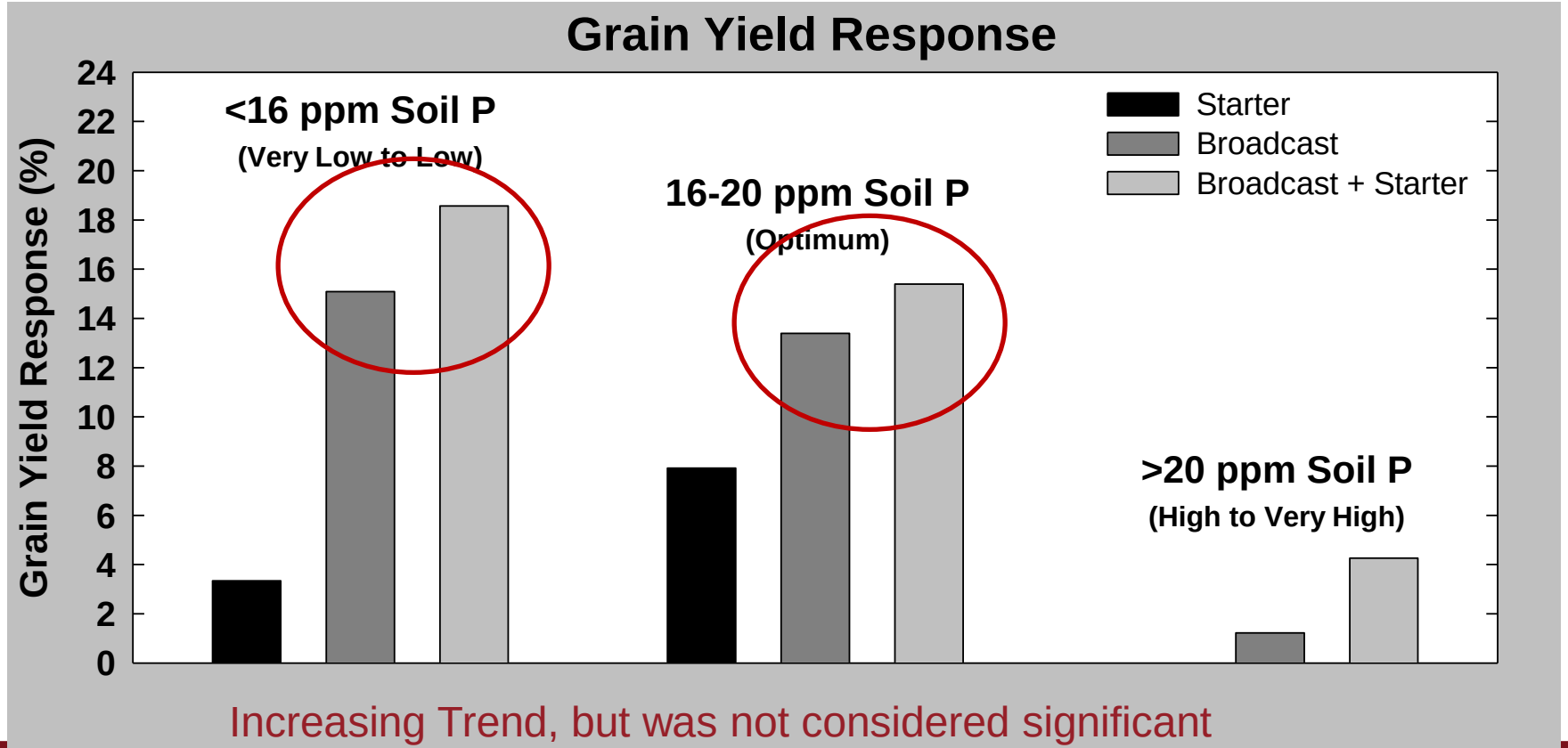
- Generally, starter fertilizers containing N, P and S applied as UAN, APP, and ATS increased early growth and reduced plant to plant variability in a reduced tillage system.
- N, P and S starter fertilizers often reduced grain moisture at harvest.
- Yield responses to fluid starters were inconsistent during this study period, however drought increased yield variability in 2 of 4 yr at Waseca.
- Responses were more likely on poorly drained glacial till soils.
- **NOTE: S yield response may be reduced with high rates of MAP, DAP or TSP as they often contain up to 1.5 to 2% S.**
  - Ex: Applying 150 lb P_2O_5/ac as MAP or DAP supplies about 5–6 lb S/ac.

Funding provided by the Fluid Fertilizer Foundation

Corn yield response to liquid starter with or without broadcast P fertilization (Kaiser and Mallarino, 2005)

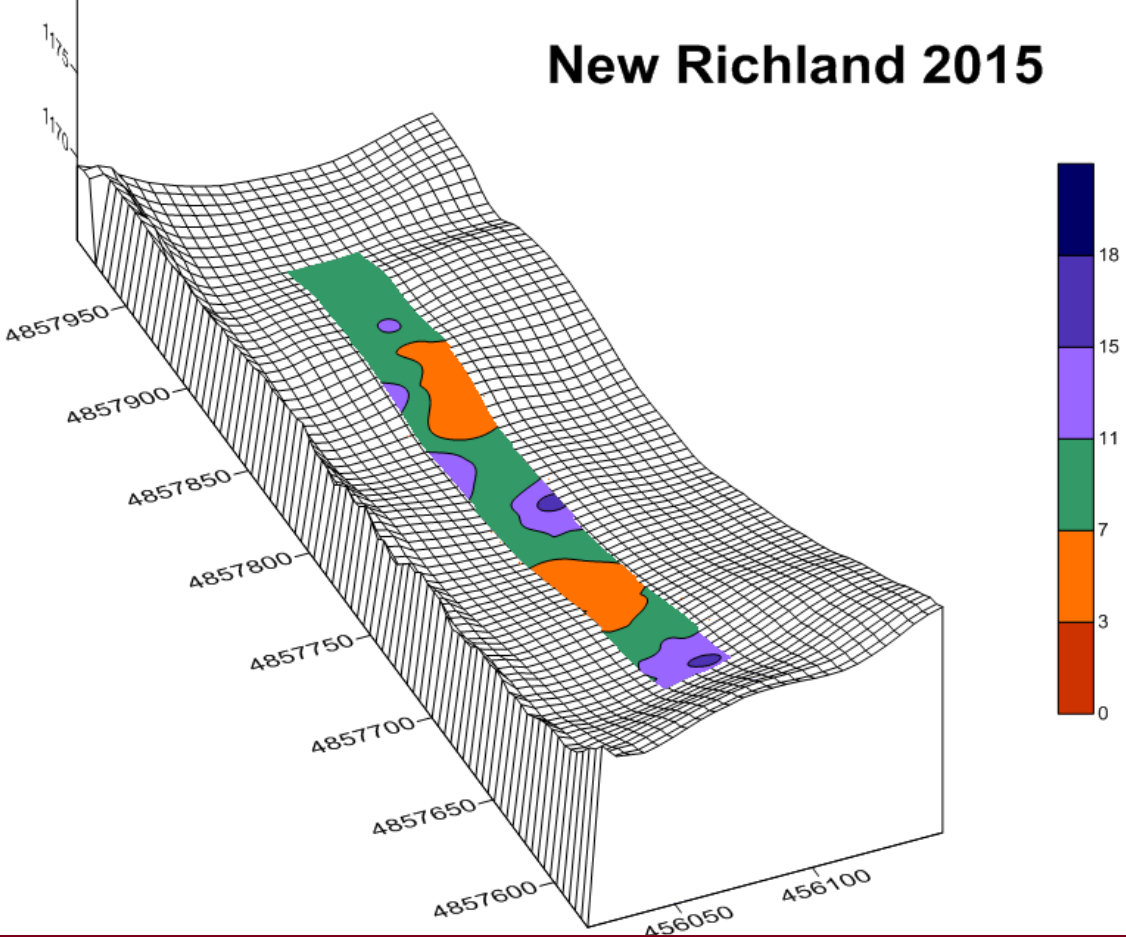


Effect of residual fertilizer P application on next year soybean yield (Kaiser and Mallarino, 2005)



Increasing Trend, but was not considered significant

New Richland 2015

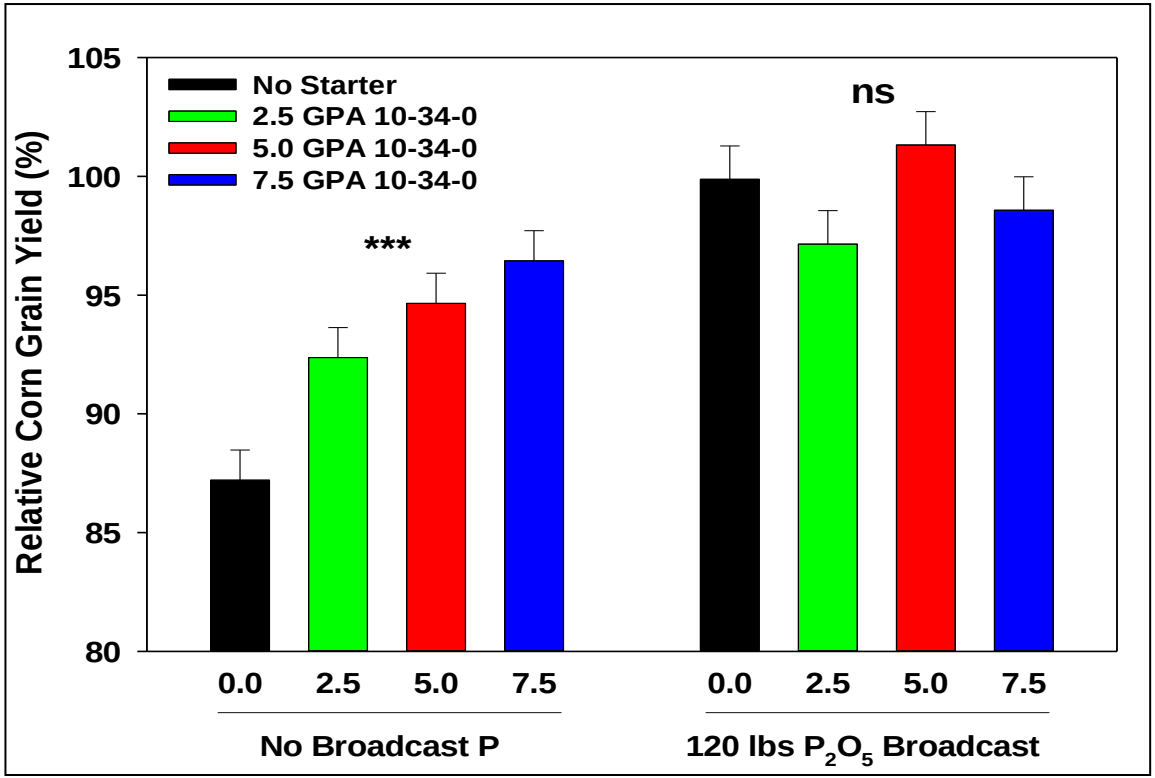


Funding provided by the
Fluid Fertilizer Foundation

MinnesotaCorn

University of Minnesota
Driven to Discover℠

Relative yield as affected by the interaction between broadcast and starter P rates.

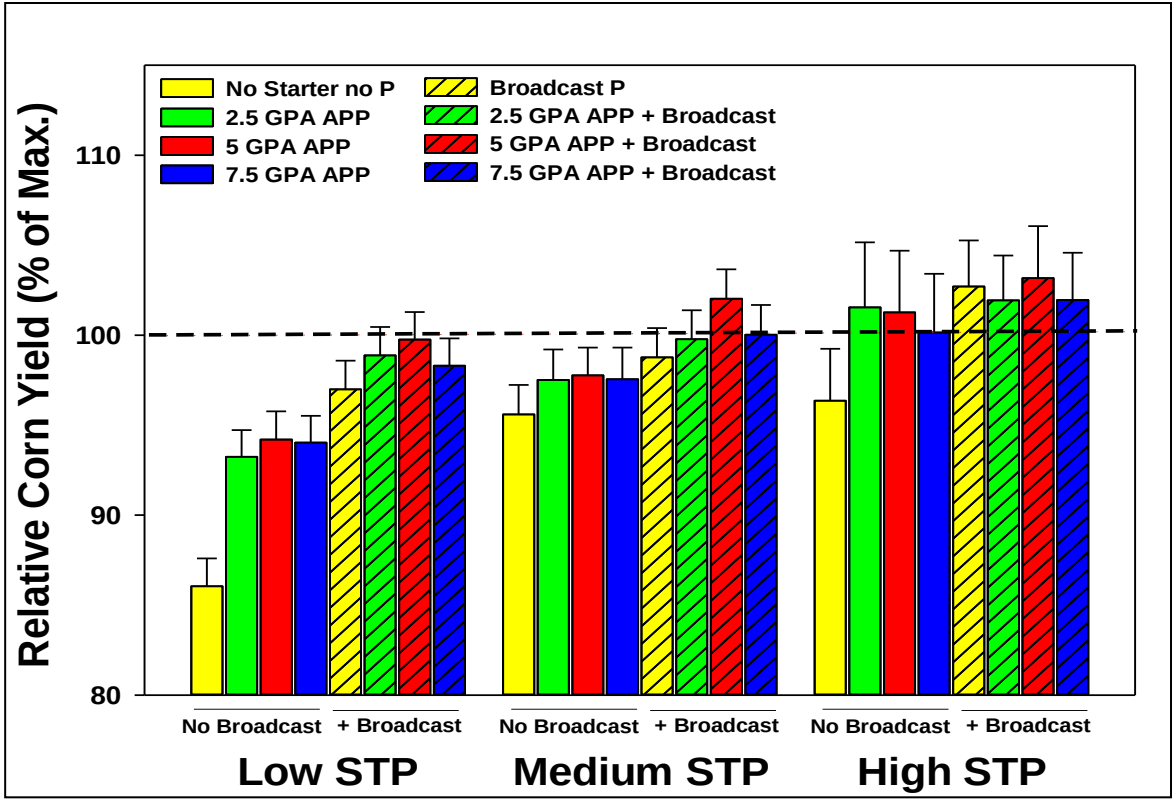


Funding provided by the Fluid Fertilizer Foundation

MinnesotaCorn

UNIVERSITY OF MINNESOTA
Driven to Discover℠

Relative yield as affected by broadcast and starter P rates across soil test P classes.



Funding provided by the
Fluid Fertilizer Foundation

MinnesotaCorn

University of Minnesota
Driven to Discover℠

Summary of N+P starter with vs without broadcast P

- **Iowa data:** When STP was very low, low or optimum
  - Starter alone provided 50-75% of the corn yield response to P
  - Broadcast produced greater corn yields than starter alone
  - Broadcast + starter not significantly greater
  - Next year soybean yield greater with broadcast
- **Iowa data:** When STP was high or very high
  - Starter produced yields equal to broadcast
  - IMPLICATIONS for when fertilizer prices are high

Funding provided by the Fluid Fertilizer Foundation

Summary of N+P starter with vs without broadcast P

- **MN data:** When STP was low (4–7 ppm Olsen)
  - Starter alone increased yields but not as much as broadcast
  - Starter + broadcast had greatest yields
  - No starter rate response
- **MN data:** When STP medium (8-11 ppm Olsen)
  - Starter produced yields equal to broadcast
  - Starter + broadcast had greatest yields
- **MN data:** When STP high (>12 ppm Olsen)
  - Starter produced yields equal to broadcast
  - IMPLICATIONS for when fertilizer prices are high

Funding provided by the Fluid Fertilizer Foundation

Summary: Where do liquid starters fit in 4R mgt?

- Tillage system: no-till, reduced till & strip-till corn
  - N, P & S applied surface dribble or N&P in-furrow
- Crop rotation: corn after corn/small grains vs soybean
  - N, P & S for corn after corn/small grain surface dribble
- Soil characteristics: poorly drained and high/low pH
  - N, P & S surface dribble on poorly drained soils; N&P in-furrow for high (>7.5) or low (<5.6) pH soils
- High rates of broadcast P often reduce starter P response
- Soil test P levels: low, medium/optimum or high - very high
  - In-furrow starter + broadcast P produces greatest yield on low and medium/optimum P testing soils.
  - $20 of in-furrow N&P starter = $100 of MAP/DAP on high P testing soils

Acknowledgments and contact info

- Funding for this research was provided by
  - AFREC (MN fertilizer check-off),
  - the Fluid Fertilizer Foundation,
  - MCR&PC (MN corn check-off),
  - industry partners (as noted in slides) and
  - the University of Minnesota.

Jeffrey Vetsch

Researcher 4

Southern Research and Outreach Center

jvetsch@umn.edu

Follow on Twitter @ jvetsch2

University of Minnesota

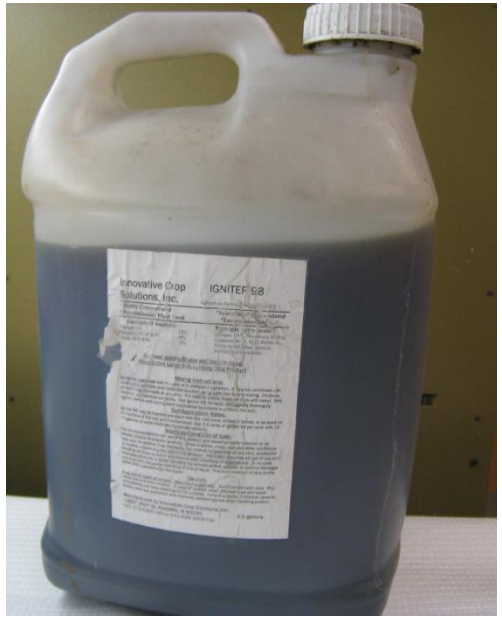
Driven to Discover®

Crookston Duluth Morris Rochester Twin Cities

New Information for Explaining How Humic Products Benefit Crops

Dan Olk and Dana Dinnes
USDA-ARS
National Lab for Agriculture and the Environment
Ames, IA

What are humic products?



Extracts of immature coals (leonardite, oxidized lignite), peats, composts.
Super-finely ground solid

Humic acid (HA), soluble in base but not acid. and/or fulvic acid (FA), soluble in both base and acid]

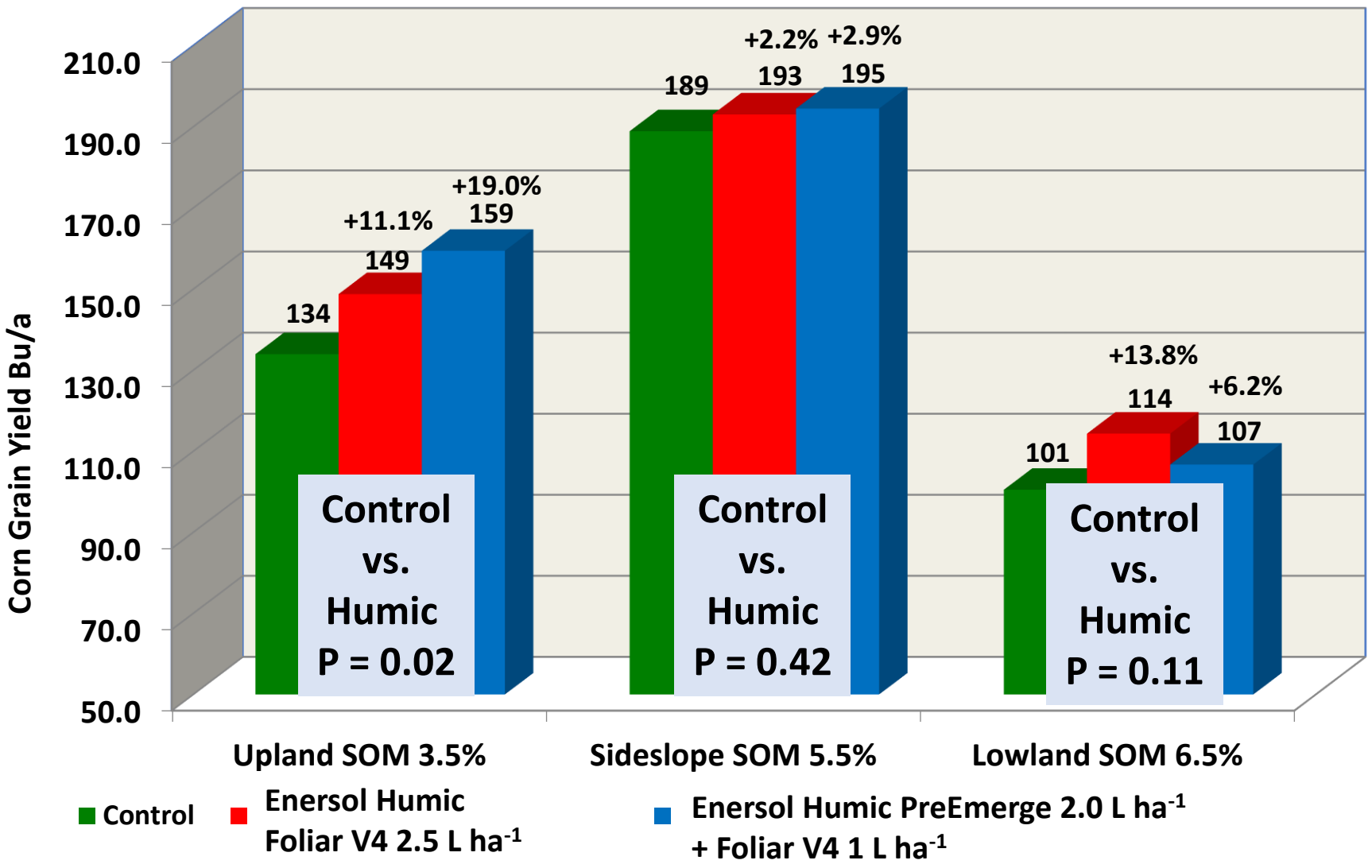
Application rates of 0.4-4 gallon/ acre. Cost as low as $10/ acre.
Some can be mixed into other agrochemical applications

Iowa research: Strongest humic product responses occur with environmental stress

Landscape position	Upland	Side-slope	Lowland
Soil organic matter (%)	3.5	5.5	6.5
Soil type	Clarion	Nicollet	Webster

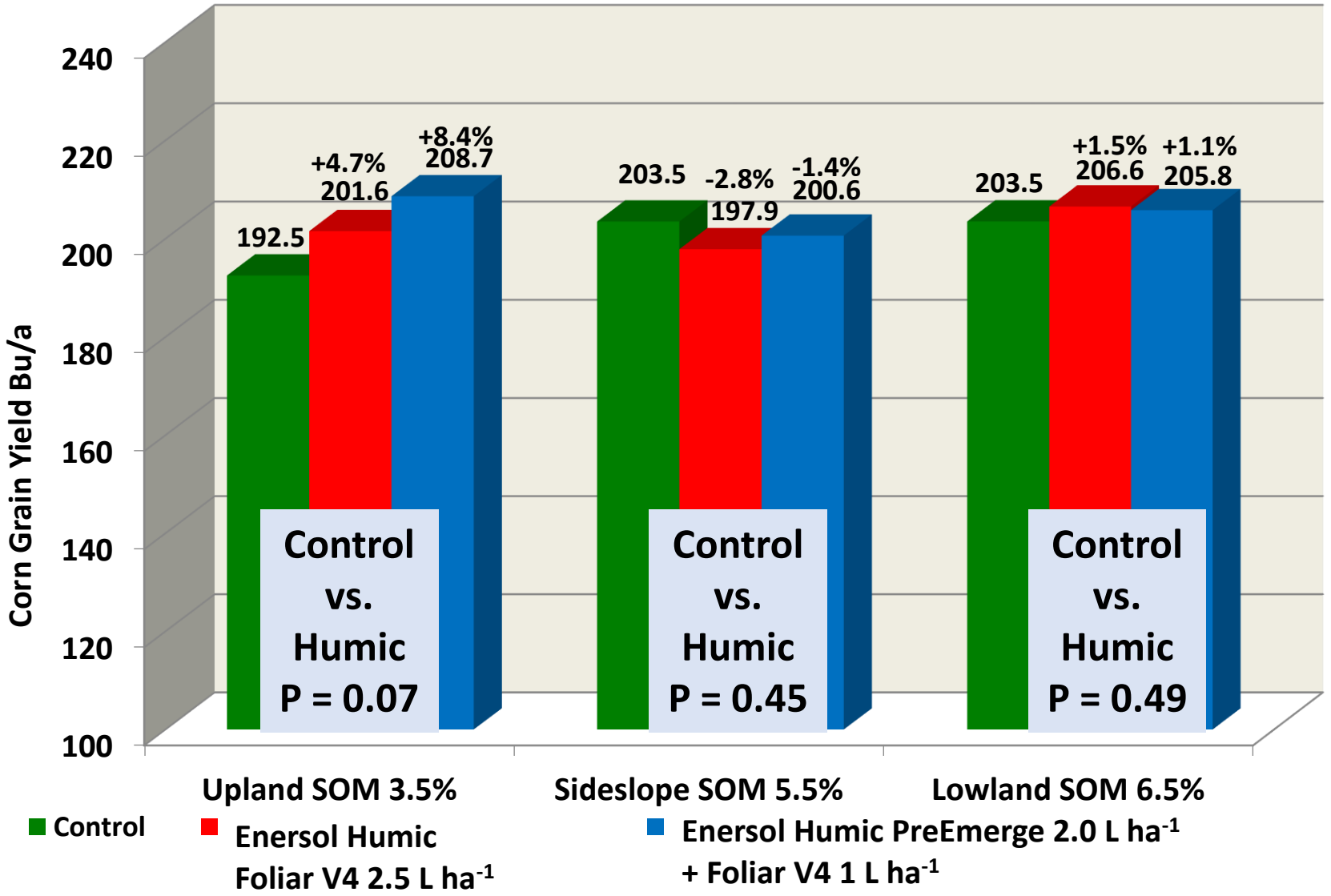
Corn Grain Yield (Combine Monitor) by Soil Type
2012 Finch Field, Ames, IA, 4 Reps

Severe Drought Year



Corn Grain Yield (Combine Monitor) by Soil Type
2014 Finch Field, Ames, IA, 4 Reps

Ideal Growing Conditions

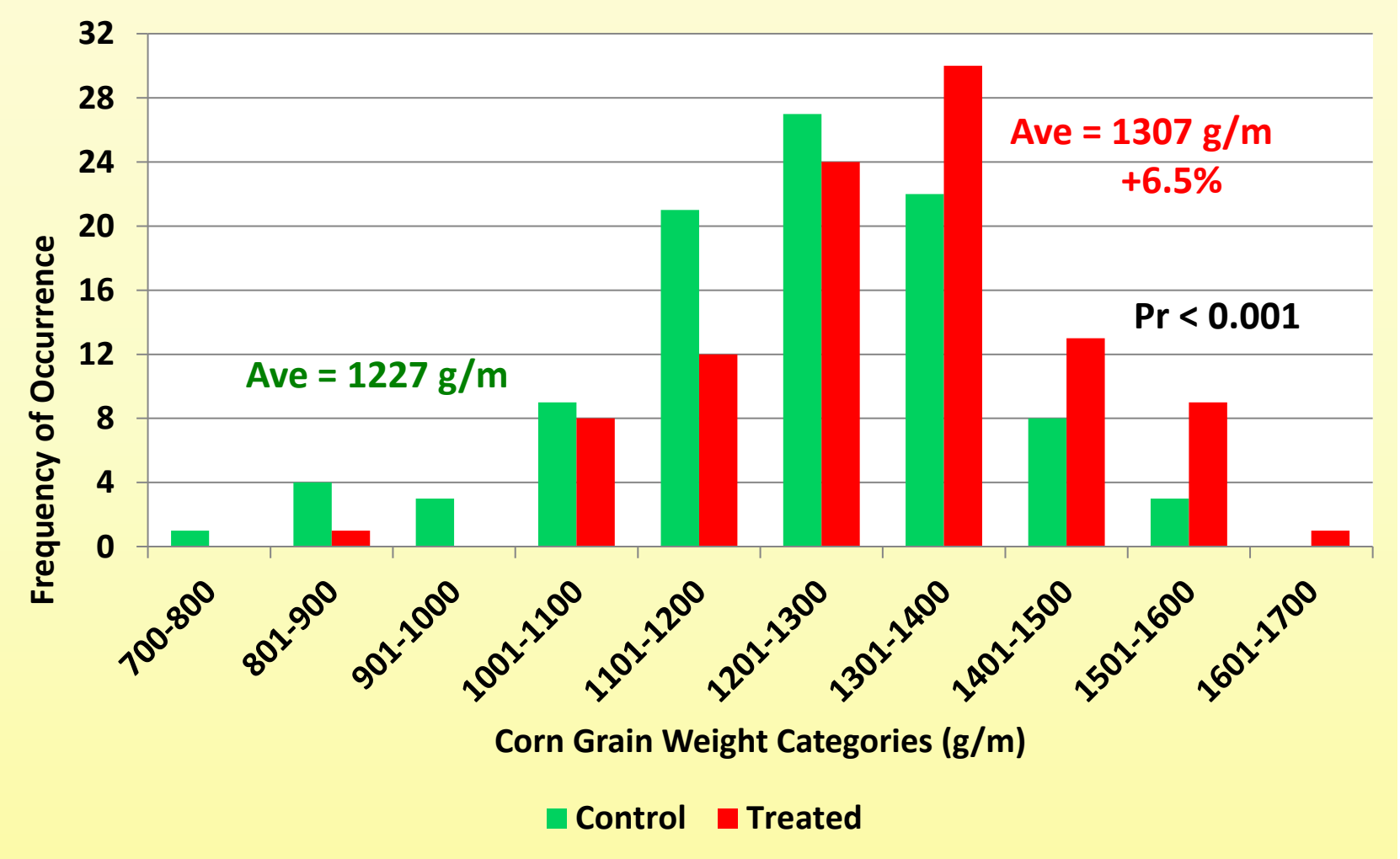


Corn and soybean yield responses to a humic product: nearly ideal precipitation patterns (2014-2015) vs. drought stress (2013, 2016-2017).Boyd 11 farm. Ames, IA

Year	Crop	Treatment	Timing	Grain Yield (bu/a)	% of Control	P > F[a] Compared to Control
2013	Soybean	Control	N/A	45.1	-----	-----
		Humic 34 oz/a	V4	48.5	+7.5	0.03
		Humic 41 oz/a	Pre-Emergence	47.9	+6.2	0.05
2014	Corn	Control	N/A	182.2	-----	-----
		Humic 34 oz/a	V4	179.4	-1.5	0.79
		Humic 27+14 oz/a	Pre-Emergence + V4	186.3	+2.2	0.69
2015	Soybean	Control	N/A	55.2	-----	-----
		Humic 64 oz/a	V4	56.9	+3.2	0.49
		Humic 128 oz/a	Pre-Emergence	57.3	+3.9	0.42
2016	Corn	Control	N/A	226.6	-----	-----
		Humic 32 oz/a	V4	233.7	+3.1	0.02
		Humic 64 oz/a	V4	236.1	+4.2	0.003
2017	Soybean	Control	N/A	54.4	-----	-----
		Humic 64 oz/a	V4	60.3	+10.8	<0.001
		Humic 128 oz/a	Pre-Emergence	61.5	+13.2	<0.001

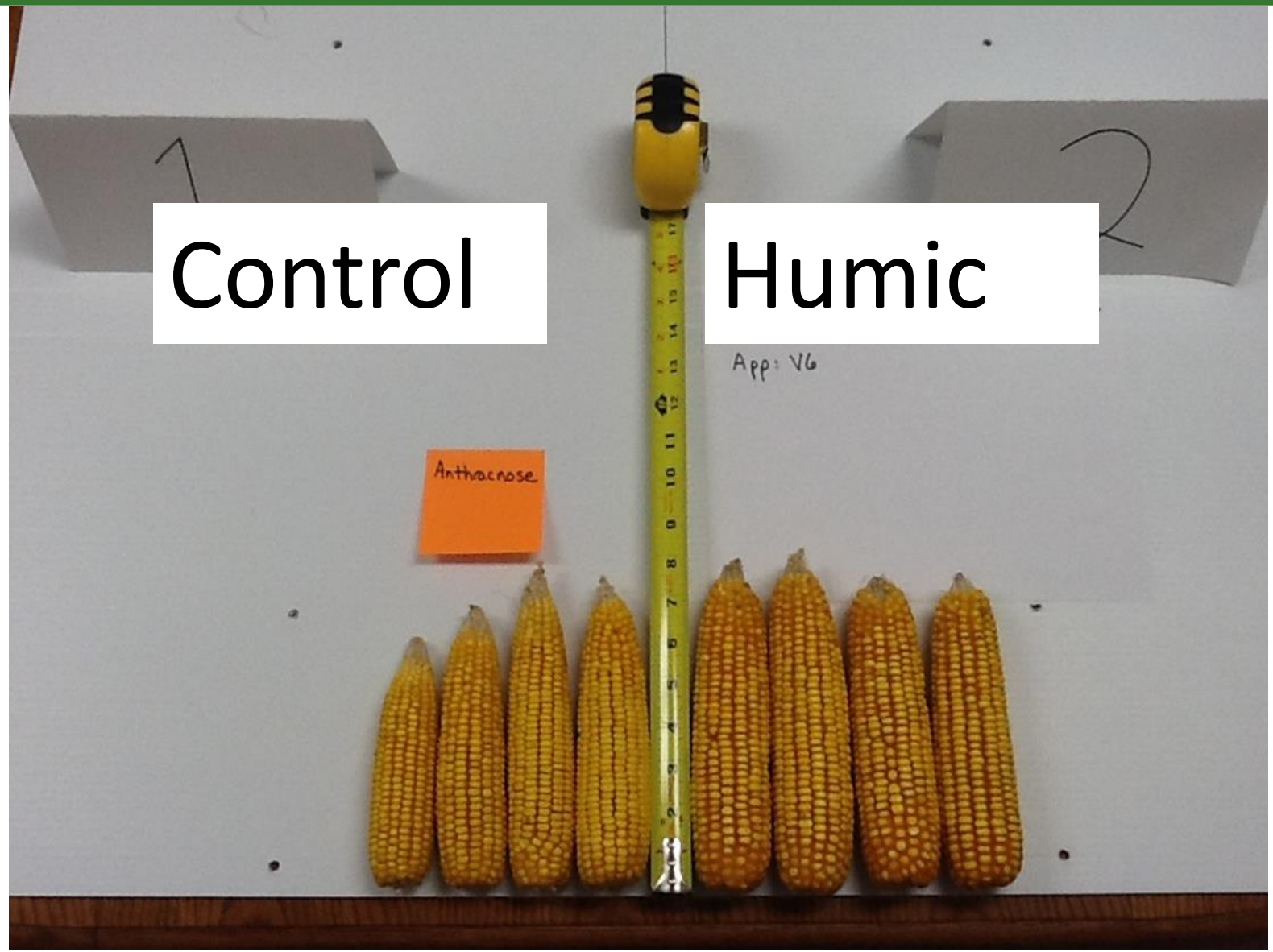
[a] **Probability of greater F values are the least significant difference T-tests from mixed models statistical analyses.**

Corn Grain Yield: On-Farm Hand-Sampled Grain Weights. 95 Pairings of Control vs. Humic Treated, 2009-2011

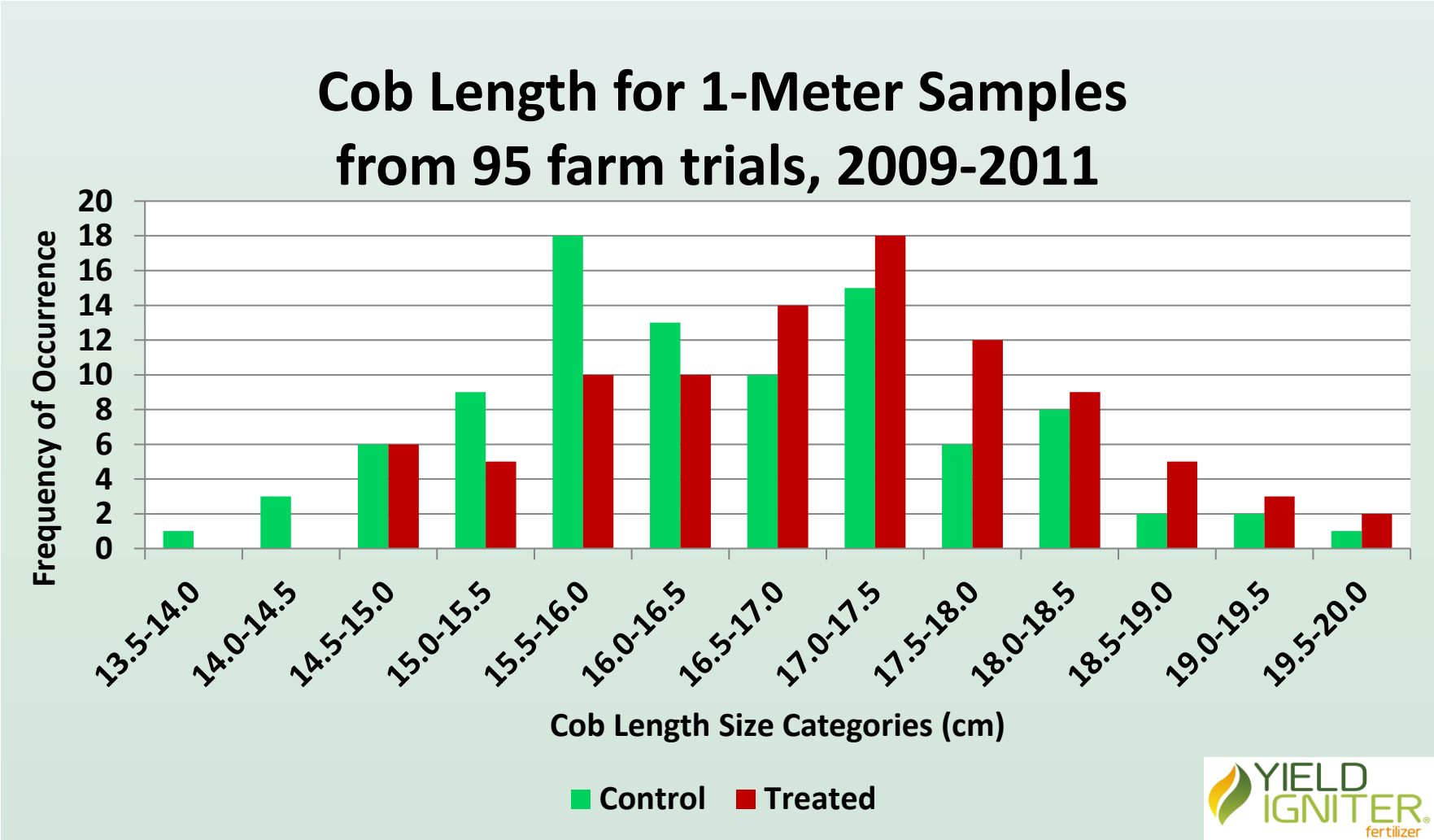


Over 3 Years, 70-80% incidence of numeric grain yield increase

Corn Cob Length
The yield component causing grain yield responses

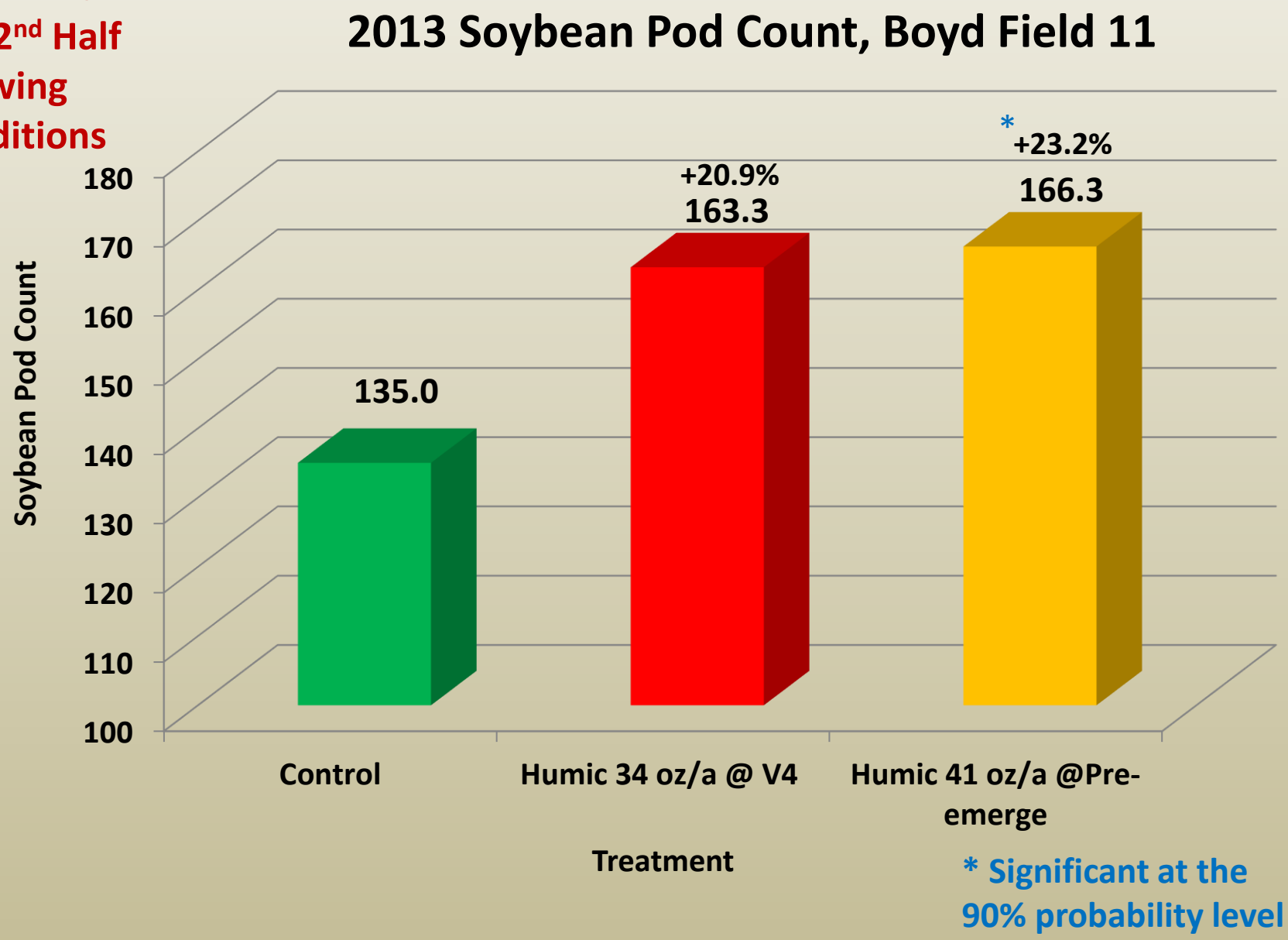


Corn Cob Length.



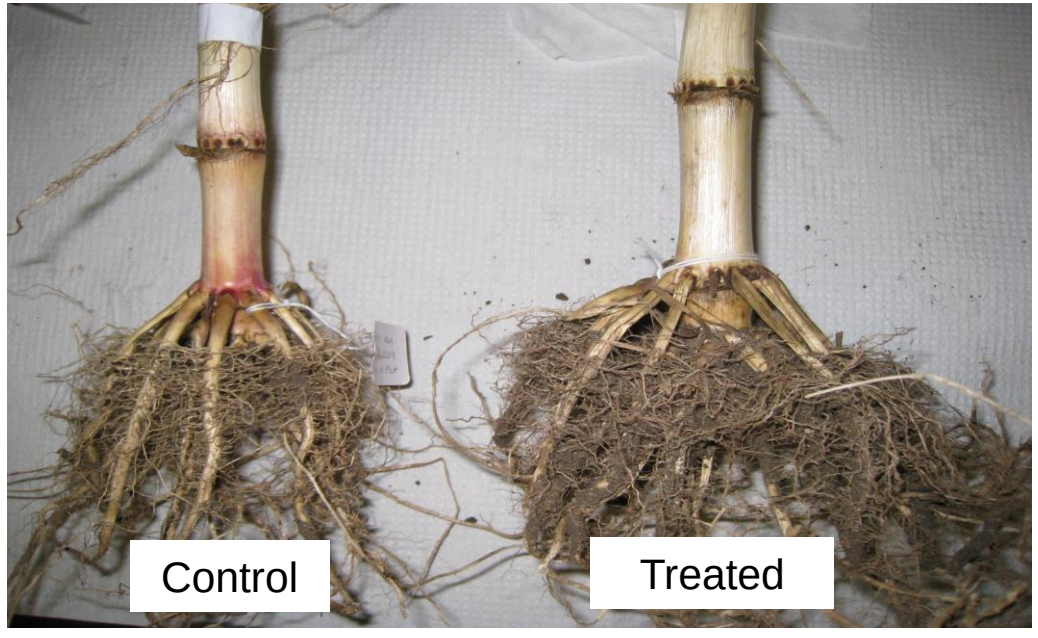
The distribution shift is a form of <u>Stress Alleviation</u>

Wet 1st Half
Dry 2nd Half
Growing
Conditions



Drought stress, 2012 Finch field, Ames, IA

Corn Root Measures (2013-2015)



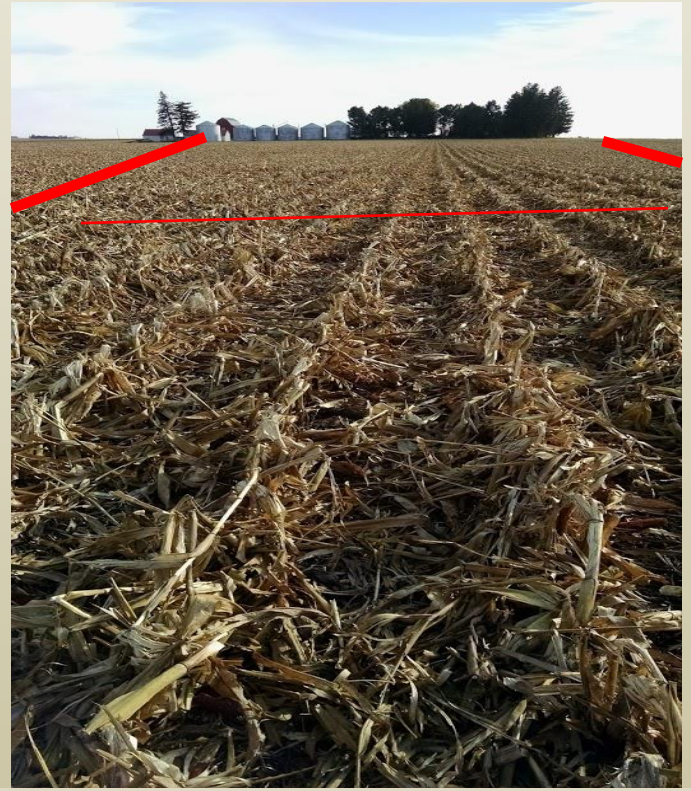
Total corn root length (cm) for three plants in a 45 dm^3 soil volume at the R2 growth stage following AMCOL product at single or split application in two years.

Year	Weather		Upland soils				Lowland soils	
2013	Wet, then drought		Control	V4#	Pre + V4		Control	V4
		Total root length	21,920	28,927 (+32%)	32,831 (+50%)		ND	ND
		P level (LSD)		0.061	0.012			
2014	Near ideal	Total root length	16,718	21,186 (+27%)	18,105 (+8%)		19,083	23,225 (+22%)
		P level (LSD)		0.16	0.67			0.13

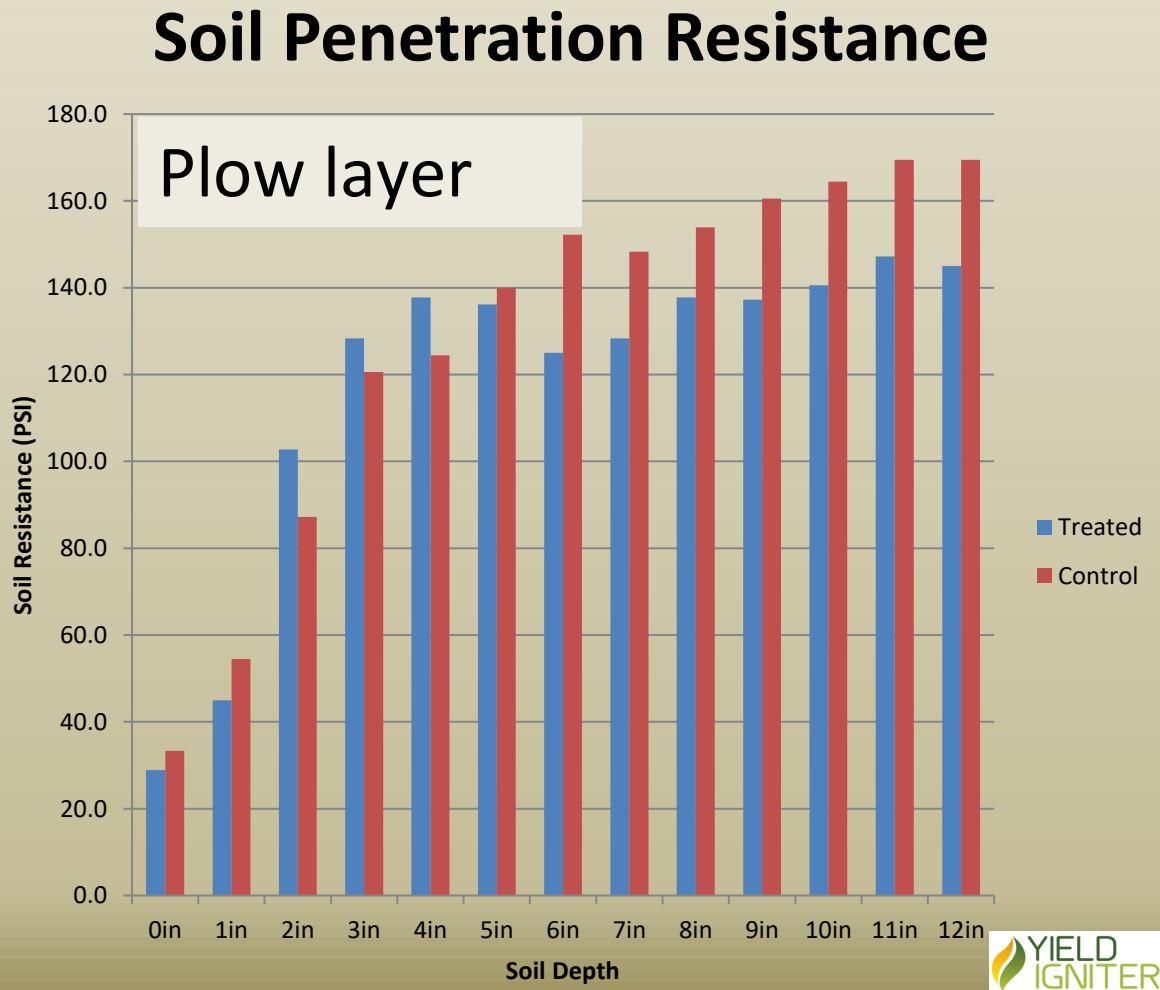
Application rates: 2.5 L ha^{-1} at V4, and 1+2 L ha^{-1} for split application at pre-emergence and V4, respectively.

MINERALS TECHNOLOGIES

Soil Benefits

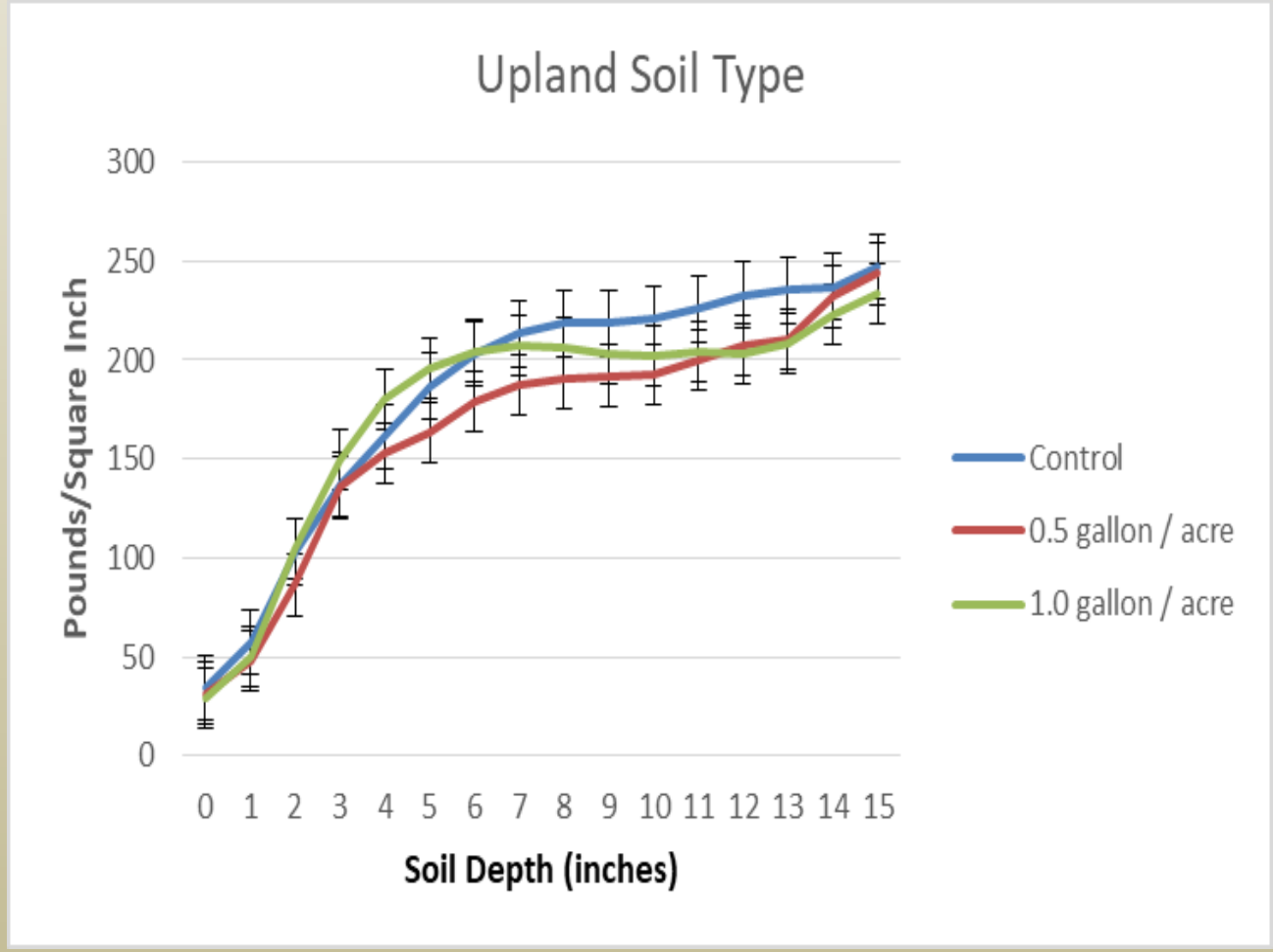


- **Strip outside Conrad, IA, received Ag Logic product 2009-2014.**
- **Soil penetration resistance measured October 2016**



Five-year field trial of Minerals Technologies “Enersol” product

Iowa State University research farm, Boone, IA



Corn Biochemistry

Humic Product Treated

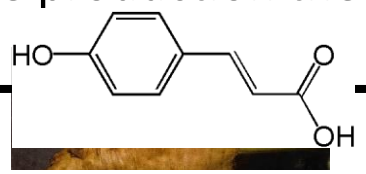
Untreated 16 Border Rows

Corn plant biochemical responses to a humic product in two farmer's fields, by year.

Year	Weather	Lignin-phenols (11)		Non-glucose Carbohydrates (4)	
		Stover	Roots	Stover	Roots
2013	Wet , then Drought	0	+9 to +28% P=0.09 and 0.24	0	0
2014	Wet , then Ideal	-6% and -11% P=0.10 and 0.32	0	0	+10 to +38% P=0.02 and 0.005

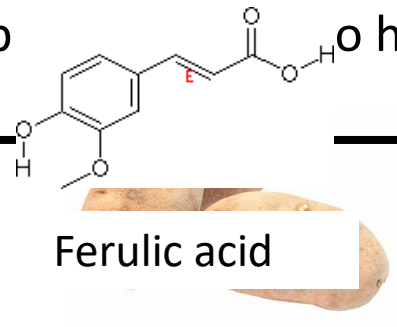
Syringaldehyde

arbohydrate production the default p ducts?



p-Coumaric acid

o humic



Ferulic acid

2022 Boyd 32 Field – N Rate X Humic Split-Plot Design
8 Row Plots with 30-inch Row Spacing

Now, let's look at nitrogen stress

Treatments

Main Treatments (Nitrogen Fertilizer Rates):

- **T1 = 0 kg N/ha (0 lb N/a)**
- **T2 = 70 kg N/ha (62 lb N/a)**
- **T3 = 140 kg N/ha (125 lb N/a)**
- **T4 = 210 kg N/ha (187 lb N/a)**
- **T5 = 280 kg N/ha (250 lb N/a)**

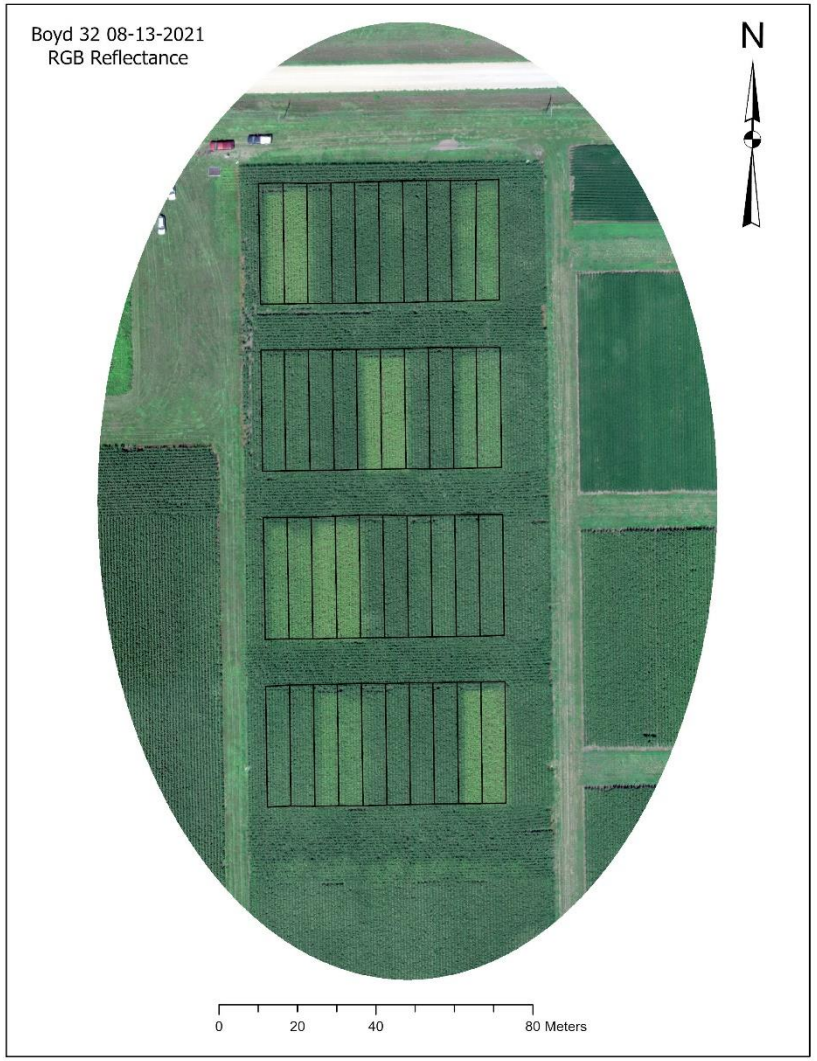
Apply UAN sidedress in interrows centers at earliest possible after emergence

Split Treatments (Humic Product):

- **H1 = Without (Control)**
- **H2 = With (Humic Treated)**
  Enersol 32 oz/a broadcast foliar-applied at ~V4

2022 Boyd 32 Field – N Rate X Humic Split-Plot Design

Rep 1	T1 H1 P1	T1 H2 P2	T4 H2 P3	T4 H1 P4	T3 H1 P5
Rep 2	T3 H1 P11	T3 H2 P12	T4 H1 P13	T4 H2 P14	T1 H1 P15
Rep 3	T2 H2 P21	T2 H1 P22	T1 H2 P23	T1 H1 P24	T5 H1 P25
Rep 4	T3 H2 P31	T3 H1 P32	T2 H2 P33	T2 H1 P34	T4 H1 P35



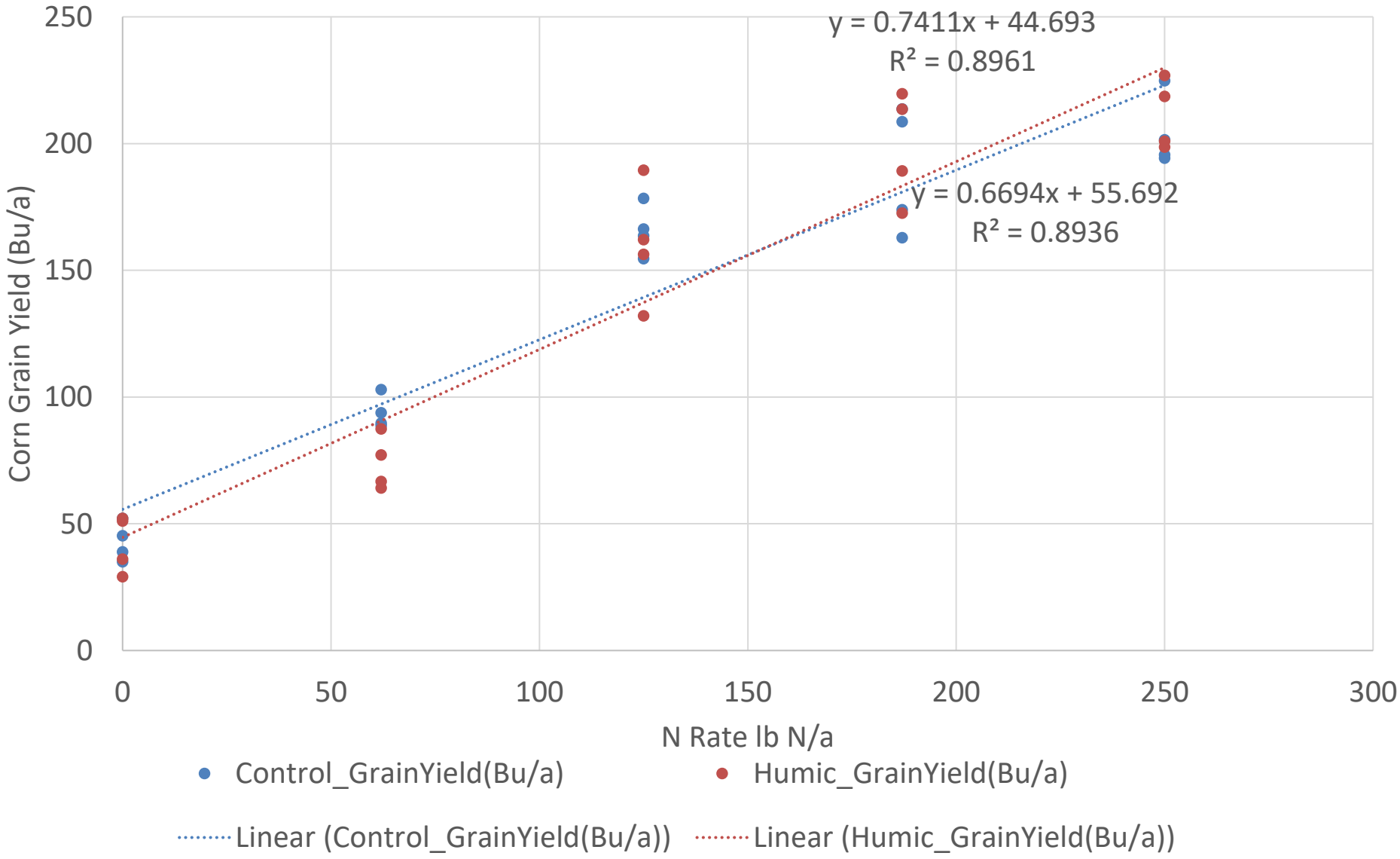
Combine grain yield response to a humic product 2021 field trial, Ames, IA (bushels/ acre)

N rate (lb acre^{-1})	Control	Humic product	Difference	P level
0	42.8	42.1	-0.7	0.920
62	93.8	73.9	-19.9	0.015
125	165.7	160.0	-5.7	0.429
187	189.8	198.7	+8.9	0.225
250	204.0	211.3	+7.3	0.323

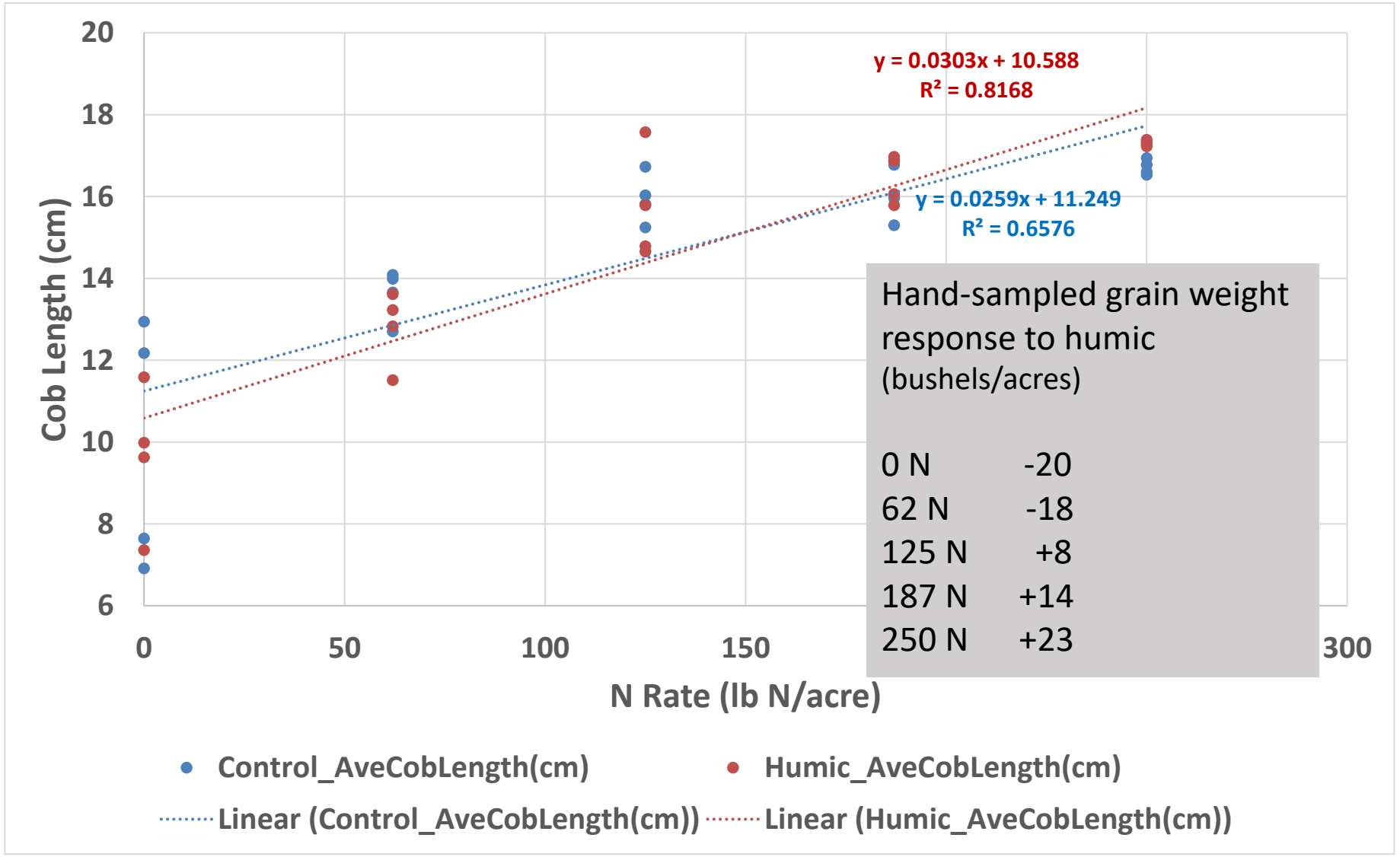
Combine grain yield response to a humic product 2021 (and 2020) field trial, Ames, IA (bushel/ acre)

N rate (lb acre^{-1})	Control	Humic product	Difference	P level
0	42.8	42.1	-0.7	0.920
62	93.8	73.9	-19.9	0.015
125	165.7	160.0	-5.7	0.429
187	189.8	198.7	+8.9	Mainplot trmt: P=0.098 for 187 N and 250 N.
250	204.0	211.3	+7.3	
		2020		
0	34.6	34.4	-0.2	0.968
62	75.2	64.2	-11.0	0.125
125	138.6	149.2	+10.6	0.138
187	170.3	178.6	+8.3	0.238
250	169.0	165.9	-3.1	0.649

2021 Combine grain yield
Humic vs Control across five N fertilizer rates



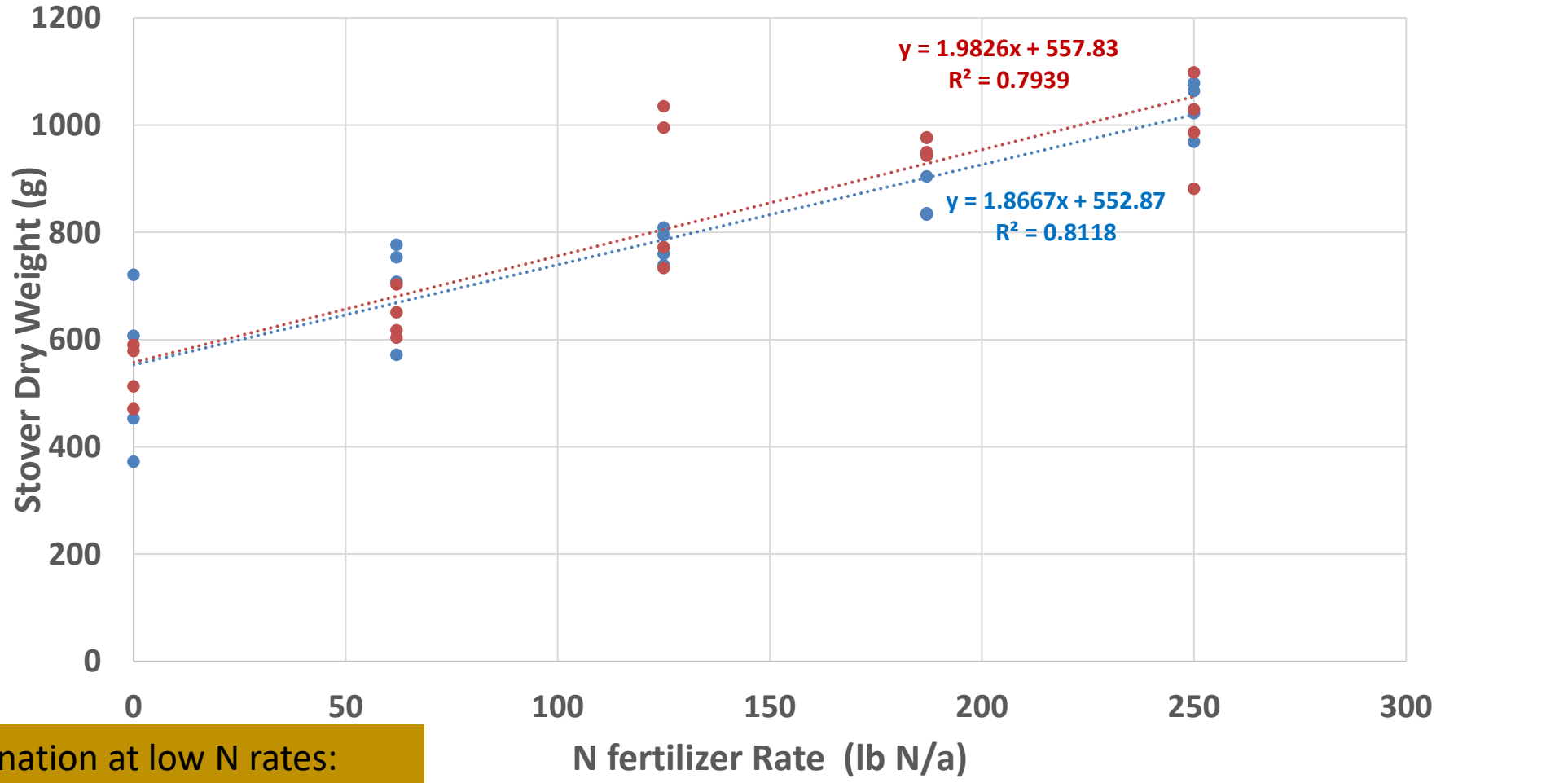
2021 Cob length for hand-samples (7 plants/plot)
Humic vs Control across five N rates



Hand-sampled grain weight response to humic
(bushels/acres)

0 N	-20
62 N	-18
125 N	+8
187 N	+14
250 N	+23

2021 Stover weight for hand-samples (7 plants/plot)
Humic vs Control across five N rates



Speculative explanation at low N rates:

The humic product stimulates the crop to grow excessively, more than the extent supported by the limited N supply.

- In this field study on fertile Iowan soils, the humic product did not increase nitrogen availability at the low N fertilizer rates.

- Yet it increased corn grain yield at the higher N fertilizer rates.

- Might there be mechanism(s) for humic product efficacy other than enhancing nutrient supply?

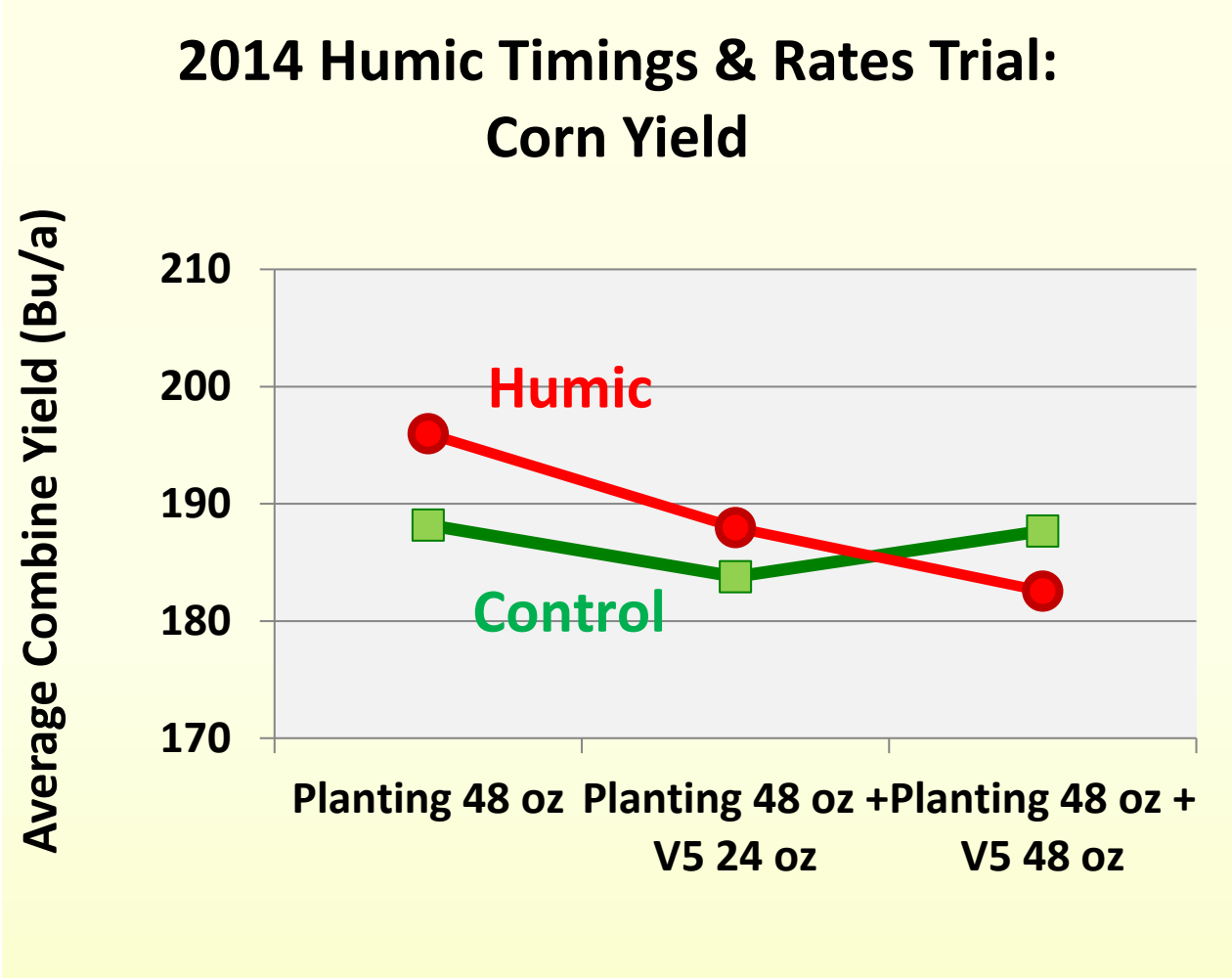
Humics can be biostimulants, not fertilizer enhancers

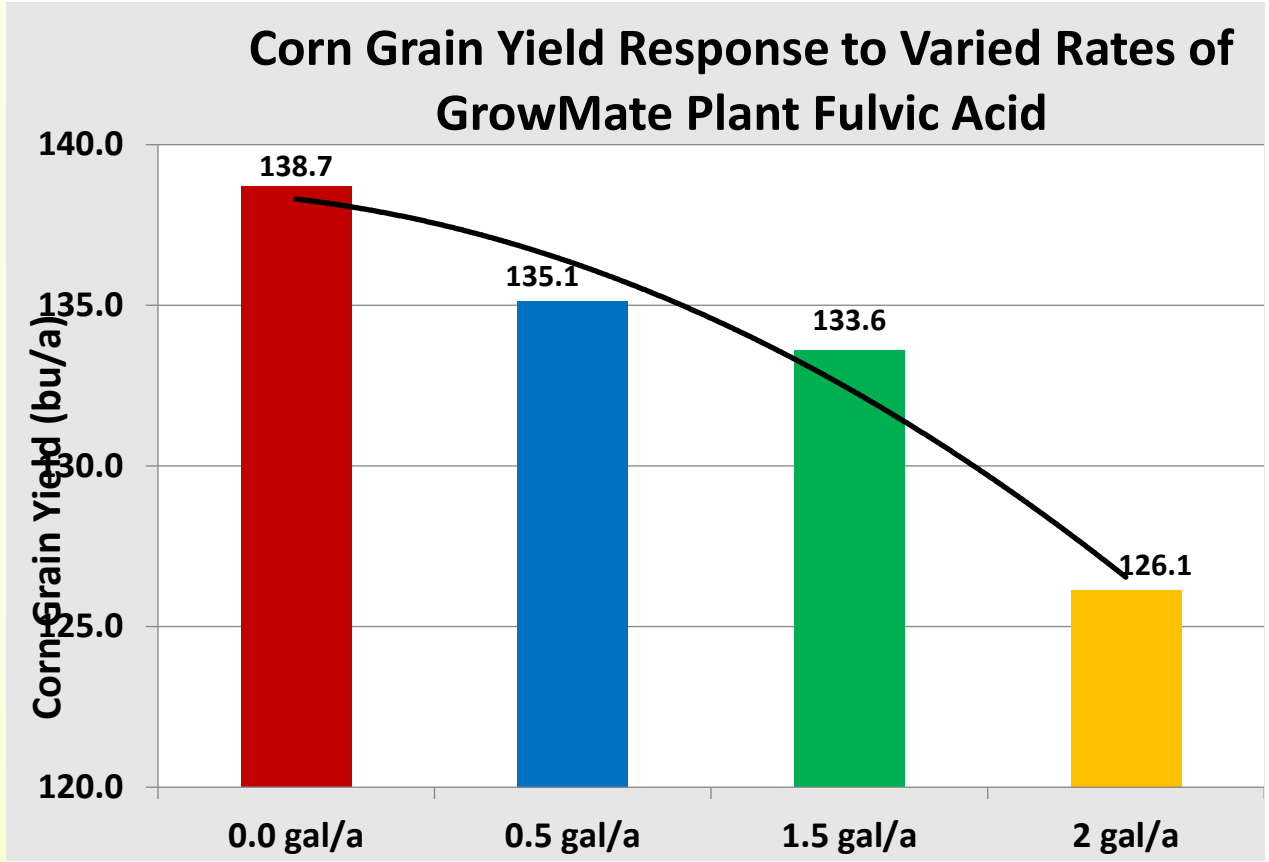
- Very low application rates—negligible nutrient input
- They make soil micronutrients more available? Must then prove micronutrients are limiting crop growth. Does not explain plant responses to foliar applications or responses in hydroponic systems.
- Excessive application rates lead to diminished crop benefits or even yield loss. USDA research, and also Rose et al. (2014) review.
- Limited evidence: Negative responses for corn in seasonally flooded soils

How much carbon are we adding via humic products?

Carbon source	Carbon input to soil (kg ha^{-1})
Humic product (2 gallon/acre, 20% HA+FA)	2
Crop residues (5 tons ha^{-1})	2150
Soil organic carbon (2% SOC, 6-inch plow layer, 1.2 g/ cm^3 bulk density)	1,800,000

Toxic effects at excessive rates





Corn and soybean yield responses to a humic product: nearly ideal precipitation patterns (2014-2015) vs. drought stress (2013, 2016-2017). Boyd 11 farm. Ames, IA

Year	Crop	Treatment	Timing	Grain Yield (bu/a)	% of Control	P > F[a] Compared to Control
2013	Soybean	Control	N/A	45.1	-----	-----
		Humic 34 oz/a	V4	48.5	+7.5	0.03
		Humic 41 oz/a	Pre-Emergence	47.9	+6.2	0.05
2014	Corn	Control	N/A	182.2	-----	-----
		Humic 34 oz/a	V4	179.4	-1.5	0.79
		Humic 27+14 oz/a	Pre-Emergence + V4	186.3	+2.2	0.69
2015	Soybean	Control	N/A	55.2	-----	-----
		Humic 64 oz/a	V4	56.9	+3.2	0.49
		Humic 128 oz/a	Pre-Emergence	57.3	+3.9	0.42
2016	Corn	Control	N/A	226.6	-----	-----
		Humic 32 oz/a	V4	233.7	+3.1	0.02
		Humic 64 oz/a	V4	236.1	+4.2	0.003
2017	Soybean	Control	N/A	54.4	-----	-----
		Humic 64 oz/a	V4	60.3	+10.8	<0.001
		Humic 128 oz/a	Pre-Emergence	61.5	+13.2	<0.001

Very different corn grain yield response under excessively wet conditions, 2018.

Factor	Trt Mean	Proc Mixed Pr>F	Proc Mixed LSD Pr>F	Proc Mixed Dunnett's Pr>F
Corn Combine Whole-Pass Grain Yield Bu/a @ 15.5% Market Moisture				
Trt 1 (Control)	182.4			
Trt 2 (32 oz/a Enersol)	183.0			
Trt 3 (64 oz/a Enersol)	169.8			
Main Trt Effect		0.1753		
Trt 1 vs. Trt 2			0.9317	0.9942
Trt 2 vs. Trt 3			0.1026	.
Trt 1 vs. Trt 3			**0.1161**	0.1933
Corn Combine Whole-Pass Grain Yield Mg/ha @ 15.5% Market Moisture				
Trt 1 (Control)	11.45			
Trt 2 (32 oz/a Enersol)	11.49			
Trt 3 (64 oz/a Enersol)	10.66			

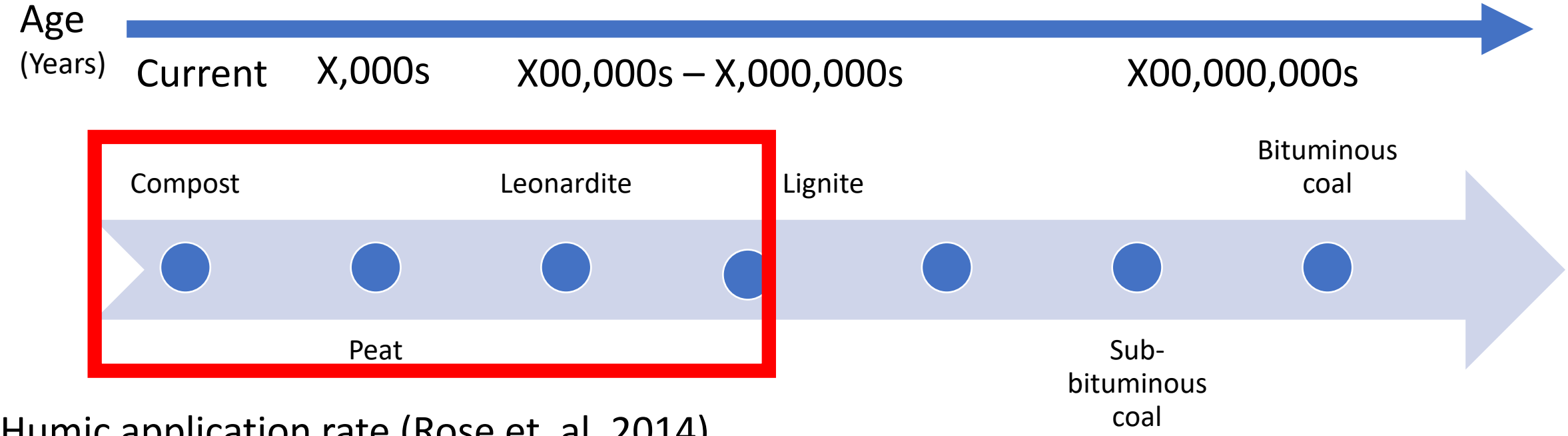
Our thoughts (Per the Scientific Process)

- The active ingredient is NOT the whole humic acid molecule or the whole fulvic acid molecule. Literature review on soil humic substances: plant growth promotion not linked with one specific fraction or subfraction (Zandonadi et al., 2013).

- The active ingredient(s) is/are specific biochemical compounds that mimic life-promoting compounds. These active compounds are likely NOT true hormones.

- What might the nature and origin of these compounds be?

- A geologic view:



Humic application rate (Rose et. al, 2014)

1,000+ ppm

<200 ppm

Amino acids,
Carbohydrates

X

Lignin,
Phenols

Aromatic rings,
Fatty acids

X

Conclusions

- Field efficacy of humic products in Iowa was demonstrated (1) especially during environmental stresses, and (2) by positive grain yield responses of corn at medium to high N fertilizer rates.

- At low N fertilizer rates, corn grain yield decreased with humic product use. This product did NOT make N more available to the crop.

- Multiple mechanisms might explain humic product field efficacy. Our data and previous results in Iowa are inconsistent with nutrient-based mechanisms. Instead, humic products might contain mimics of growth-promoting compounds, possibly of lignin origin.


THANK
YOU

Fluid Fertilizer Technology Workshop

"Which Starter Nutrients Close The Yield Gap When Corn Is Planted After Cereal Rye

Jacob Vossenkemper, PhD – Director of Research & Agronomy
For Twin State Inc.

Davenport, IA Nov 30th and Dec 1st 2022

jpv@liqui-grow.com liqui-grow.com

- **Special Thanks**
  - Lowell Gentry, Principal Research Specialist at Univ of Illinois
  - Dr. Shalamar Armstrong, Soil Ecosystems and Nutrient Dynamics Lab at Purdue Univ
  - Hunter Bielenberg, Agronomy Research Manager at Twin State Inc.
  - My “army” of interns who make all this work possible

Research Rationale/Background

- Increasing societal interest in addressing climate change
  - Soil health
  - Regenerative agriculture
  - Carbon/GHG markets
  - Nutrient loss reduction
  - Land stewardship etc……

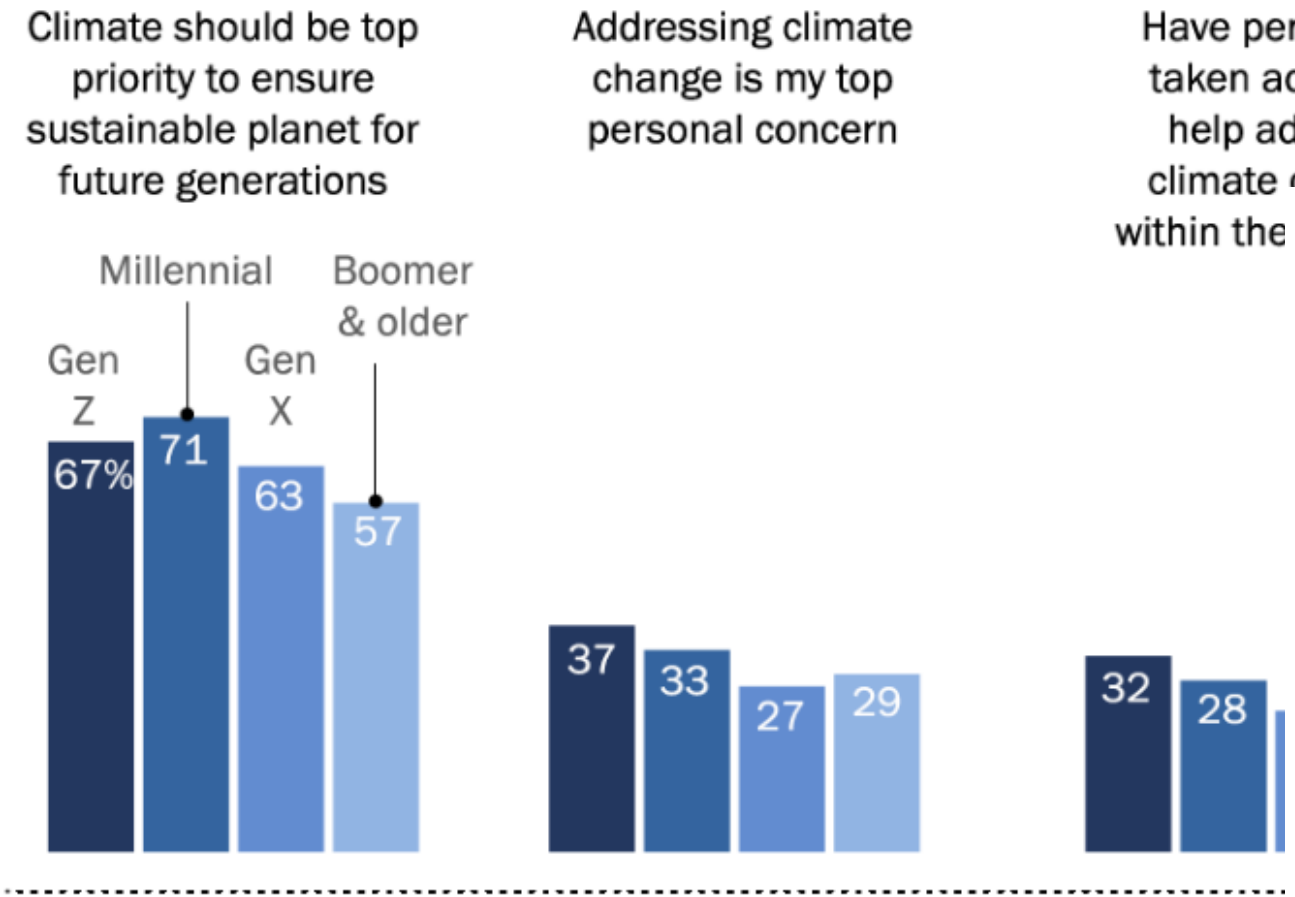
Pew Research Center Survey, May 2021

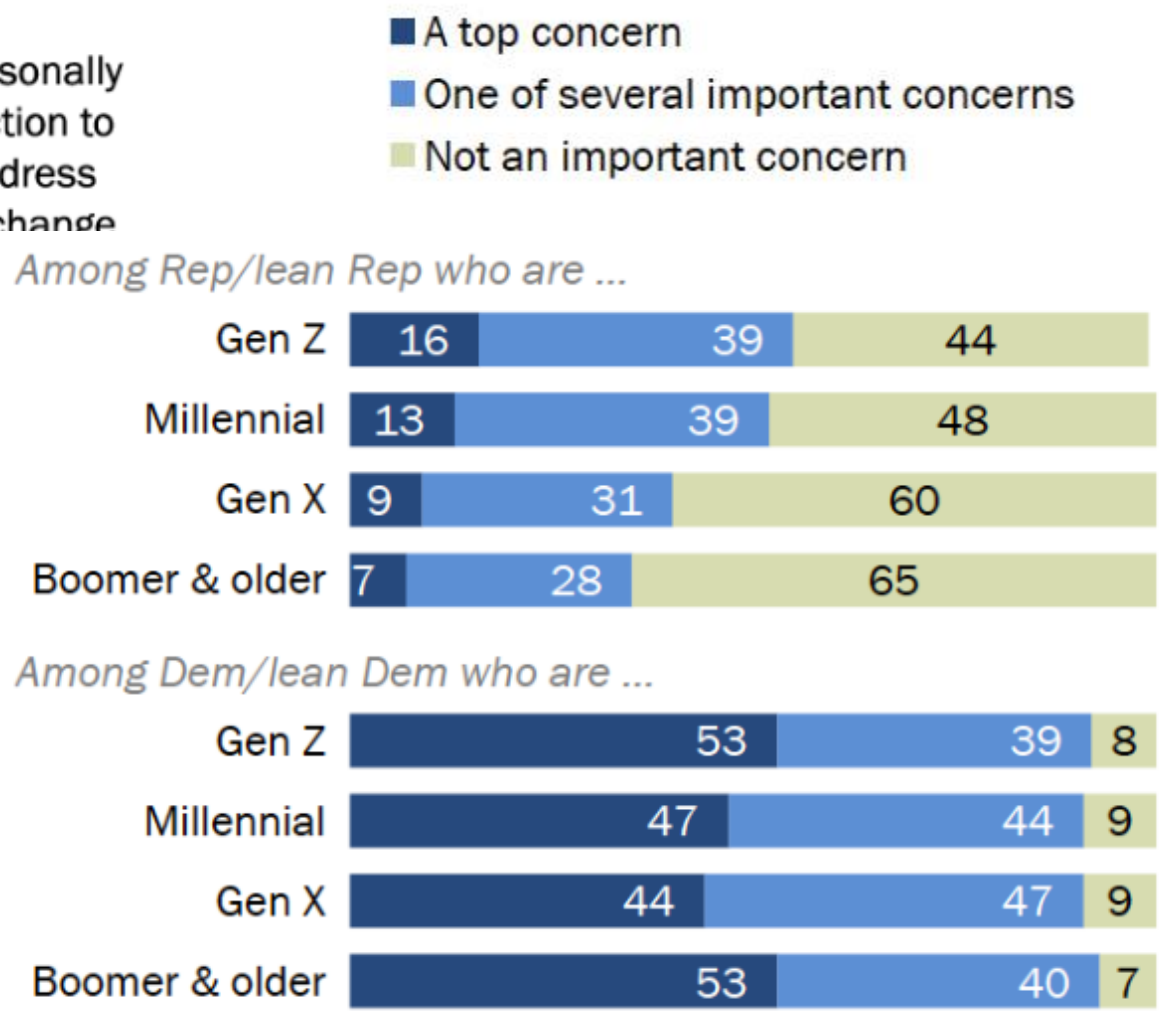
SCIENCE DRIVEN DECISIONS

Gen Z, Millennials more active than older generations addressing climate change on- and offline

https://www.pewresearch.org/science/2021/05/26/climate-engagement-and-activism/

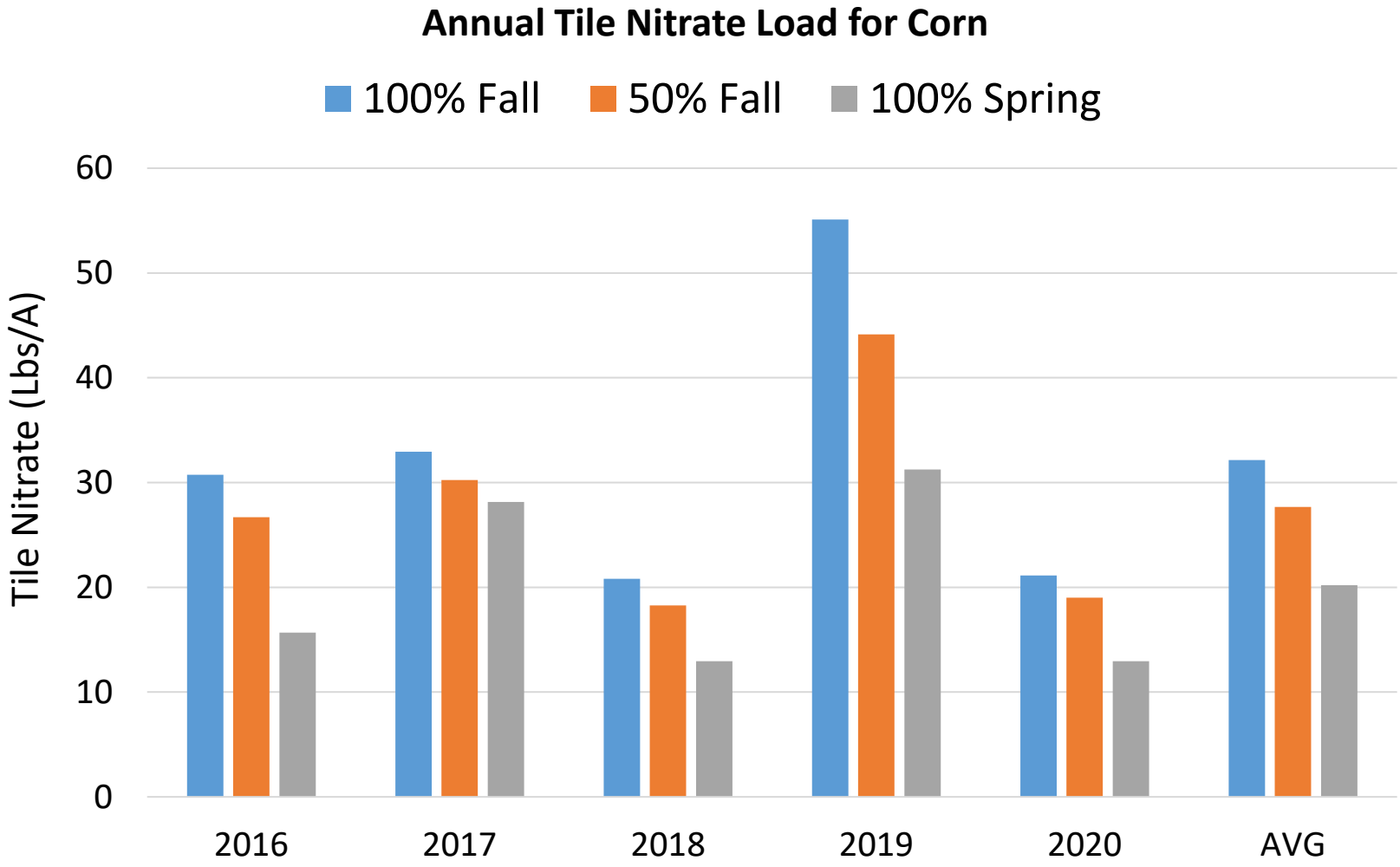
% of U.S. adults who say ...





Timing of N Application is Important

Figure Courtesy of Lowell Gentry, Univ of Illinois



Fall N plots lost 12 lbs/A more tile nitrate than spring N plots.

Research Rationale/Background

- Cover crops proposed to help address these issues that society is becoming more concerned about
  - Reduce soil erosion
  - Increase nutrient stewardship/reduce loss
  - Increase soil water retention/infiltration
  - Increase soil organic carbon
    - Store CO_2 in soil = less in atmosphere curbs global warming

4-yr Cumulative Tile Nitrate Load 2016-2019

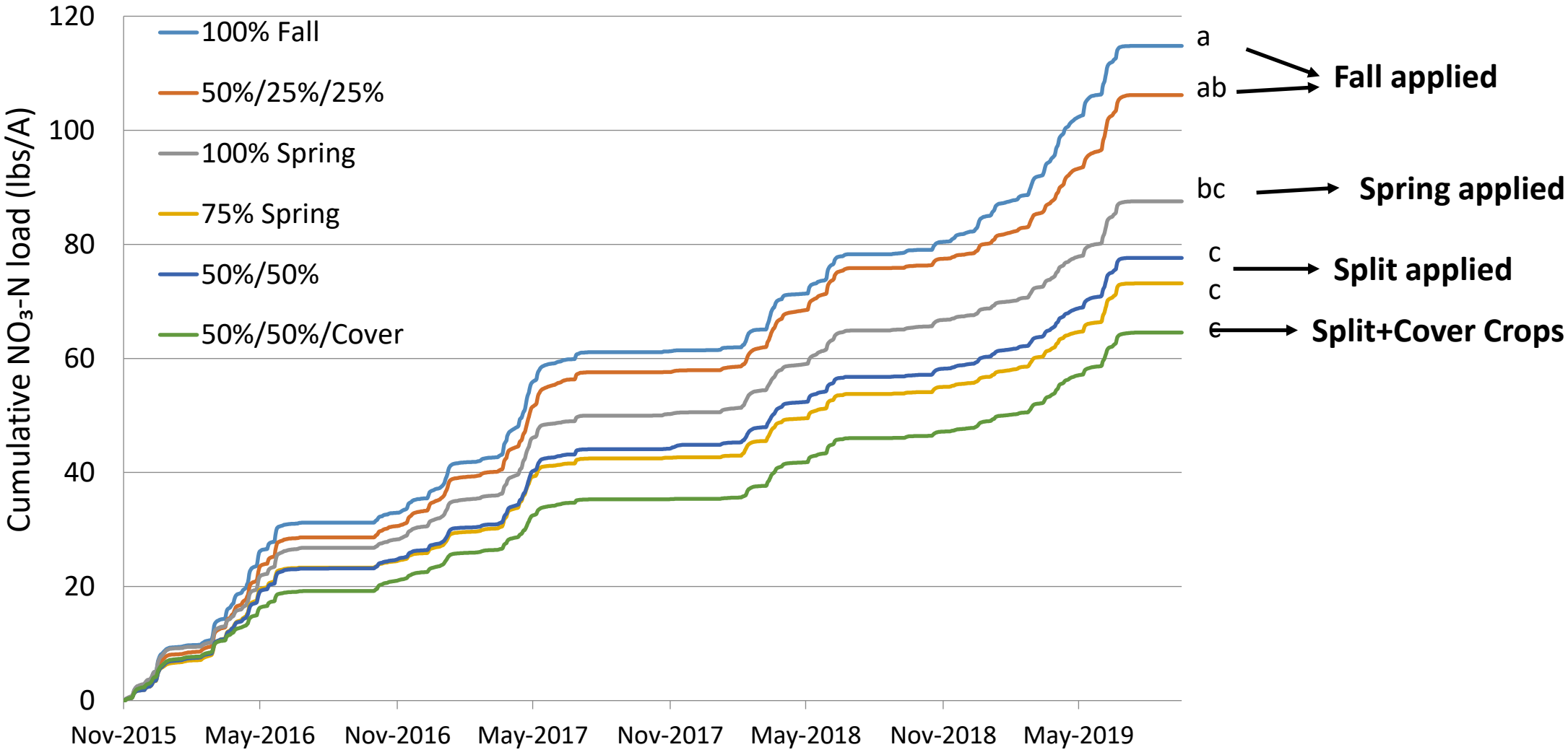


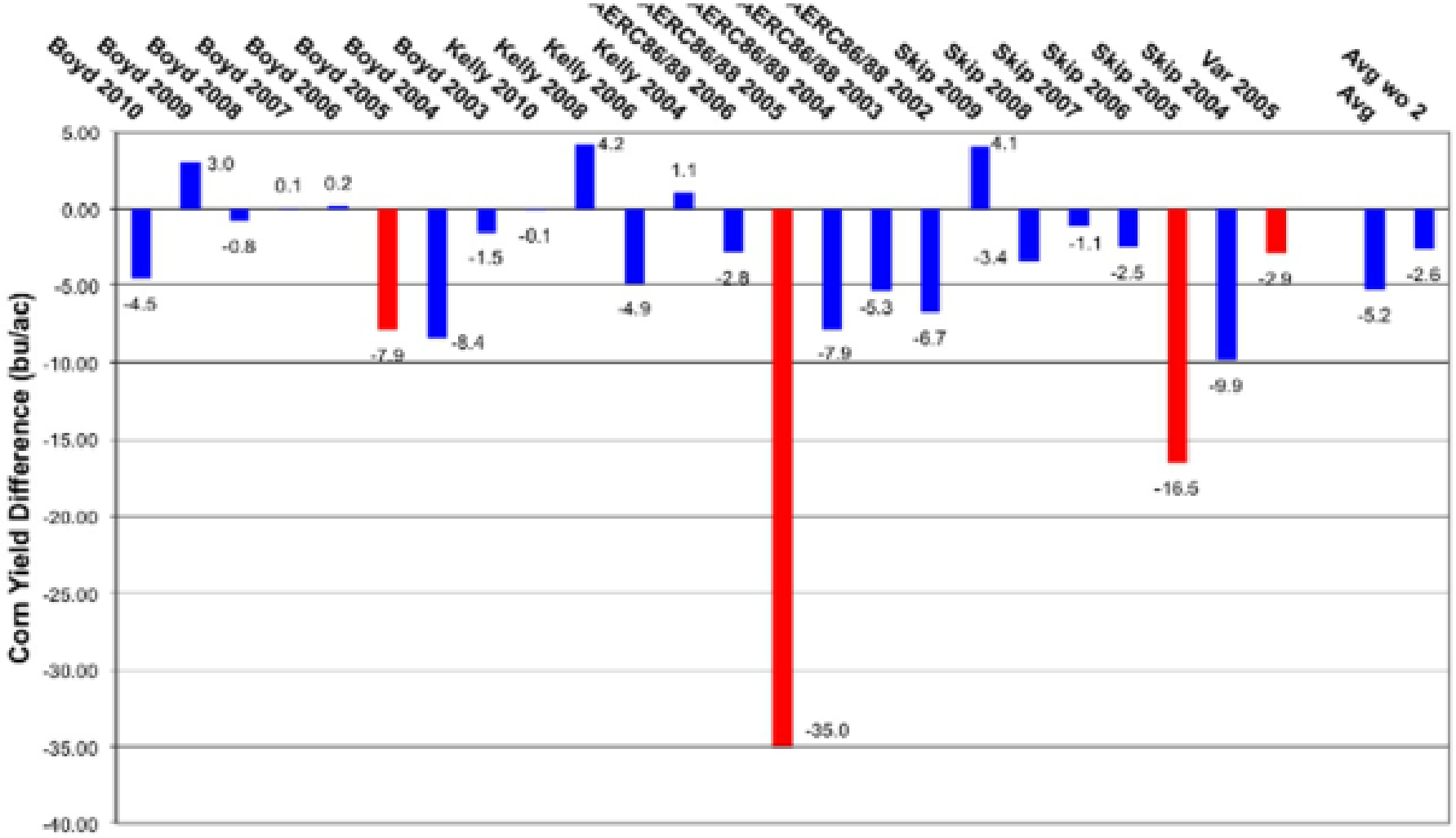
Figure Courtesy of Lowell Gentry, Univ of Illinois

Research Rationale/Background

- Cereal rye has become the most widely used cover crop in the north-central United States
  - Will germinate and grow at soil temps of 35 deg F
  - Deep rooted, excellent nitrogen scavenger
  - Quick green up and biomass in spring
  - Relatively easy to kill – winter annual suppression
  - Relatively inexpensive ($15/ac or so)
  - **Great cover crop – except????**

Corn Yield Differences Following a Rye Cover Crop

Summary of 23 trials from 2003 – 2010



IOWA STATE UNIVERSITY
Extension and Outreach

Kaspar unpublished

ENCE DRIVEN

Averaged over the 23 trials 5.2 bu/ac yield decrease when corn followed cereal rye

$4.50 corn that's $23.40/ac, there went your payment

How can we avoid this?

Why **can** cereal rye reduce corn yields?

- **Stand** - Difficult to get effective seed to soil contact, need a no-till planter prepared for the job
- **Green bridge** – Pythium over winters very well in cereal rye and acts as a bridge to the next corn crop
- **Allelopathy?** – Debated, but natural herbicidal compounds are released from some grasses as they decay effecting germination and vigor of future crops
- **Nutrient deficiencies** – Because of cereal ryes aggressive root system and vigorous biomass accumulation it is an excellent scavenger of nitrogen and other mineral nutrients
  - Those nutrients may or may not be released to the proceeding corn crop in time to meet crop demand
- **Soil temps** can remain wet and cool if a mat of cereal rye is on soil surface in early spring

Species such as cereal rye, which has a high carbon-to-nitrogen ratio, will tie up fixed nitrogen during the beginning of subsequent planting season,

Green Bridge – Pythium

Plant Disease • 2017 • 101:591-600 • http://dx.doi.org/10.1094/PDIS-07-16-0975-RE

Time Interval Between Cover Crop Termination and Planting Influences Corn Seedling Disease, Plant Growth, and Yield

J. Acharya, Department of Plant Pathology and Microbiology, Iowa State University, Ames 50011; **M. G. Bakker, T. B. Moorman,** and **T. C. Kaspar,** National Laboratory for Agriculture and the Environment, United States Department of Agriculture–Agricultural Research Service, Ames, IA 50011; **A. W. Lenssen,** Department of Agronomy, Iowa State University, Ames; and **A. E. Robertson,** Department of Plant Pathology and Microbiology, Iowa State University, Ames

Acharya et al., 2017

Bottom line: burndown cereal rye 2 to 3 weeks before planting corn to avoid seedling diseases and yield loss

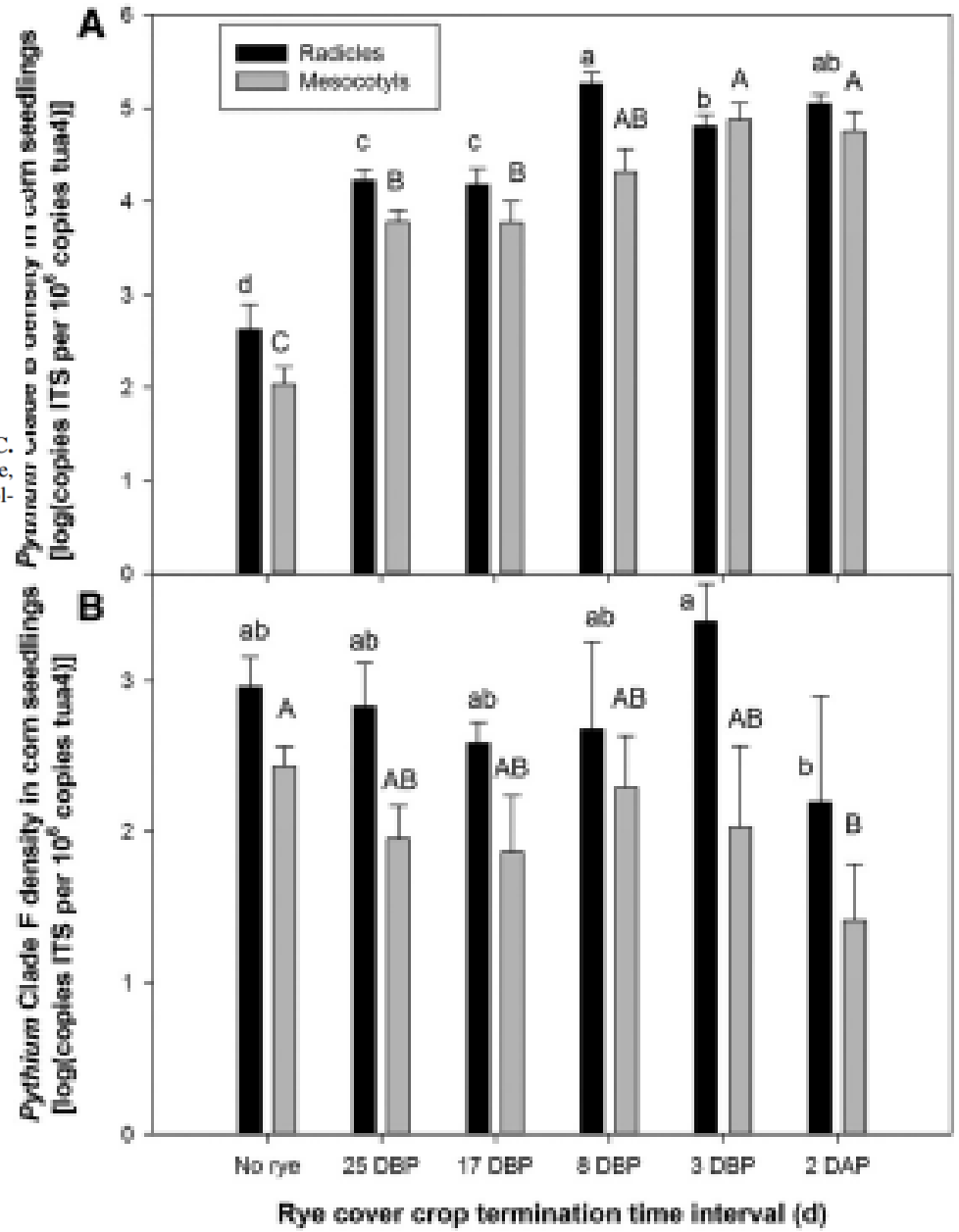


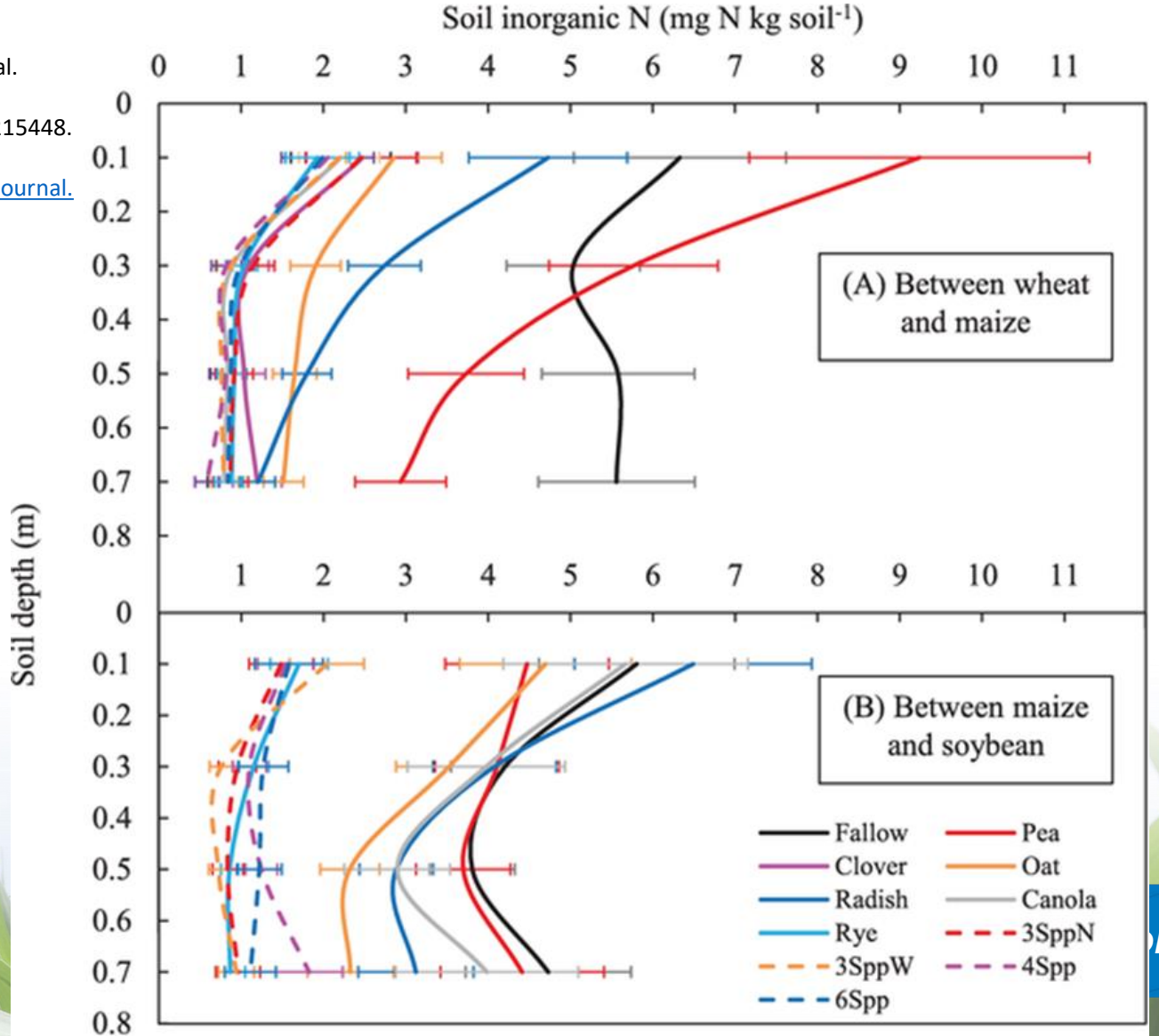
Fig. 3. Density of *Pythium* spp. belonging to **A**, clade B and **B**, clade F in radicles and mesocotyls of corn seedlings in the 2015 field experiment, in relation to rye cover crop termination-time interval (days). Pathogen density (copies of *Pythium* spp. internal transcribed spacer [ITS] gene) was assessed relative to host plant DNA (copies of corn tua4 gene). DBP = days before planting and DAP = days after planting. Bars topped with the same letter are not significantly different at *P* value = 0.05.

Research Rationale/Background

SCIENCE DRIVEN DECISIONS

Fig 4. The concentration of extractable soil inorganic N with depth in spring 2014.

Kaye J, Finney D, White C, Bradley B, Schipanski M, et al. (2019) Managing nitrogen through cover crop species selection in the U.S. mid-Atlantic. PLOS ONE 14(4): e0215448. https://doi.org/10.1371/journal.pone.0215448
https://journals.plos.org/plosone/article?id=10.1371/journal.pone.0215448



Management Considerations

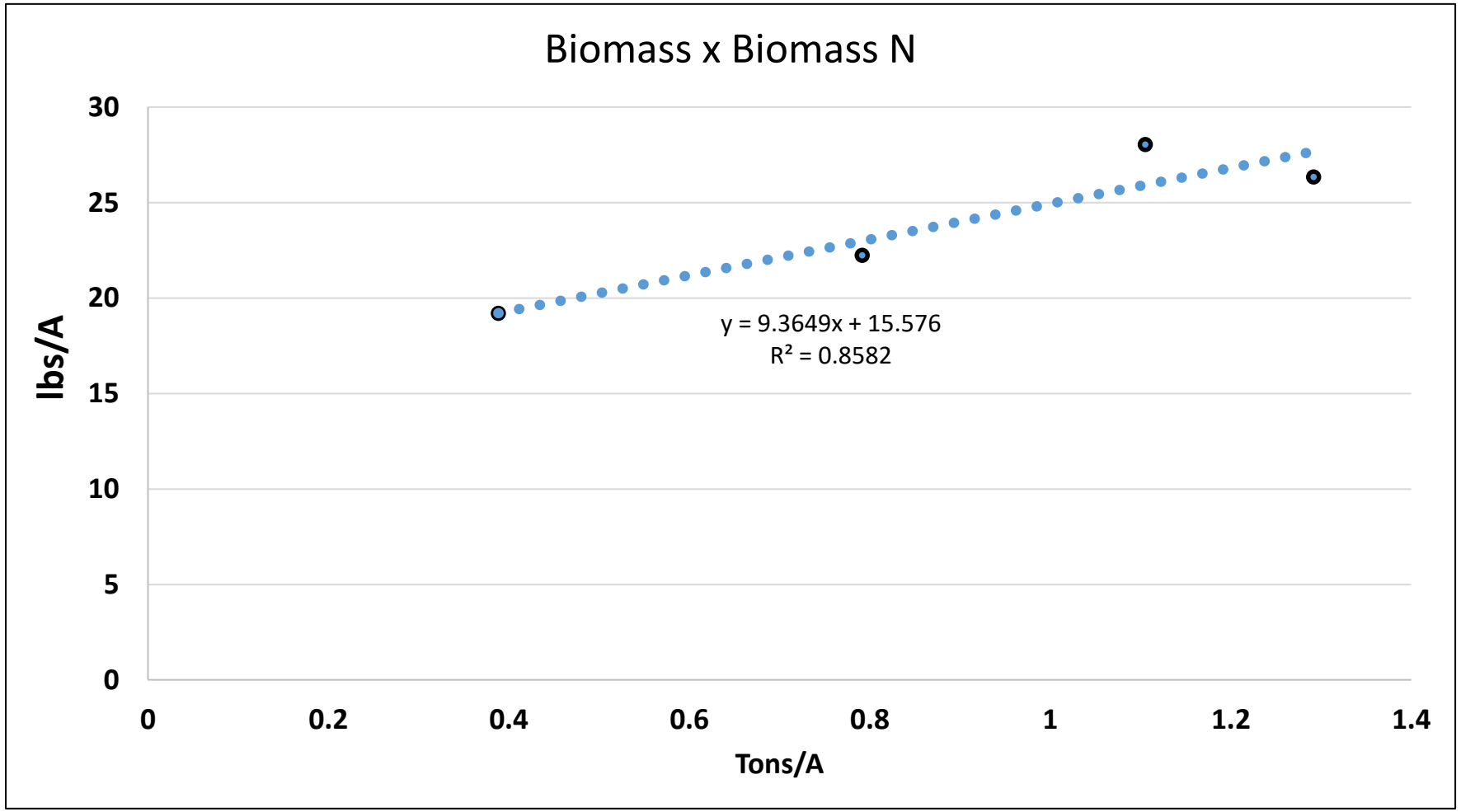


Figure Courtesy of Lowell Gentry, Univ of Illinois

Where Does The N In Cereal Rye Go?

SCIENCE DRIVEN DECISIONS

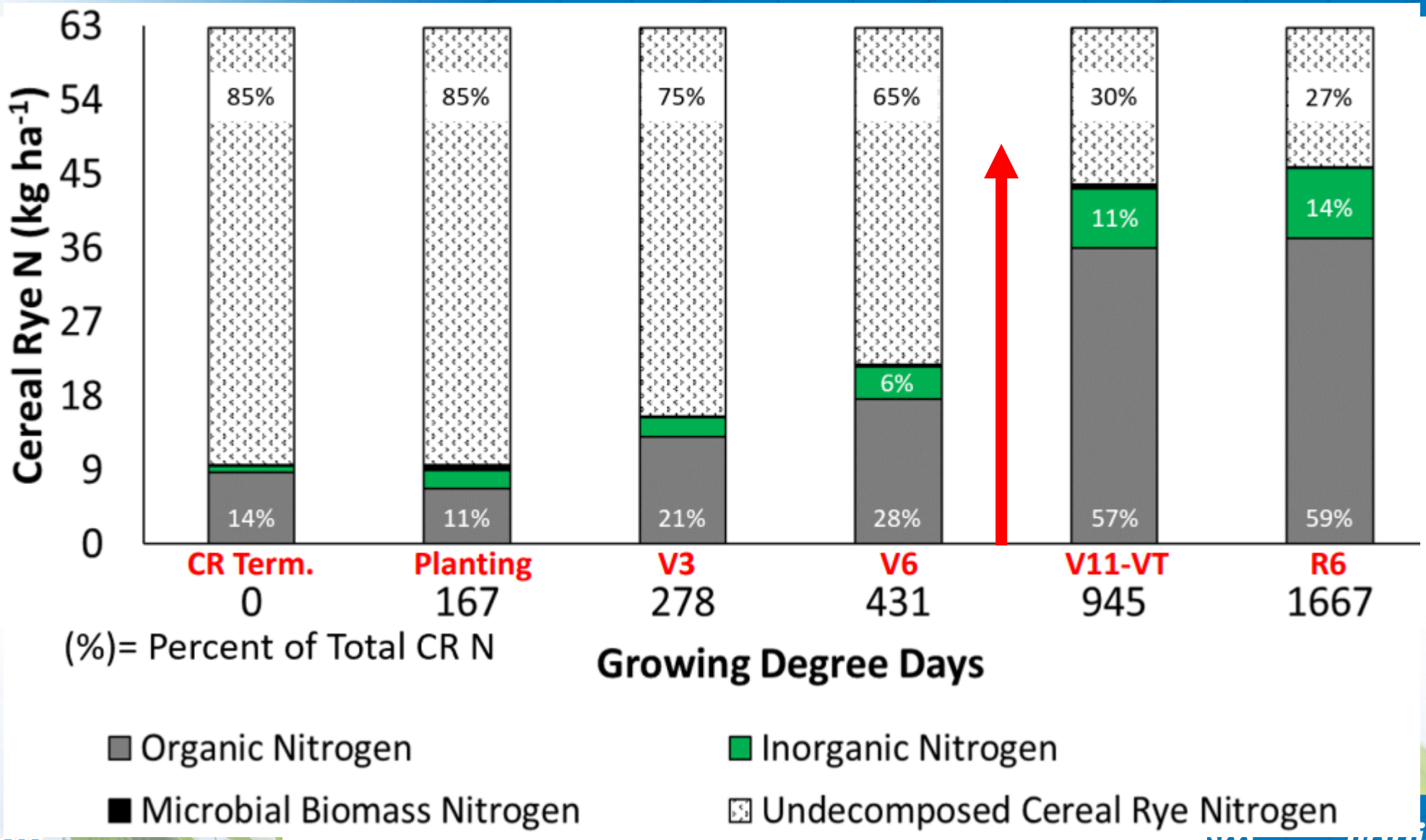


Figure Courtesy of Shalamar Armstrong, Purdue Univ

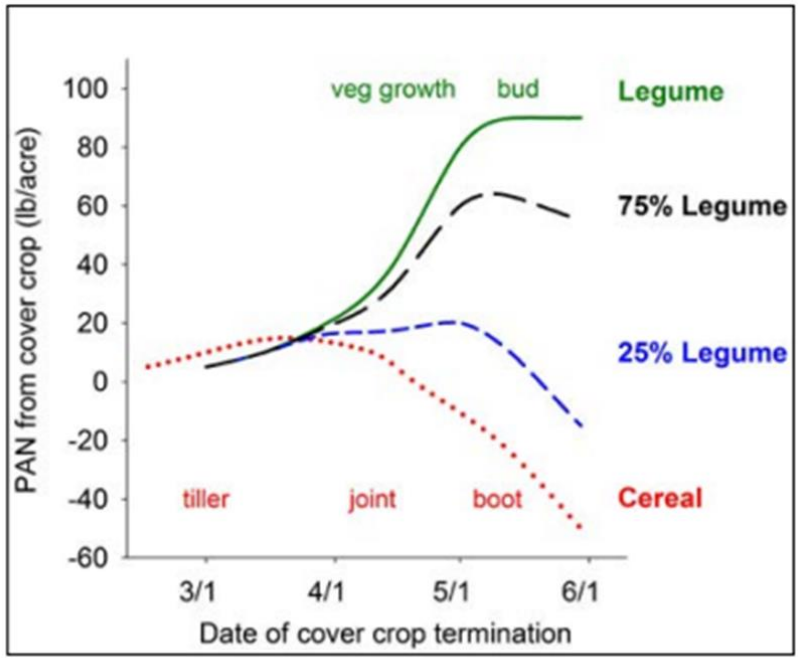
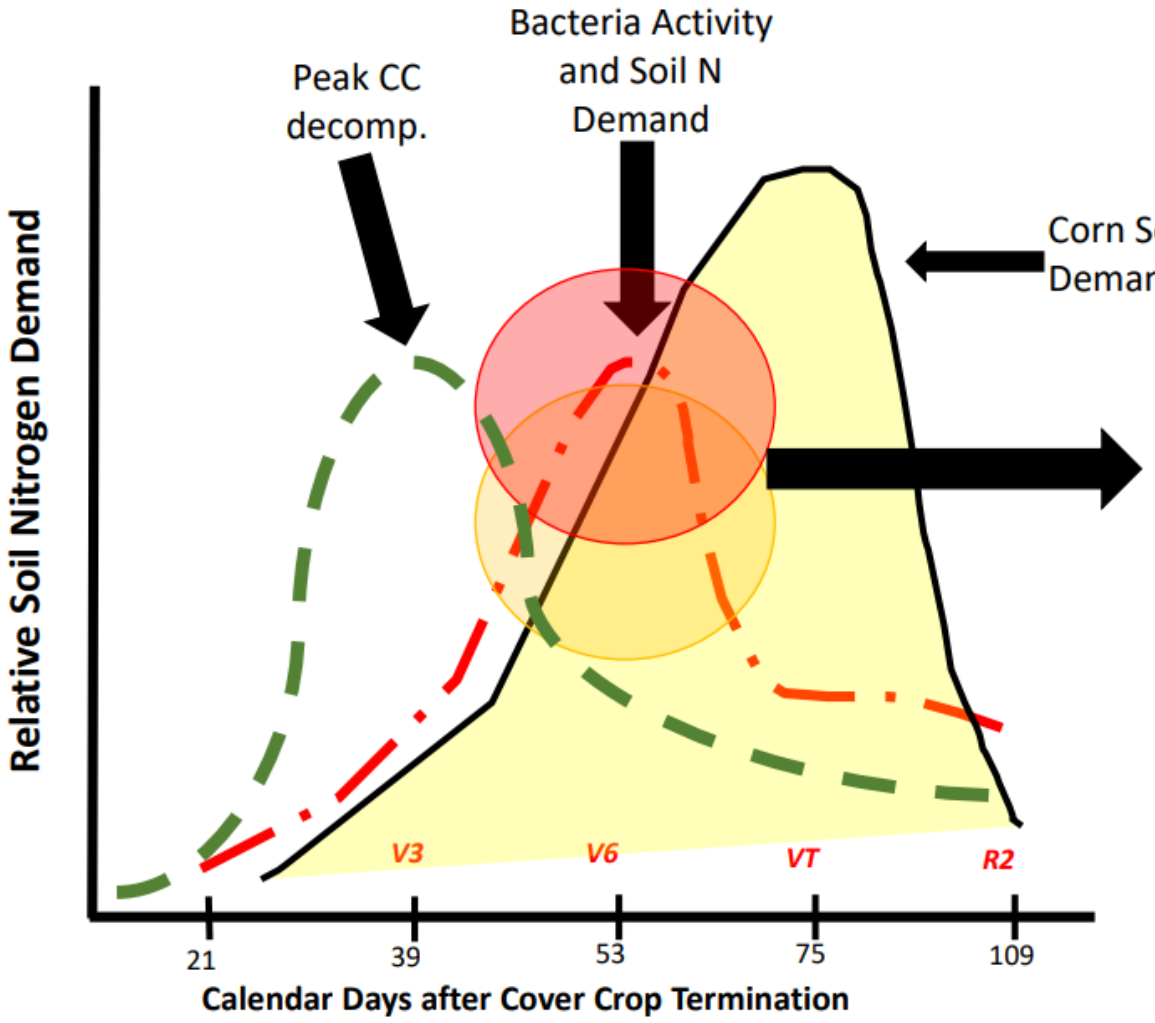


FIgure 4.—Effect of kill date on typical plant-available N (PAN) release from cereal, legume, or mixed stands. Based on compilation of field data from Willamette Valley cover crop trials. Source: D. Sullivan.

https://catalog.extension.oregonstate.edu/sites/catalog/files/project/pdf/pnw636.pdf

Soil N Demand Synchrony



Soil N demand synchrony between the soil microbiome and corn that occurs approximately 53-65 days after cover crop termination.

Nevins et al. (2018) Soil Biology and Biochemistry

Figure Courtesy of Shalamar Armstrong, Purdue Univ

Corn and Cereal Rye The Nitrogen Problem

- Cereal Rye is an excellent scavenger of nitrogen
- Nitrogen concentrations in the soil often very low after cereal rye cover crop is grown
- As cereal rye gets larger in the spring C:N ratio goes up
- In some cases, the plant available N balance in the soil can be negative
- Explosion of microbes breaking down carbon (cereal rye residue) use up all available soil N
  - Including fertilizer N added to the soil – leaves very little N for corn
- Makes since that a well-placed N source that's not highly available to soil microbes and is available to corn would increase yields in this cropping system
  - 2x2, 0x2 etc…. Out-of-furrow high-rate planter applied N applications

Corn and Cereal Rye The Nitrogen Problem

SCIENCE DRIVEN DECISIONS

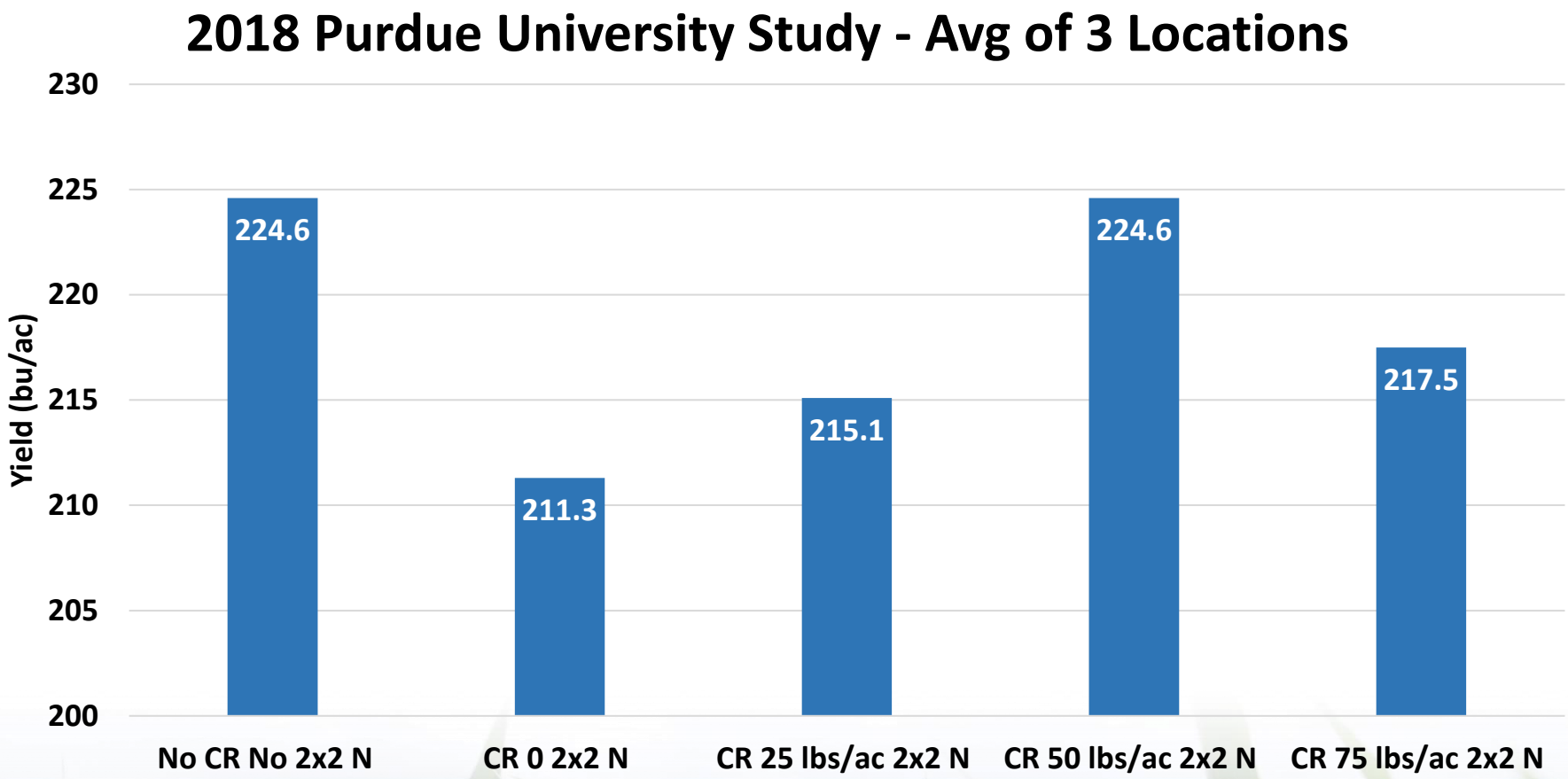


Figure adapted from: Preza-Fontes, G., Miller, H.,Camberato, J., Roth, R., & Armstrong, S. (2022).Corn yield response to starter nitrogen rates followinga cereal rye cover crop.Crop, Forage & TurfgrassManagement,8,e20187.https://doi.org/10.1002/cft2.20187

LiquiGrow®

row.com

John Sawyers Lab, Iowa State – 2014-2016

Table 3. Corn population, plant height, and grain yield, 2014-2016.

Practice		V6 Population	V6 Height	Yield
		plants/acre	*inch*	*bu/acre*
Tillage	Till	32,500b†	24a	209a
	No-till	33,500a	22b	203b
Starter	Starter **30 lbs N/ac 2X2**	33,000a	23a	207
	No starter	33,000a	22b	205
Cover Crop	With rye	33,000a	22b	204b
	No rye	33,000a	23a	208a

† Letters indicate significant difference ($p \leq 0.10$). No interaction between practices. Results across four locations.

2017 Integrated Crop Management Conference - Iowa State University
https://www.agronext.iastate.edu/soilfertility/info/NitrogenDynamics-RyeCoverCrop_ICM2017.pdf

- Not exactly cut and dry that out-of-furrow N applications are required, despite my speculation
- What about sulfur, similar soil dynamics/cycling at work as nitrogen (sulfur immobilizations/mineralization)
- Cereal rye probably results in colder wetter soils (particularly if terminated well before planting) so roots grow slower, and P&K would also diffuse slower toward roots
- What about root uptake efficiency with pythium, would this mean a higher NPKS concentration is needed to meet crop requirement?

Materials and Methods

SCIENCE DRIVEN DECISIONS

						Sand	Silt	Clay	Bray P1	NH4 Acetate K	
Previous Crop	**Location Name**	**Grid Coordinates**	**CEC**	**O.M. %**	**Texture**	%			(ppm)		**1:1 pH**
Corn	Walnut, IL	41.476756, -89.635747	20.4	4.6	Silty Clay Loam	16	48	36	20	169	5.7
Soybean	Illinois City, IL	41.304872, -91.066138	14.1	2.3	Clay Loam	28	42	24	6	113	5.9
Soybean	Chillicothe, IL	40.912036, -89.556579	10.0	2.2	Loam	34	42	24	40	131	6.3

jpv@liqui-grow.com liqui-grow.com

Materials and Methods

SCIENCE DRIVEN DECISIONS

Starter Nutrient	Nutrient Rate	Source Fertilizer
	- - -lbs/ac N-P-K-S-Zn - - -	
Broadcast Nitrogen (UAN)	180	UAN 32%
+Starter N	60	UAN 32%
+Starter NP	60-10	+APP
+Starter NPK	60-10-10	+KCL
+Starter NPKS	60-10-10-10	+ATS
+Starter NPKSZn	60-10-10-10-0.5zn	+15% Ammoniated Zn

No other crop nutrients applied in these studies other than the nutrients in the high rate out-of-furrow starter

Materials and Methods

- Split plot design, cereal rye main-plots and starter treatments as sub-plots
- Mixed model ANOVA in SAS
- Fixed effects: starter treatments, cereal rye and cereal rye x starter treatments
- Random effects: location, blocks(location), split-plot error term cereal rye x blocks(location)
- Mean separation PDMIX 800 for LSD at alpha 0.10

Results

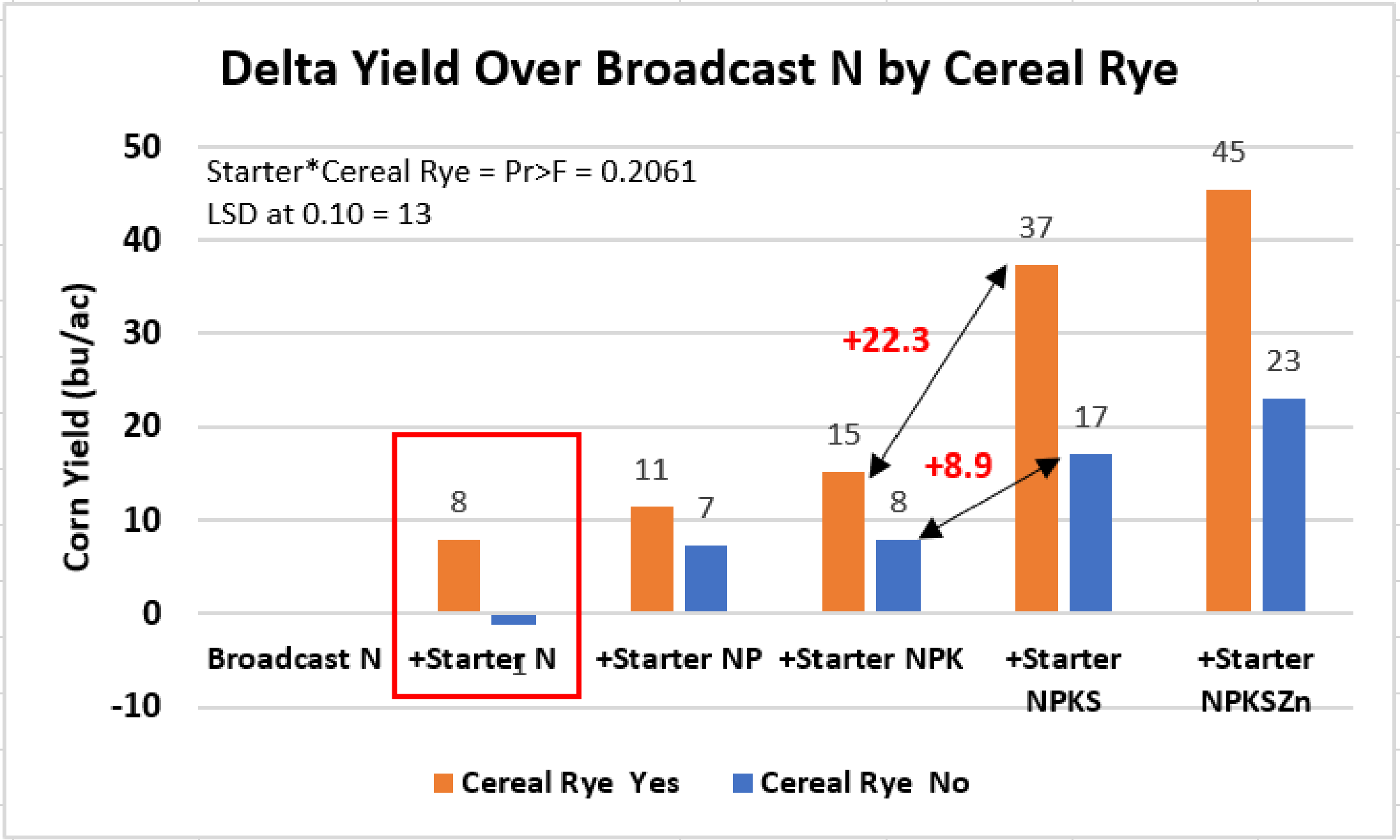
SCIENCE DRIVEN DECISIONS

Type 3 Tests of Fixed Effects				
Effect	**Num DF**	**Den DF**	**F Value**	**Pr > F**
Starter Treatment	5	138	13.17	<.0001
Cereal Rye	1	14	31.1	<.0001
Cereal Rye*Treatment	5	138	1.46	0.2061

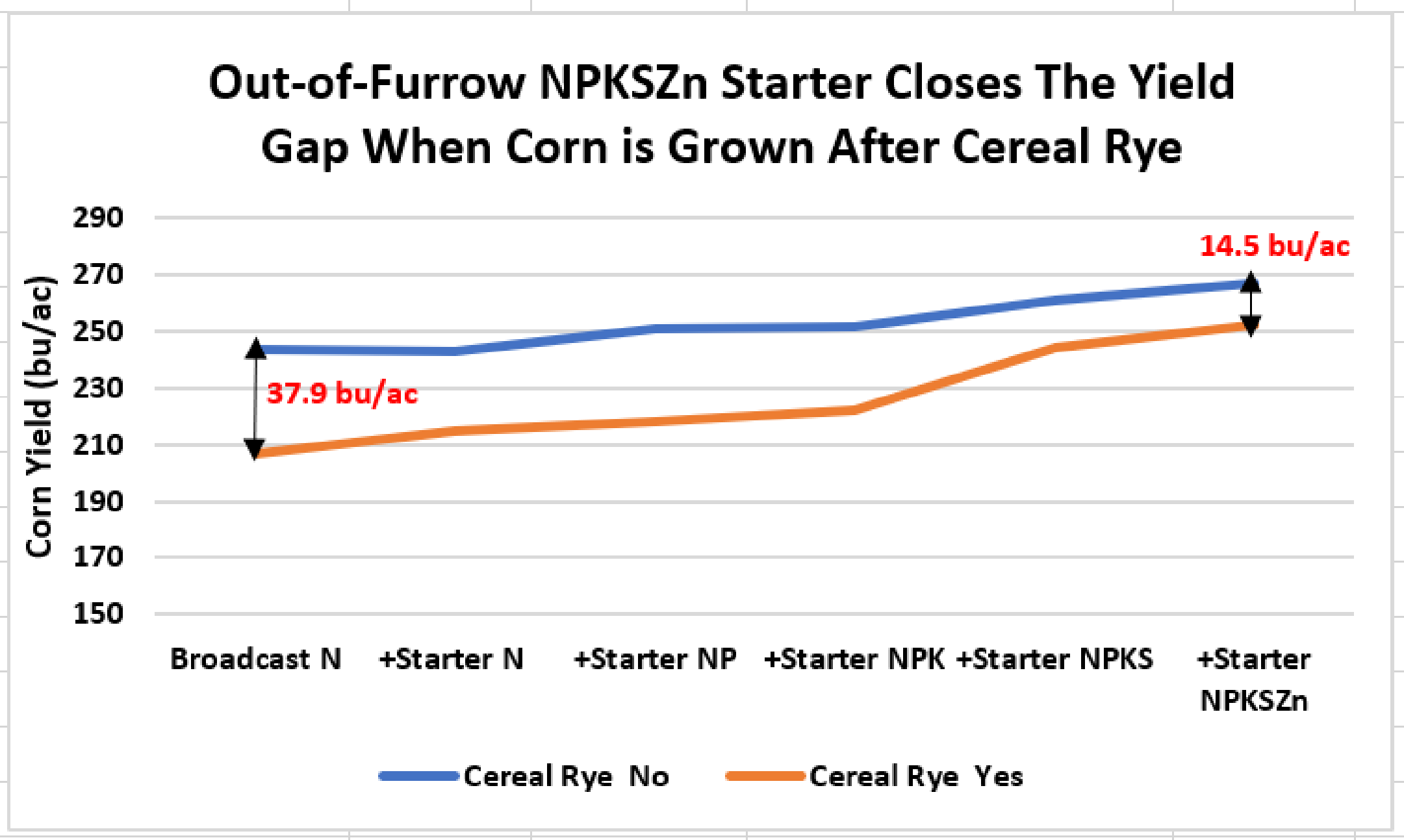
Starter Nutrient	Nutrient Rate	Corn Yield	Delta Yield Over Base N
	- - -lbs/ac N-P-K-S-Zn - - -	- - - - - - - - - - - -bu/ac - - - - - - - - - - -	
Broadcast Nitrogen (UAN)	180	225.2	
+Starter N	60	228.5	3.3
+Starter NP	60-10	234.5	9.3*
+Starter NPK	60-10-10	**236.7**	11.5*
+Starter NPKS	60-10-10-10	**252.3**	27.1**
+Starter NPKSZn	60-10-10-10-0.5zn	259.4	34.2*
	Starter Nutrient Pr>F =<.0001	**LSD at 0.10 = 8.7**	

jpv@liqui-grow.com liqui-grow.com

Re


Delta Yield Over Broadcast N by Cereal Rye
Starter*Cereal Rye = Pr>F = 0.2061
LSD at 0.10 = 13
Corn Yield (bu/ac)
50
40
30
20
10
0
-10
8
11
7
15
8
37
17
45
23
+22.3
+8.9
Broadcast N
+Starter N
+Starter NP
+Starter NPK
+Starter NPKS
+Starter NPKSZn
Cereal Rye Yes
Cereal Rye No

Res


Out-of-Furrow NPKSZn Starter Closes The Yield Gap When Corn is Grown After Cereal Rye
Corn Yield (bu/ac)
290
270
250
230
210
190
170
150
14.5 bu/ac
37.9 bu/ac
Broadcast N
+Starter N
+Starter NP
+Starter NPK
+Starter NPKS
+Starter NPKSZn
Cereal Rye No
Cereal Rye Yes

Manage Research & Development

Sales Support (grower meetings/key account visit's)

Lead Agronomic Trainings

Agronomic Service Calls

jpv@liqui-grow.com liqui-grow.com

The Future of Liquid Fertilizers

Dr. Karl Wyant
Director of Agronomy
Nutrien

December 6, 2022

Main Statement

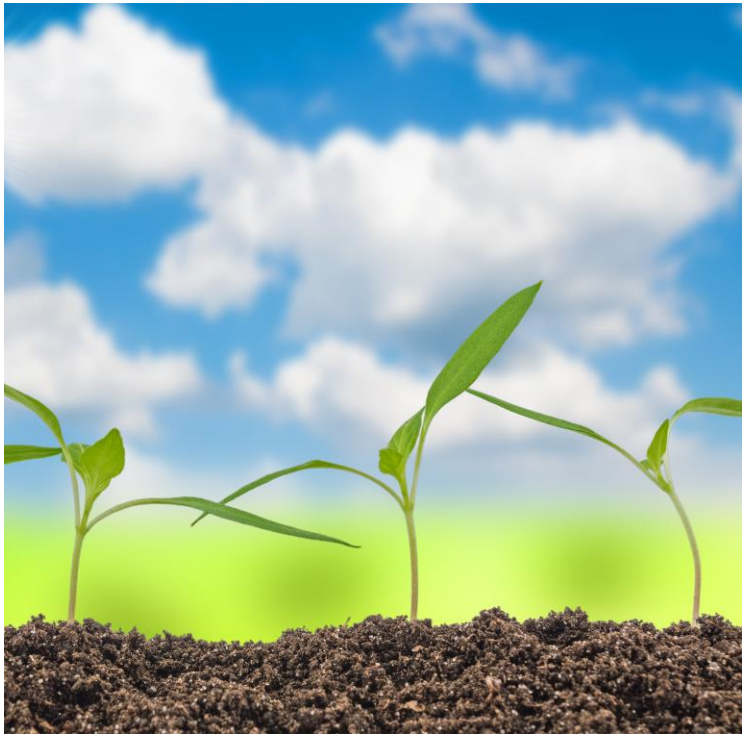
Current Liquid Fertilizers

“New” Novel Ingredients

Fertilizers 2.0/3.0

Biostimulants

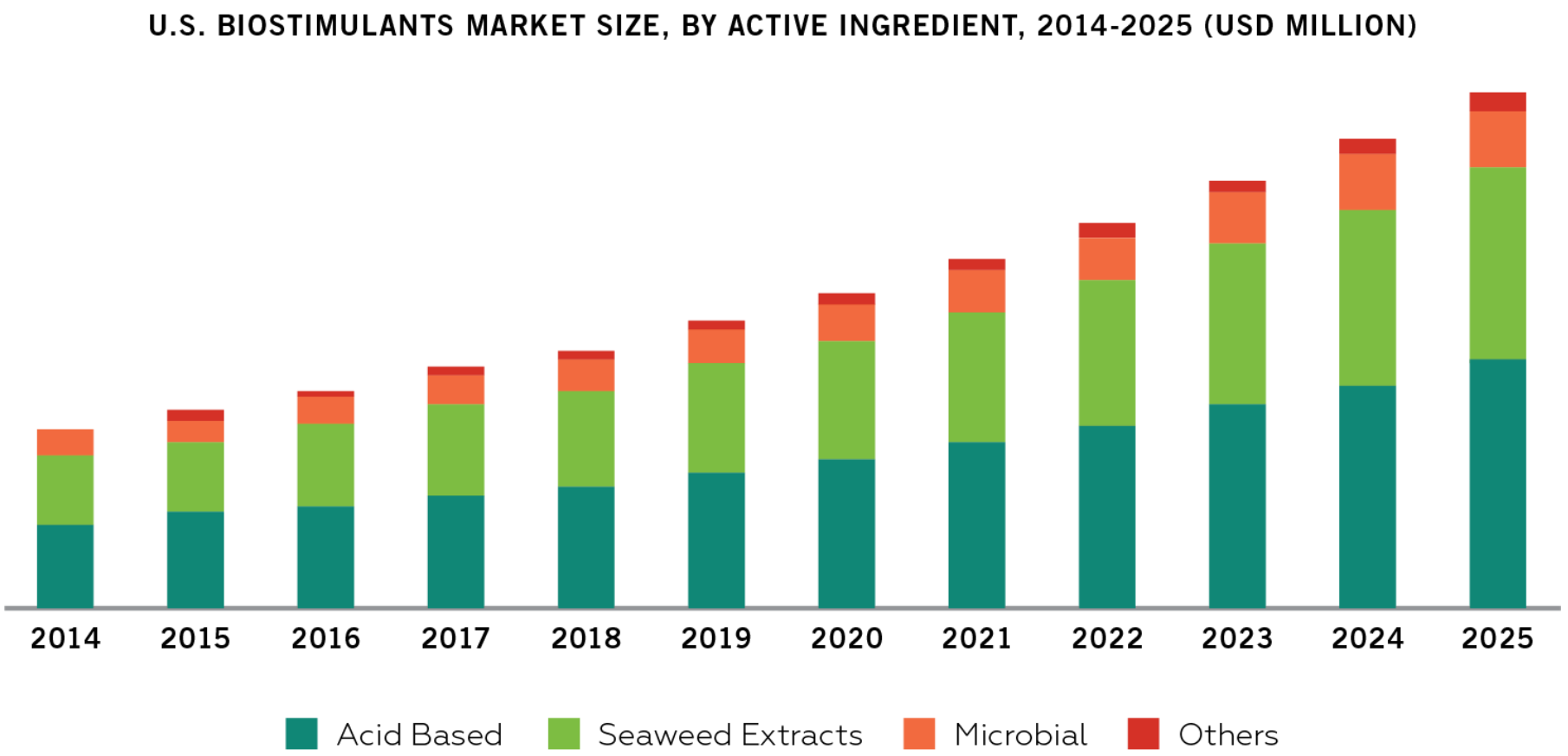
- Clarify the marketplace
- Regulatory changes
- Moving forward – **finding the right fit**
- Crucial Questions



Nutrien™
Feeding the Future™

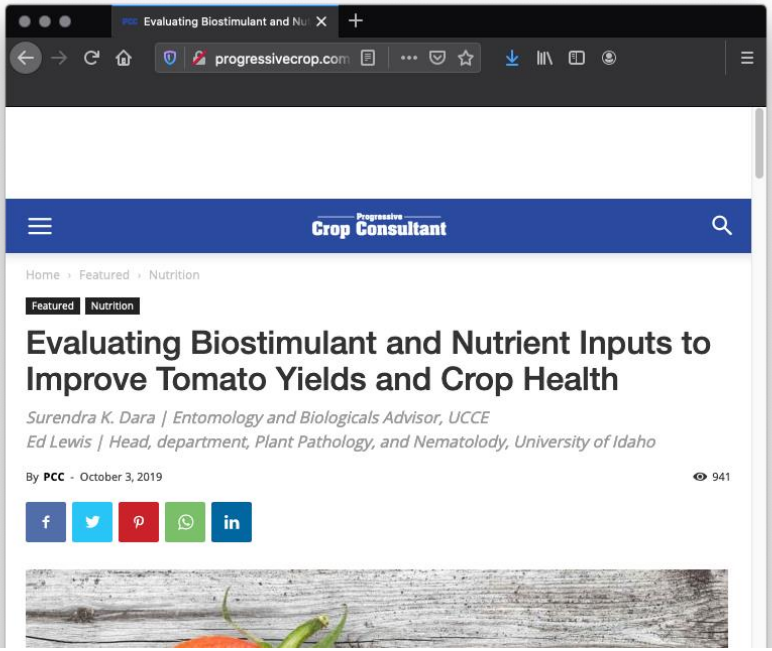
Category Momentum

Biostimulants Market Growth

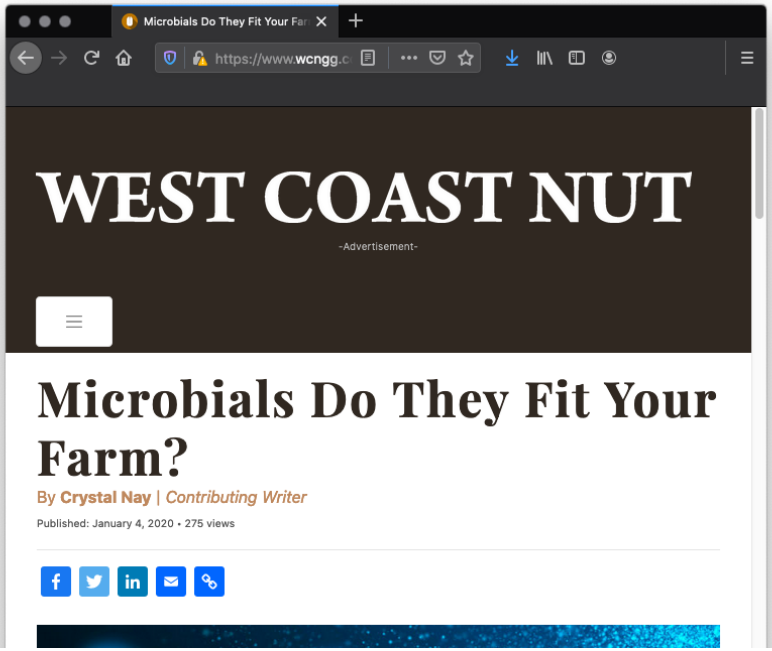


https://www.grandviewresearch.com/industry-analysis/biostimulants-market

Market Interest



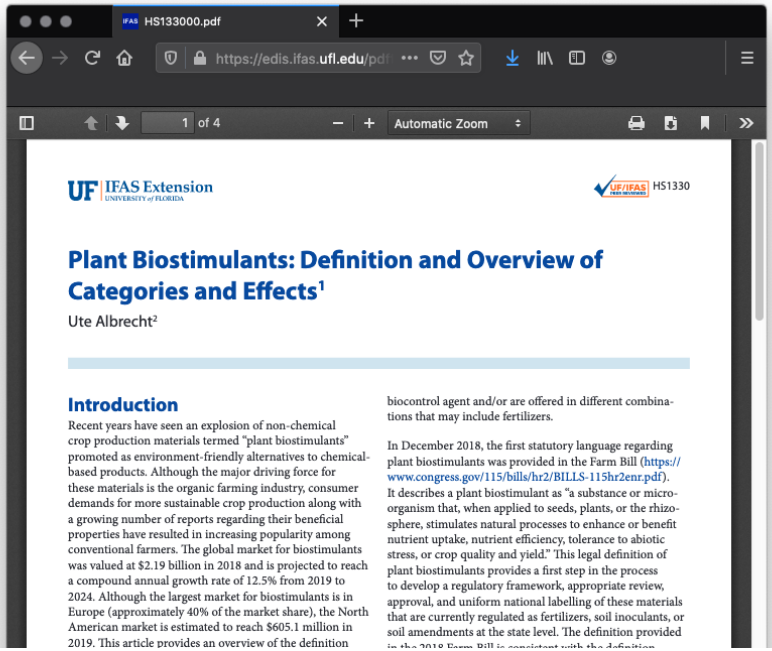
http://progressivecrop.com/2019/10/evaluating-biostimulant-and-nutrient-inputsto-improve-tomato-yields-and-crop-health/



https://www.wcngg.com/2022/01/04/microbials-do-they-fit-your-farm/

Academic & Extension Support

https://link.springer.com/content/pdf/10.1007/s11104-014-2131-8.pdf



https://edis.ifas.ufl.edu/pdffiles/HS/HS133000.pdf

Legislative Positioning – 2018 Farm Bill

SEC. 10111. REPORT ON PLANT BIOSTIMULANTS.

(a) REPORT.—Not later than 1 year after the date of the enactment of this Act, the Secretary shall submit a report to the President and Congress that identifies any potential regulatory, non-regulatory, and legislative recommendations, including the appropriateness of any definitions for plant biostimulant, to ensure the efficient and appropriate review, approval, uniform national labeling, and availability of plant biostimulant products to agricultural producers.

(b) CONSULTATION.—The Secretary shall prepare the report required by subsection (a) in consultation with the Administrator of the Environmental Protection Agency, the several States, industry stakeholders, and such other stakeholders as the Secretary determines necessary.

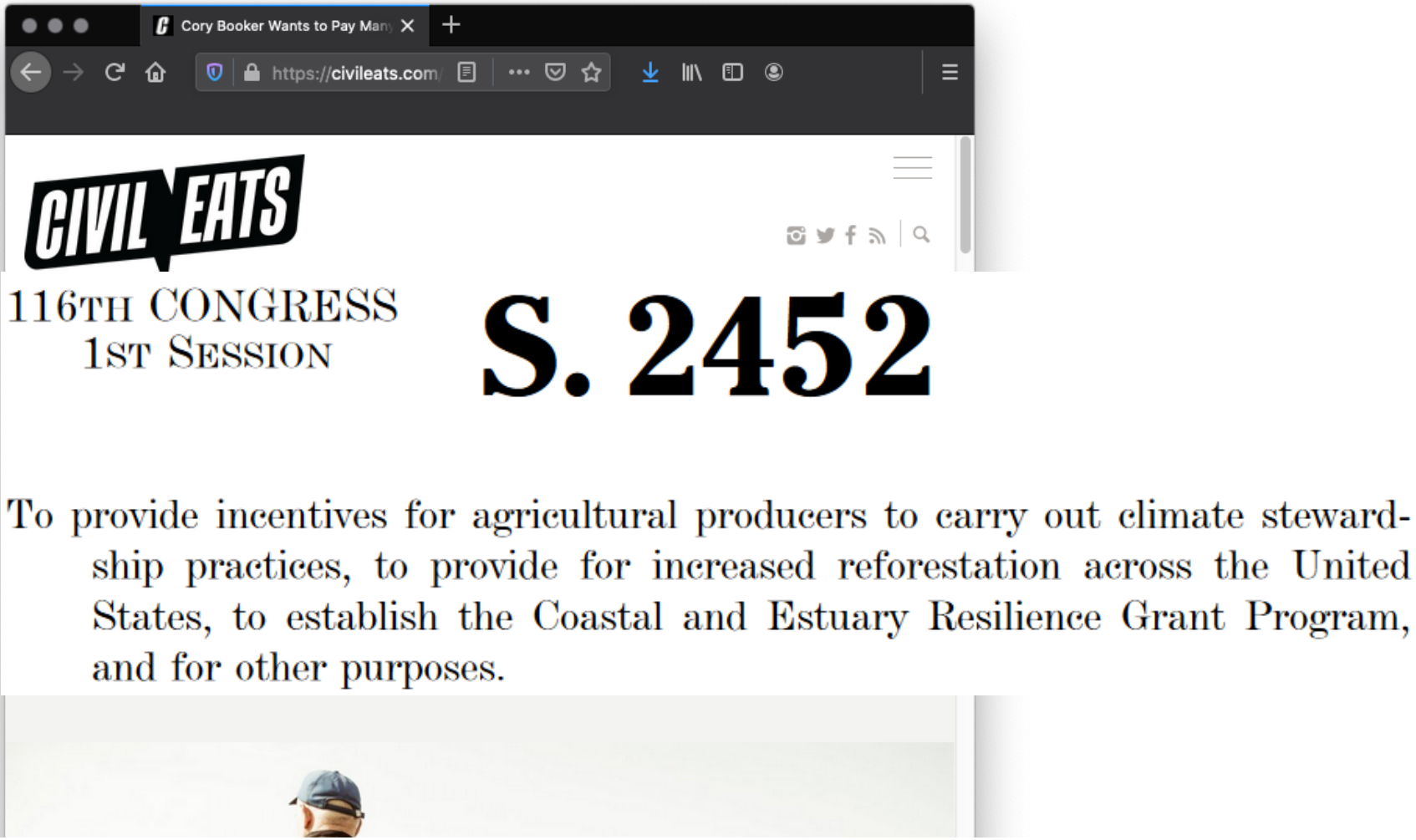
(c) PLANT BIOSTIMULANT.—For the purposes of the report under subsection (a), the Secretary—

(1) shall consider "plant biostimulant" to be a substance or micro-organism that, when applied to seeds, plants, or the rhizosphere, stimulates natural processes to enhance or benefit nutrient uptake, nutrient efficiency, tolerance to abiotic stress, or crop quality and yield; and

(2) may modify the description of plant biostimulant, as appropriate.

https://www.congress.gov/115/bills/hr2/BILLS-115hr2enr.pdf

Legislative Positioning - Continued



https://civileats.com/2019/08/08/cory-booker-wants-to-pay-many-more-farmers-to-practice-carbon-farming/

Nutrien™
Feeding the Future™

Challenges for Category

December 6, 2022

What are Biostimulants?

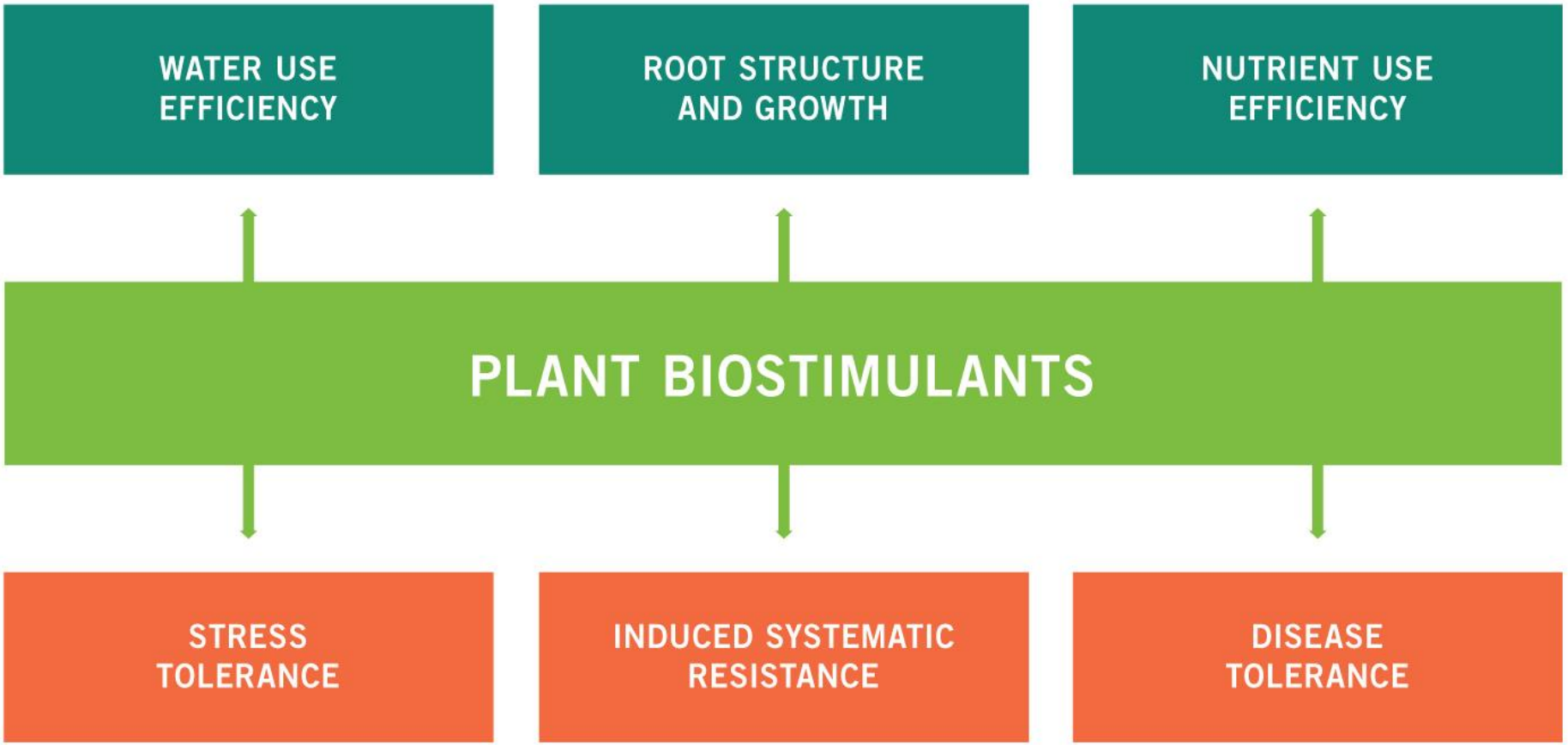
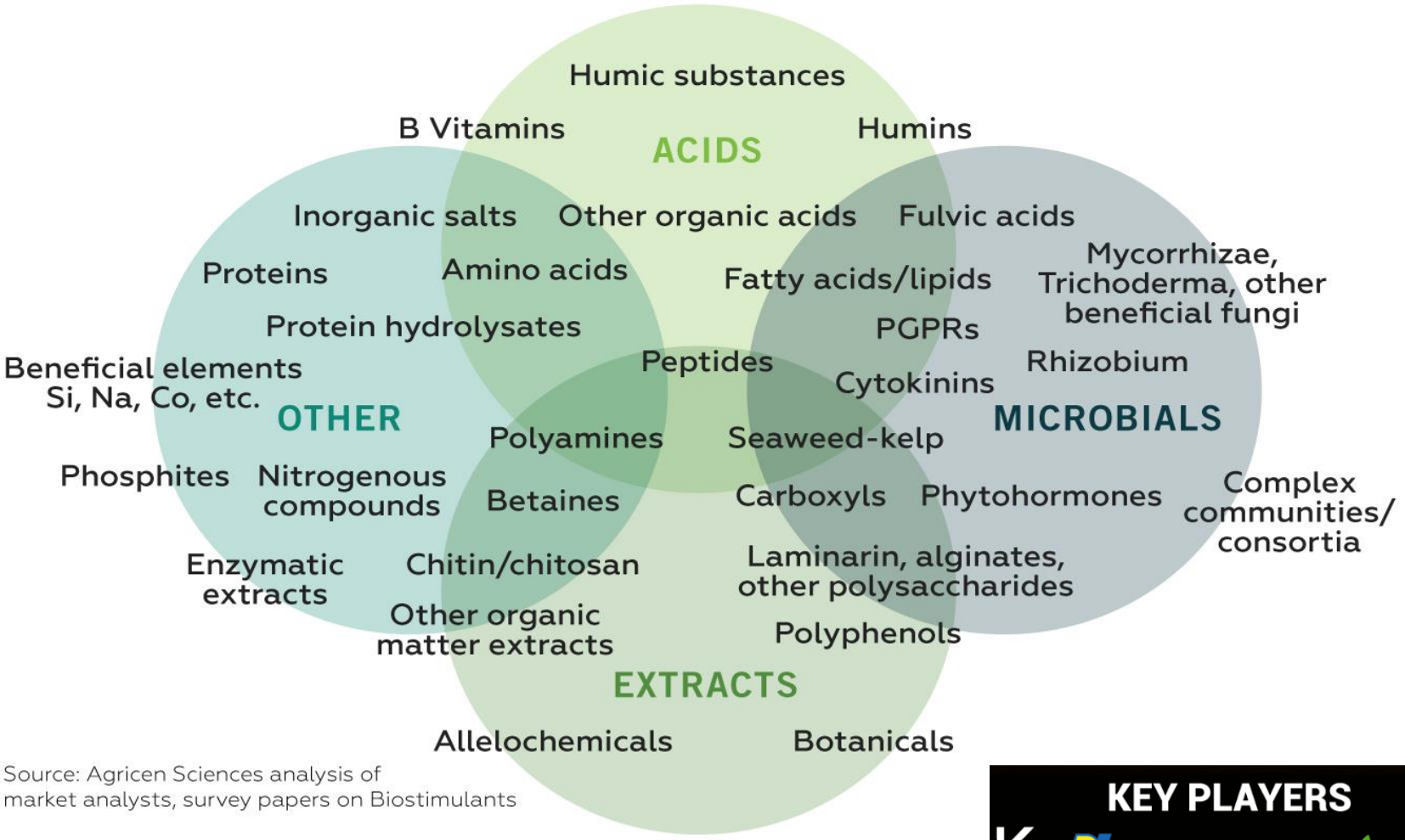


Figure 1. Biostimulant effects on plants.

Albrecht 2019

Marketplace Noise



Source: Agricen Sciences analysis of market analysts, survey papers on Biostimulants

https://www.bpia.org/solutions-provided-by-biological-products-biostimulants/#acid-based-biostimulants

Biostimulant Market Size, Growth, Share | 2022 - 27 (mordorintelligence.com)

Infographics - Biostimulants Market (fortunebusinessinsights.com)

Marketplace Maturity

Market Concentration

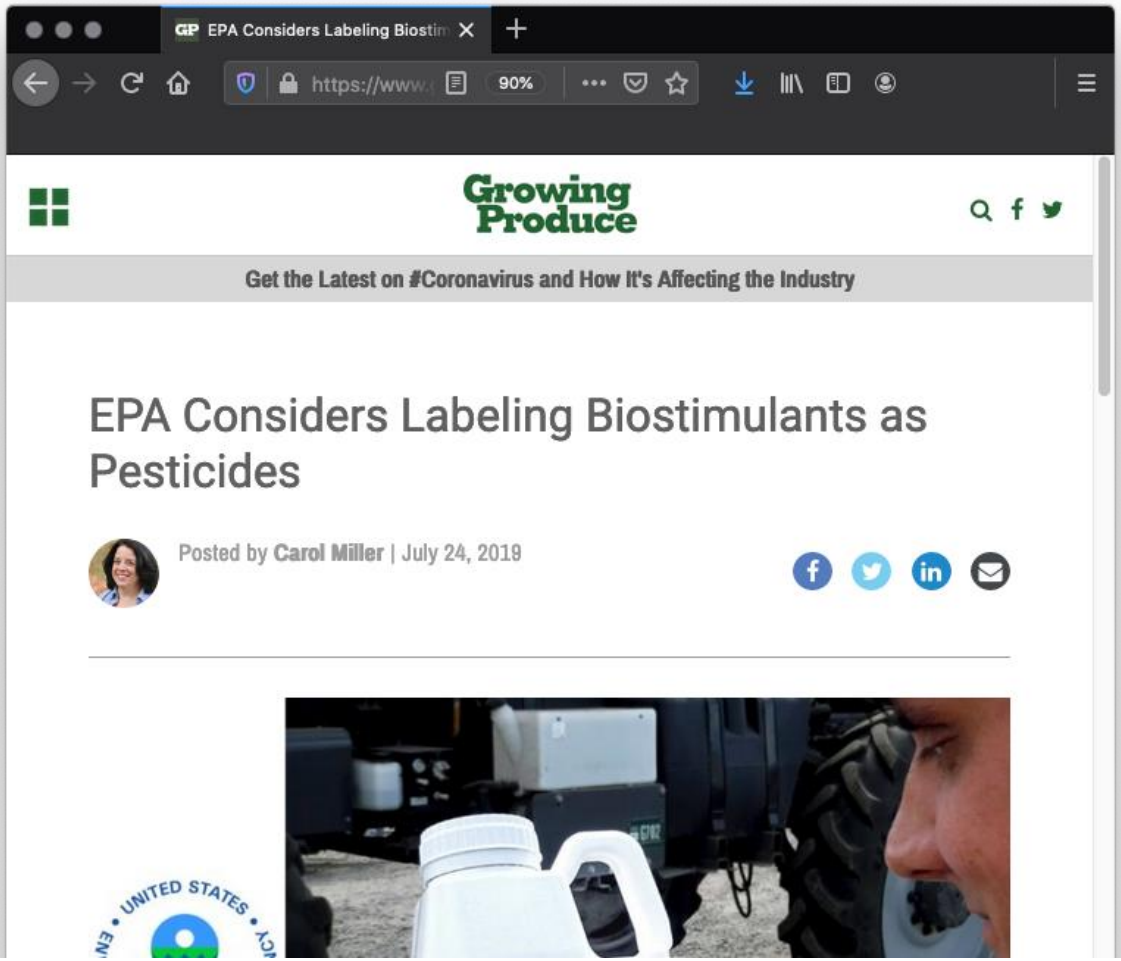
BAU

Consolidated- Market dominated by 1-5 major players

Source: Mordor Intelligence

Biostimulant Market Size, Growth, Share | 2022 - 27 (mordorintelligence.**com**)

Challenges for Category



https://www.growingproduce.com/vegetables/epa-considers-labeling-biostimulants-as-pesticide/

Making Progress

117TH CONGRESS
2D SESSION

H. R. 7752

Date	All Actions
06/08/2022	Referred to the Subcommittee on Biotechnology, Horticulture, and Research. Action By: Committee on Agriculture
05/12/2022	Referred to the House Committee on Agriculture. Action By: House of Representatives
05/12/2022	Introduced in House Action By: House of Representatives

BILLS-117hr7752ih.pdf (govinfo.gov)

Unanswered Questions

- **Problem**: *What exactly is a biosimulant?*
- Unclear definition - pg. 419 pf 2018 Farm Bill
- EPA Draft Guidance – 2019 - **Table 4** list of ingredients (pg. 11)
- Clear up what product label language claims and FIFRA categories
- **Conflation of ingredients** - PGRs, ag chem, and fertilizers
- **Alignment issues** - USDA, EPA, and a variety of state regulators
- Clarify international standards and pathways to market

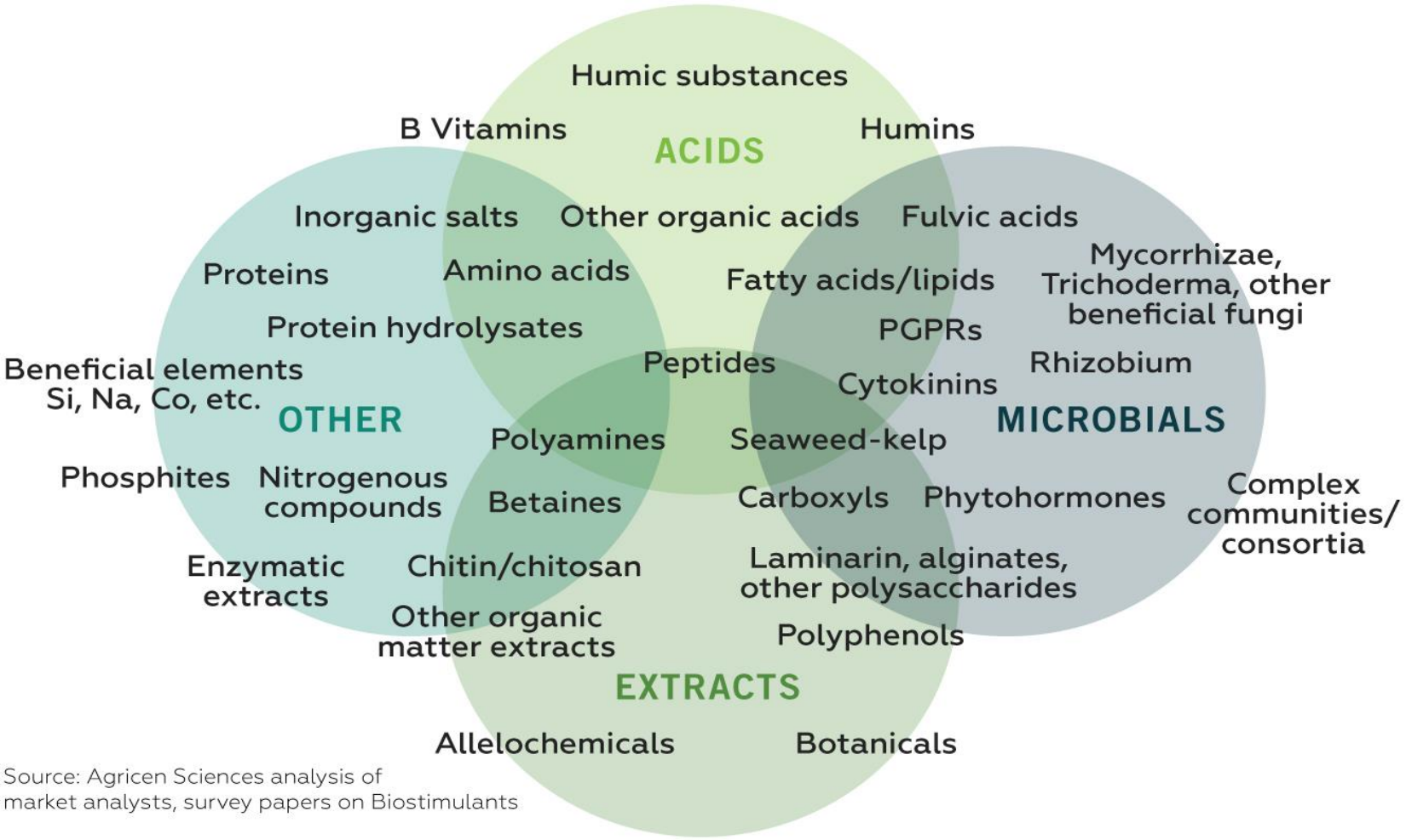
Question for Audience

How do we **innovate** liquid fertilizers with **new and novel** ingredients?

Nutrien™
Feeding the Future™

Which New Ingredient Do I Pick?

Marketplace Noise



Source: Agricen Sciences analysis of market analysts, survey papers on Biostimulants

https://www.bpia.org/solutions-provided-by-biological-products-biostimulants/#acid-based-biostimulants

Biostimulant Market Size, Growth, Share | 2022 - 27 (mordorintelligence.com)

Infographics - Biostimulants Market (fortunebusinessinsights.com)

Some Ground Rules

- New active ingredients have **utility**
- **Species identity** determines role in soil:
  - Living inoculants
- **Carbon chemistry** determines function in soil:
  - Size
  - Charge
  - C:N ratio
  - Macromolecule diversity - *food sources*

Inoculant Cheat Sheet - Fungi

Yeasts/protein mixes – nutrient delivery source for plants (amino acids, NPK, etc.)

***Trichoderma* species** – a beneficial **fungus** that helps protect the plants against pathogens

Mycorrhizae – a beneficial plant/**fungal** symbiosis that help trees get more water and phosphate

Plant Production and Protection Division: Soil biological management with beneficial microorganisms (fao.org)

Inoculant Cheat Sheet - Bacteria

Bradyrhizobia – nodule forming, living **bacteria** that helps with N fixation on legumes.

Azospirillium/Klebsiella – free-living **bacteria** that helps with N fixation on *non-legumes*

Bacillus species – **bacteria** that helps with pathogen control and nutrient availability

Pseudomonas species – **bacteria** that helps with pathogen control and nutrient availability

Aspergillus species **- bacteria** that produce enzymes that break down hard-to-digest plant fibers

Plant Production and Protection Division: Soil biological management with beneficial microorganisms (fao.org)

Challenges with Inoculants

- **Viability** is a concern
- **Living vs. spore form**
- Sensitive to fluctuations in environment – **moisture, temperature, UV, competition**
- Some labs can help **confirm label CFU** count
- Challenges with **mixing and compatibility** in the field

- **Key question: how alive is your product?**

Nutrien™
Feeding the Future™

Non-living Carbon Products: Spotlight on Food Sources, Organic Acids, Enzymes & Seaweeds

Some Ground Rules

- New active ingredients have **utility**
- **Species identity** determines role in soil:
  - Living inoculants
- **Carbon chemistry** determines function in soil:
  - Size
  - Charge
  - C:N ratio
  - Macromolecule diversity - *food sources*

Feed the Microbiome

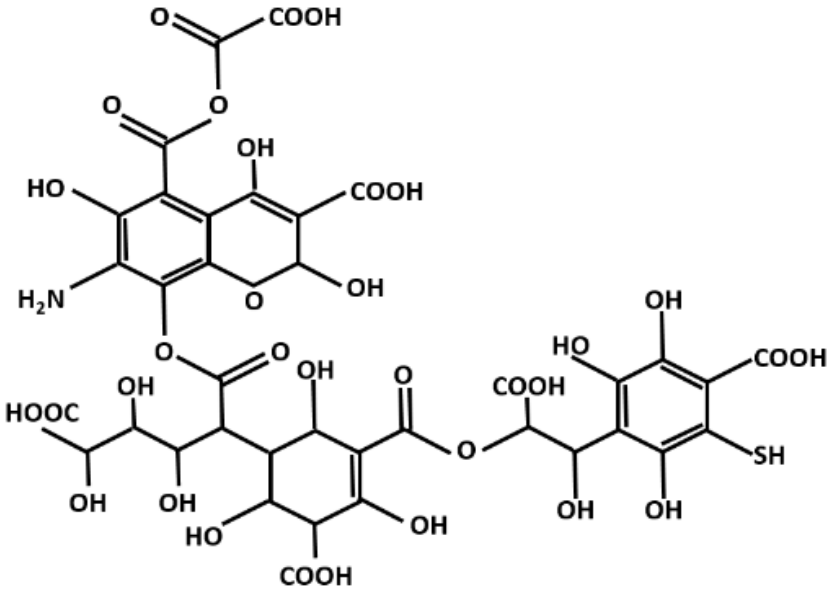
From: Kallenbach et al. 2016 Nature Comm.

Images of sugar-treated model soils over time (a); the far-left panel is an uninoculated sterile kaolinite and sand mixture, and the far-right panel is the same mixture, inoculated and treated with **weekly glucose additions for 15 months.**

Lots of sources: molasses, sugars, microalgae, etc.

Fulvic Acids

- Smaller than humic acids and honey colored
- High CEC (**500-600!**) – holds nutrients like humic acids
- Nutrient **carrier** into plant
- Stimulates plant roots



What is Fulvic Acid – Fulvic Force

https://soilsolutions.net/humic-acid-vs-fulvic-acid/
http://www.earthgreen.com/humic-vs-fulvic-acids
https://pubchem.ncbi.nlm.nih.gov/compound/5359407#section=2D-Structure

Seaweeds & Kelps

- Old technology to improve soil
- **Macro-algae** – brown algae *Ascophyllum nodosum is common*
- Complex, variable extracts
- Plant growth promoting
- Helps with plant stress tolerance
- **Plant response well studied**
- **Regulatory path looks rough**

Exact mechanism needs work

Van Oosten et al. 2017

Enzymes

Phosphatase

Breakdown insoluble phosphate into available P

Enzymes - a substance produced by a living organism that acts as a catalyst to bring about a specific biochemical reaction

http://www.m.elewa.org/JAPS/2013/18.2/3.pdf; http://web.mit.edu/12.000/www/m2015/2015/microbial_background.html

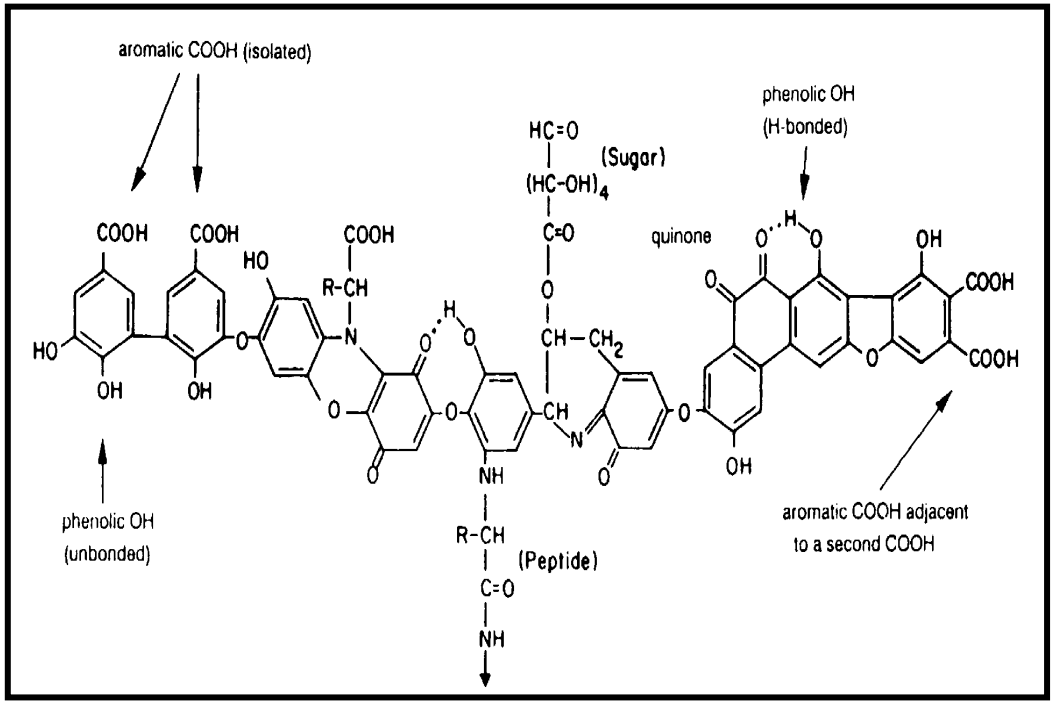
Specific Enzymes = Specific Action

- Protease
- β glucosidase
- Amidase & Urease
- Phosphatase & Sulfatase

- **Protein breakdown**
- **Cellulose breakdown**
- **N cycle**
- **P and S release**

Yang et al. 2012 – Soil Enzyme Activities and Soil Fertility Dynamics

Humic Acids



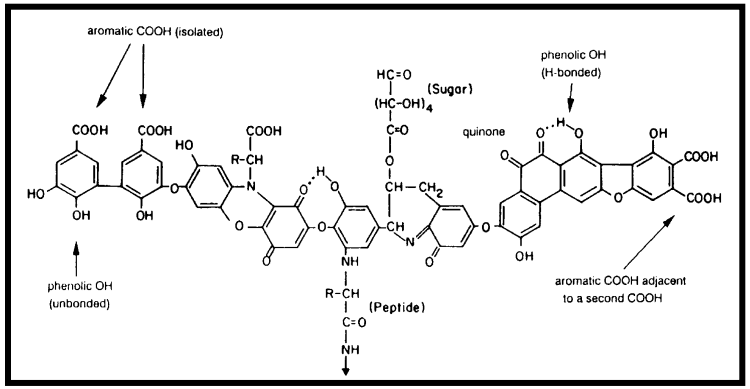
F. J. Stevenson, Humus Chemistry, 1994, 289

- Dual charge (+/-)
- Large size
- *Poor food choice*

Promotes:

- Nutrient retention (**high CEC**)
- Physical Structure

Using Humic Acids for N Management



NO_3^- NH_4^+

https://udextension.s3.amazonaws.com/factsheet/wp-content/uploads/2015/01/N-loss.jpg

F. J. Stevenson, Humus Chemistry, 1994, 289

- Humic acids **reduced peak urea → ammonia gas loss by ~68%** (Ahmed et al. 2006)
- Humic acids slowed down conversion of **ammonium → nitrate** (Dong et al. 2009)
- Humic acids soils leached **~54%-60% less nitrate** (Liu et al. 2009)

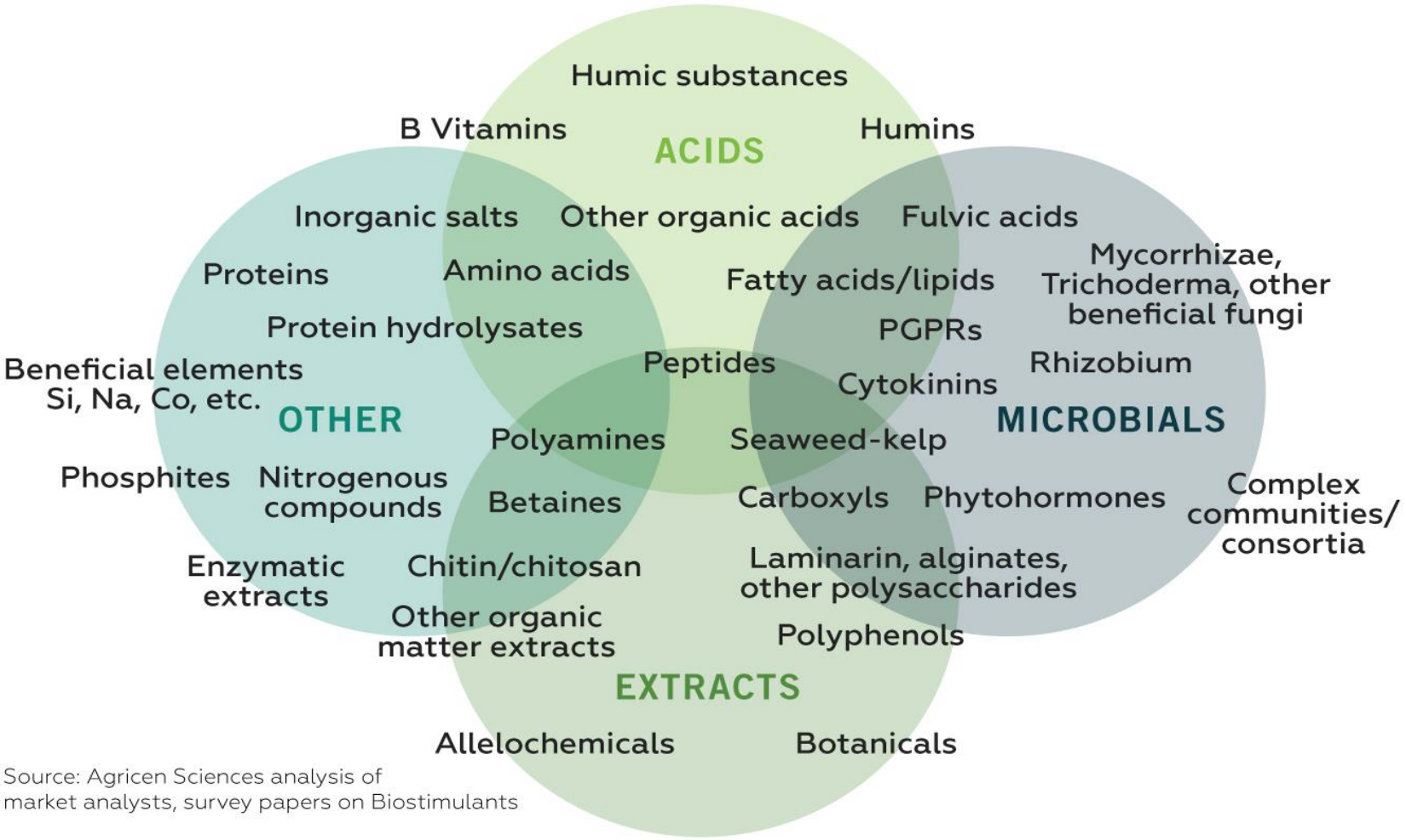
Challenges with Non-living Products

- Variance in quality and efficacy
- **Will it blend?**
- Laundry list of label claims – **what does it do best?**
- Logistics at all levels – *need for agitation?*
- **Biostimulant/fertilizer mixtures**

Nutrien™
Feeding the Future™

Closing Statements

Marketplace Noise



Source: Agricen Sciences analysis of market analysts, survey papers on Biostimulants

https://www.bpia.org/solutions-provided-by-biological-products-biostimulants/#acid-based-biostimulants

Biostimulant Market Size, Growth, Share | 2022 - 27 (mordorintelligence.com)

Infographics - Biostimulants Market (fortunebusinessinsights.com)

Crucial Questions for Suppliers and Growers

Robust Trial Data?

Clear MOA?

Probability of +ROI?

Patents and IP?

Regulatory Future?

Portfolio Fit?

VC $ Source?

Moving Forward

- Consultants/advisers are crucial **for translating MOA** into product selection – **the 'WHY'**
- **Nuanced functionality/crowded marketplace**
- **Watch out for wild claims**
- Start with the **end goal** in mind
- Focus on blending and in-can options
- **Unknowns for blend safety**
- Proposed regulatory changes are sure to **shake things up**

More Resources

- Academic review
- Complete Academic Overview (600+ pages
- UF Extension Article

http://progressivecrop.com/2020/07/making-sense-of-biostimulants-for-improving-your-soil/

Dr. Karl Wyant
Director of Agronomy – Nutrien
karl.wyant@nutrien.com

Thank You!

Nutrien™
Feeding the Future™

December 6, 2022

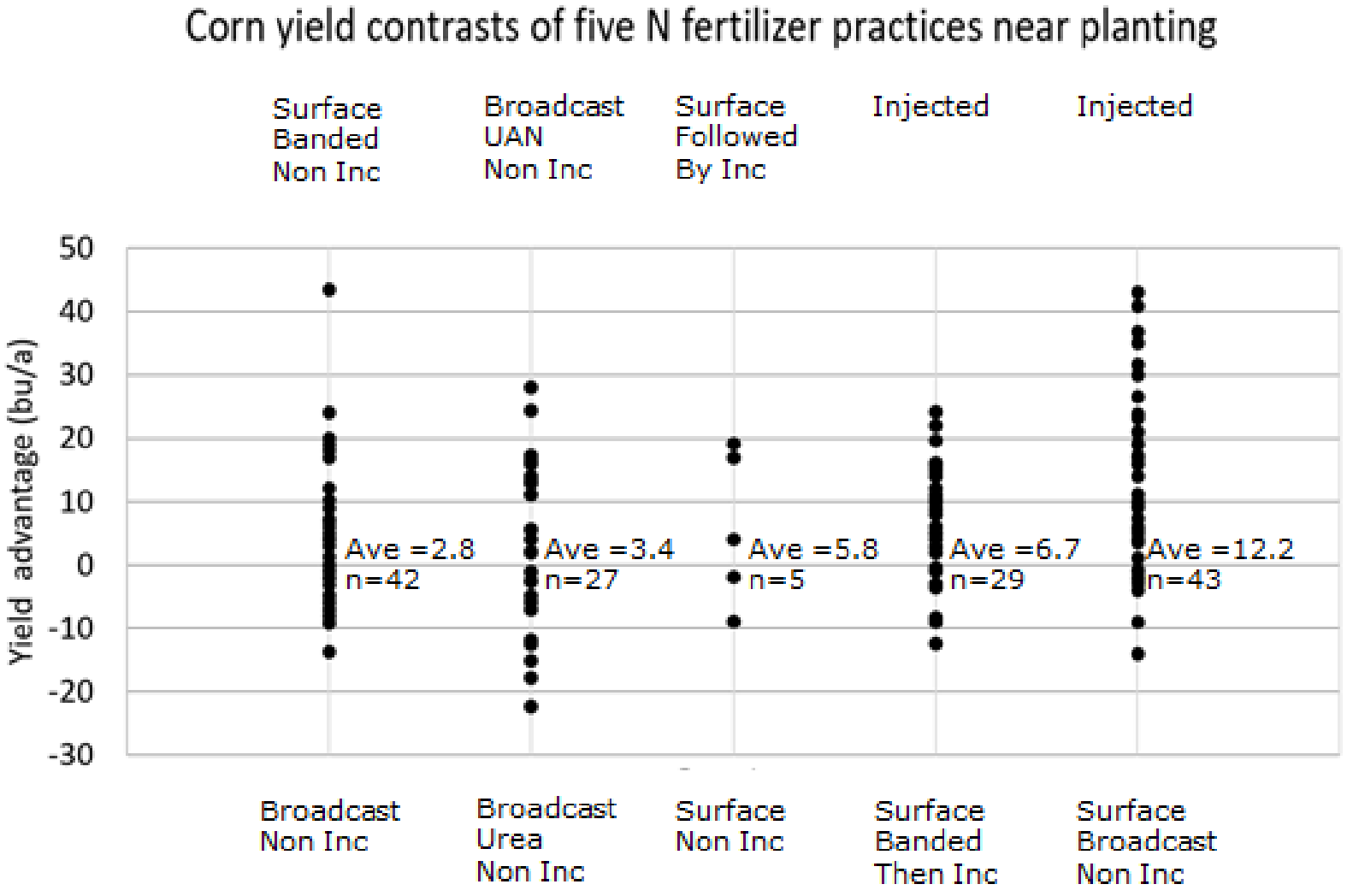
INNOVATION THAT GROWS

Planter-applied Fertilizer Systems

2022 Fluid Fertilizer Foundation Technology Workshop

Brad Van De Woestyne

Nitrogen Fertilizer Form and Placement

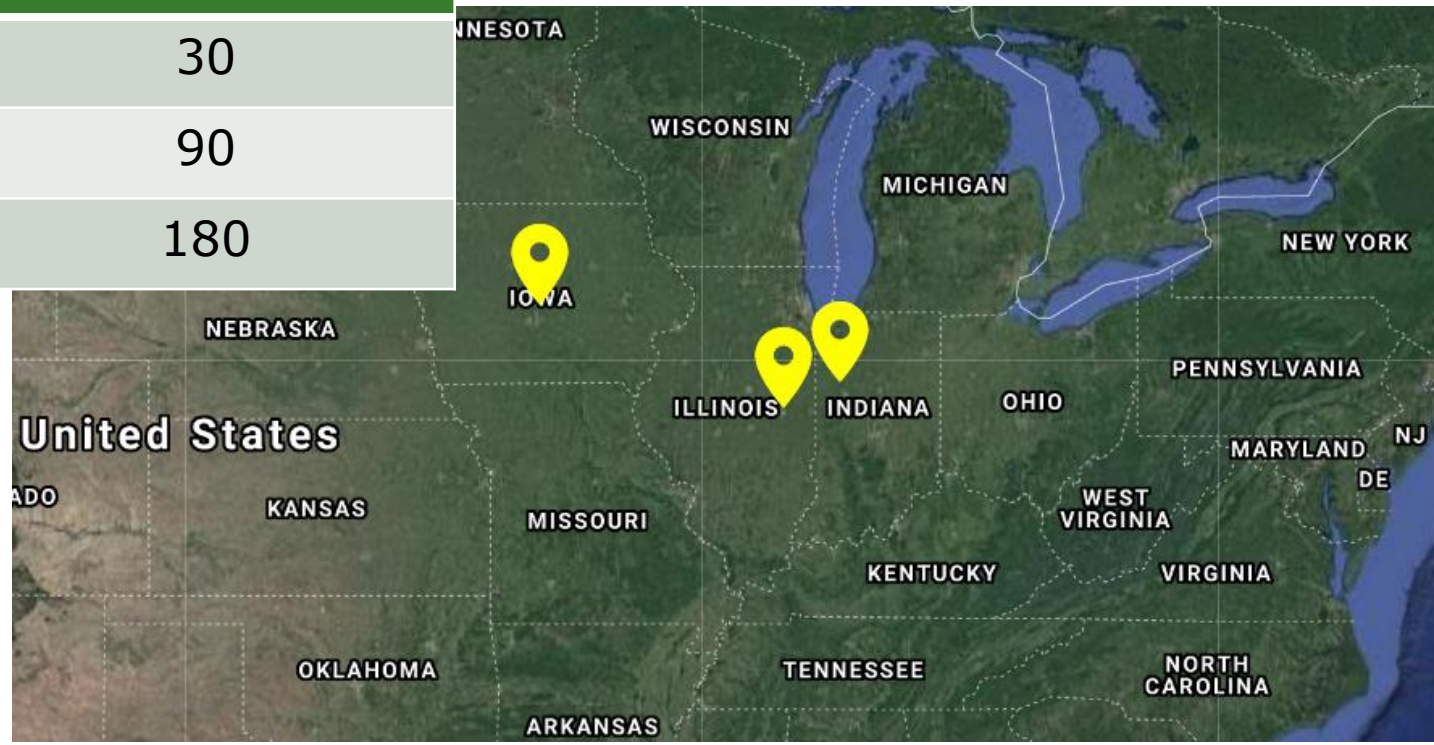


Key Takeaways:

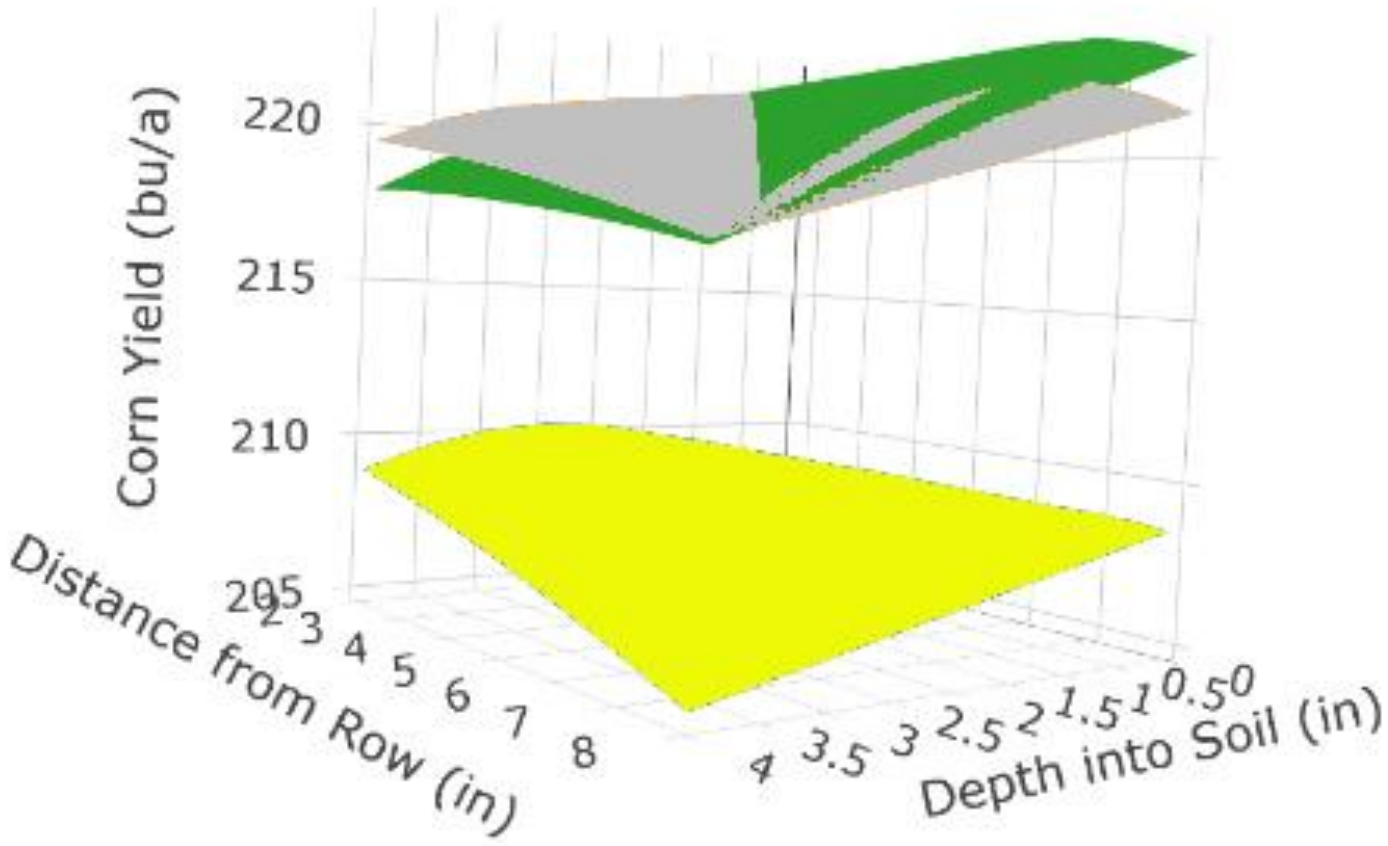
- Literature review 13 scientific articles from 12 states
- Each dot represents one site-year comparing forms and placements
- Results show injected nitrogen better than surface or surface and incorporated UAN or Urea

Field Trials

Depth from Surface (inches)	Distance from Row (inches)	Rate of N at Planting (lbs N/a)
0	2	30
2	5	90
4	8	180



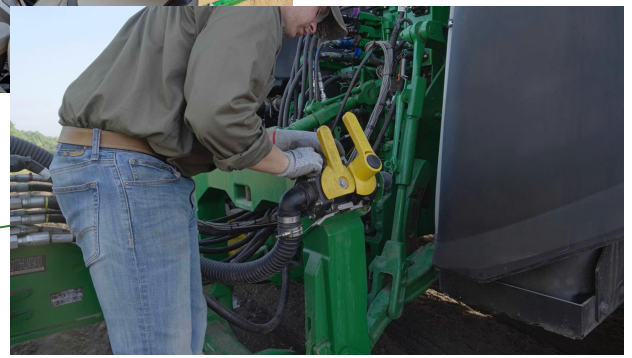
Results

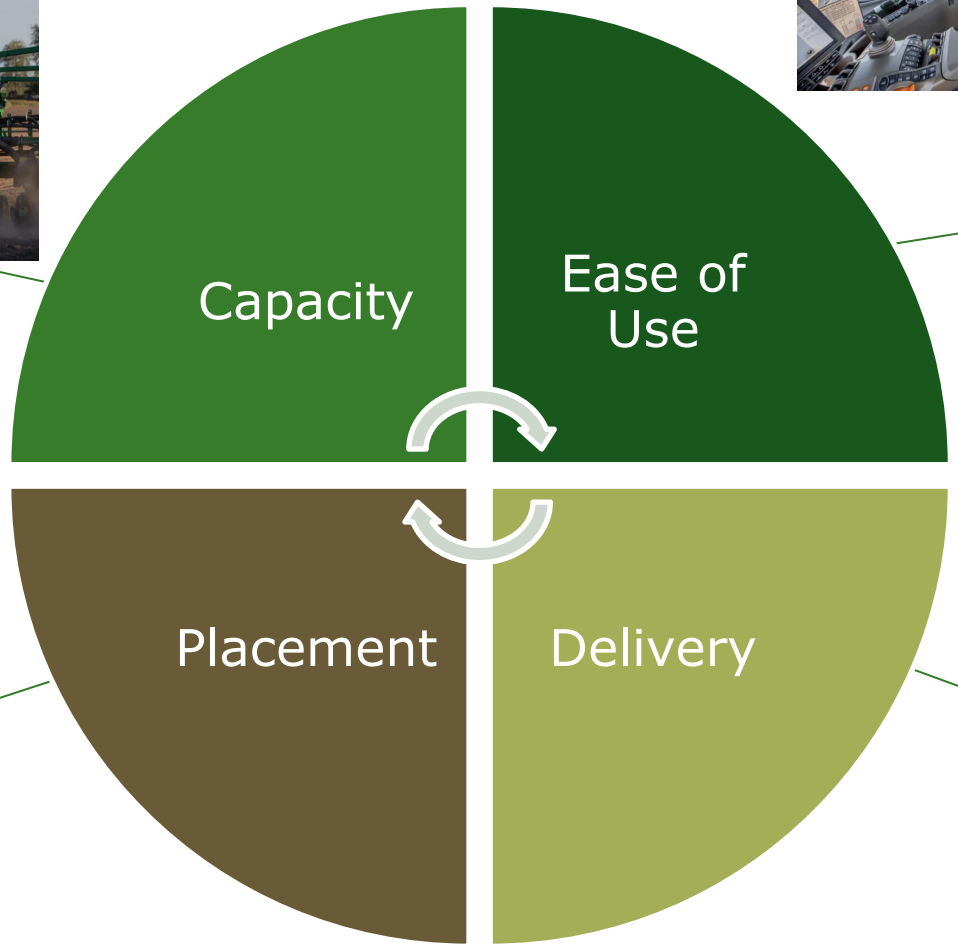


Key Takeaways:

- Fertilizer placement from the row and depth into soil minor
- Rate of fertilizer most significant response

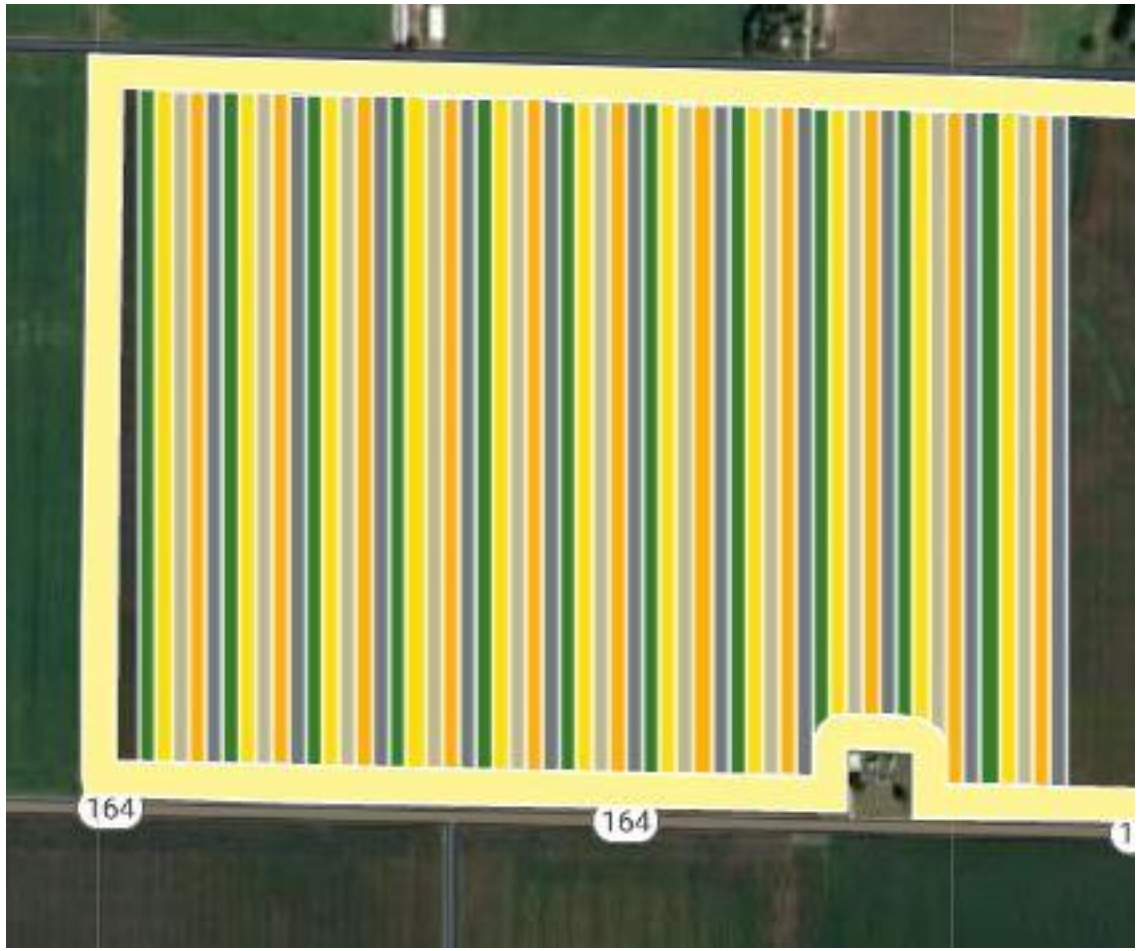
Planter-applied Fertilizer Challenges





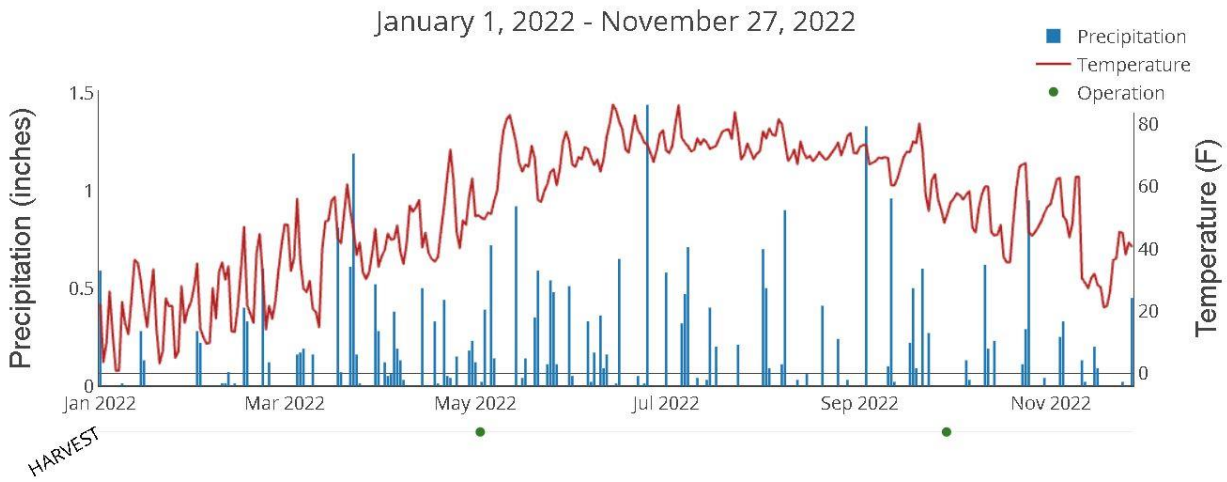
In-Furrow Fertilizer

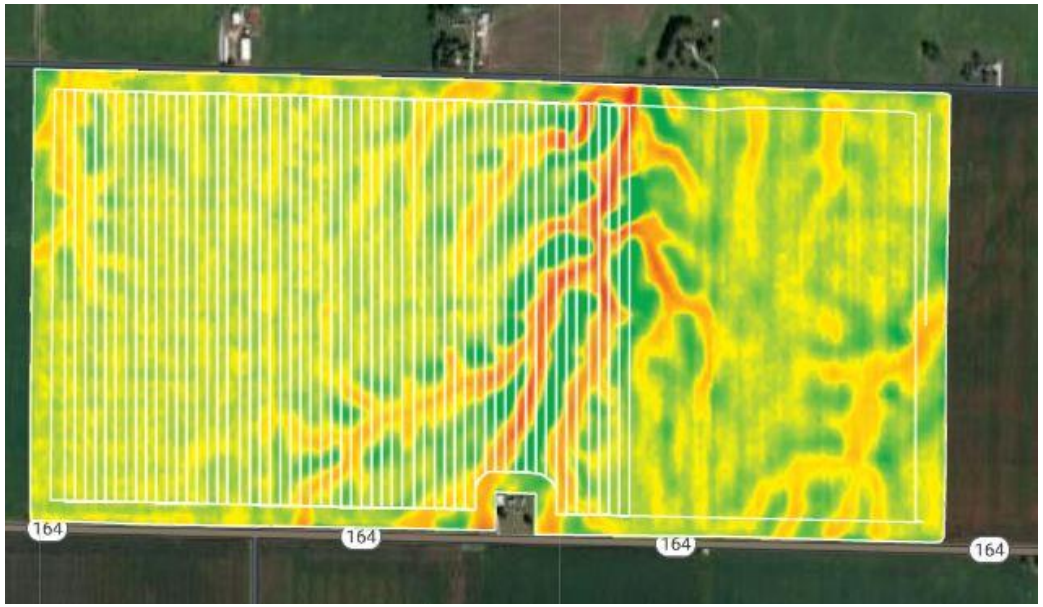
Protocol

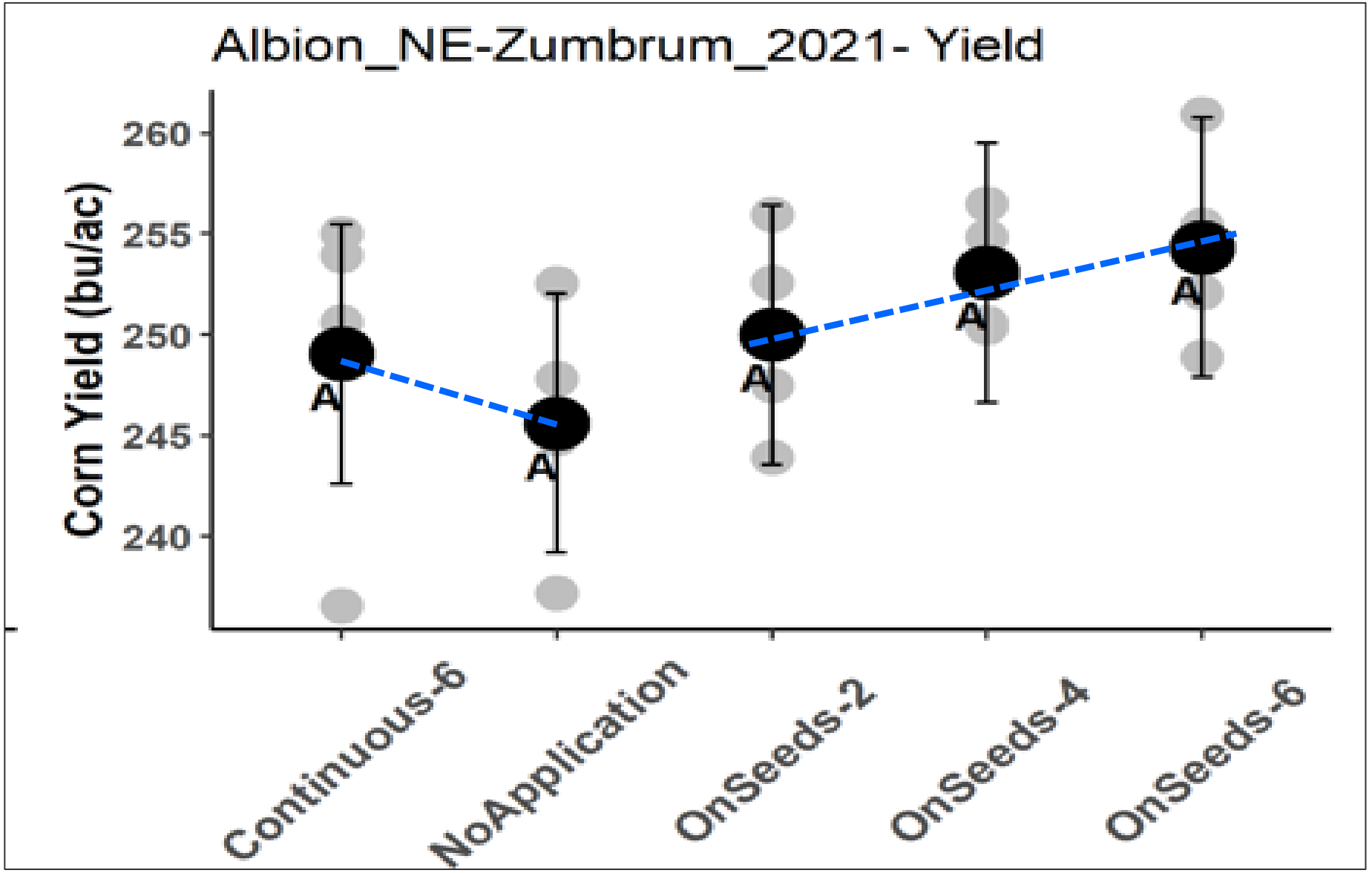


	Trt	Fertilizer placement at planting	Starter Fertilizer Rate (gal/ac)
	1	In-Furrow - Continuous	6
	2	No Application	0
	3	In-Furrow - On Seeds	2
	4	In-Furrow - On Seeds	4
	5	In-Furrow - On Seeds	6

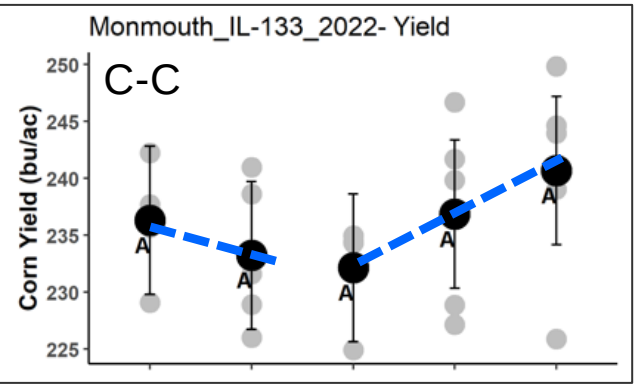
Variables to explain outcomes:

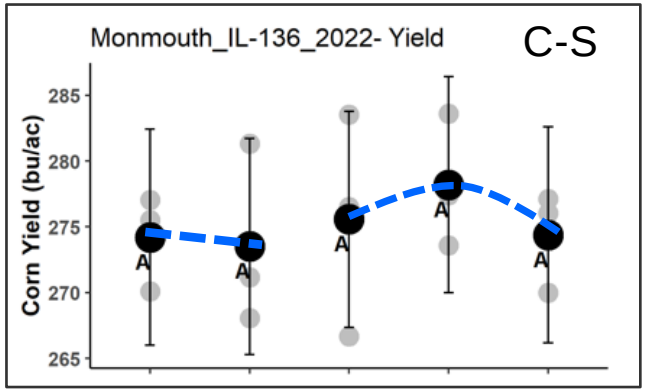


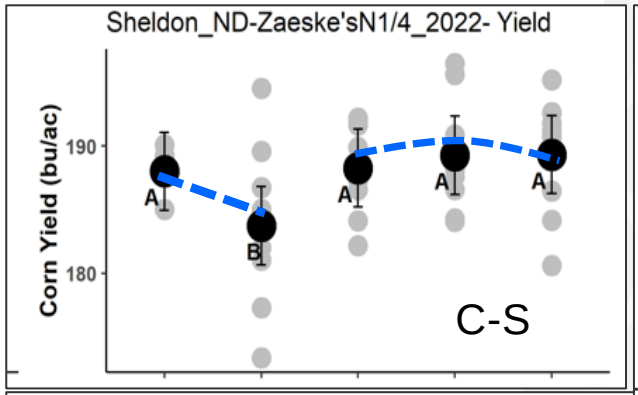


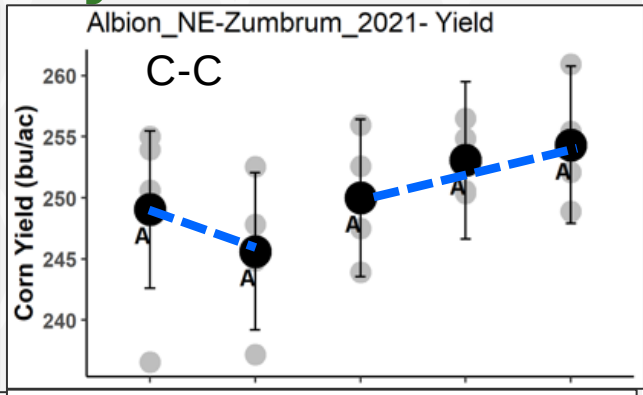

Albion_NE-Zumbrum_2021- Yield
Corn Yield (bu/ac)
260
255
250
245
240
A
A
A
A
A
Continuous-6
NoApplication
OnSeeds-2
OnSeeds-4
OnSeeds-6

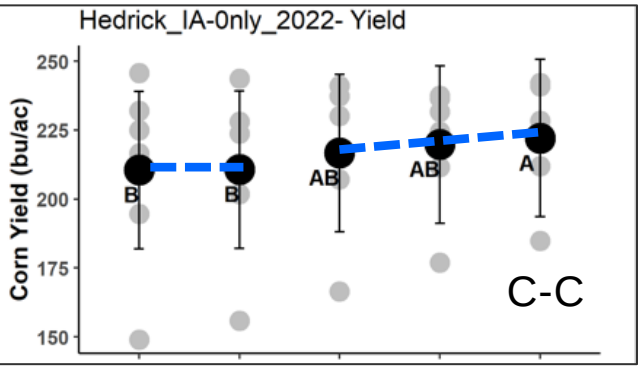
ExactShot OnSeed Fertilizer: 21 Site-Years Yield Summary

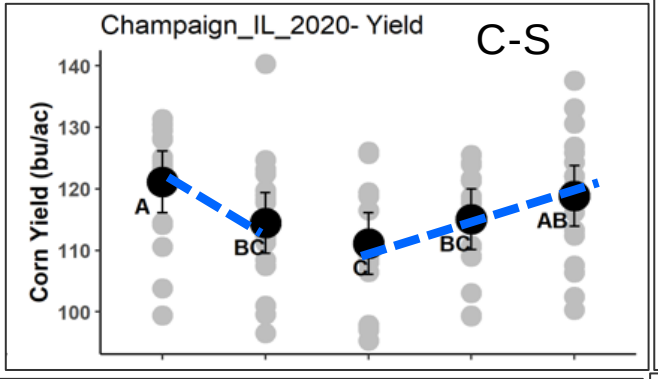


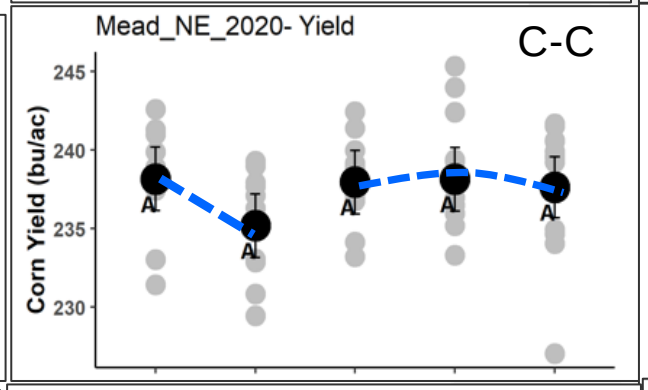


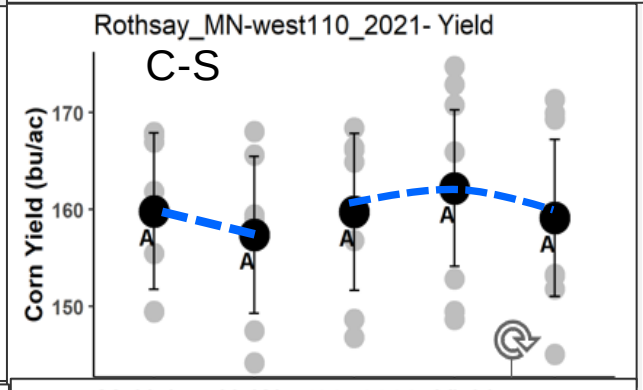


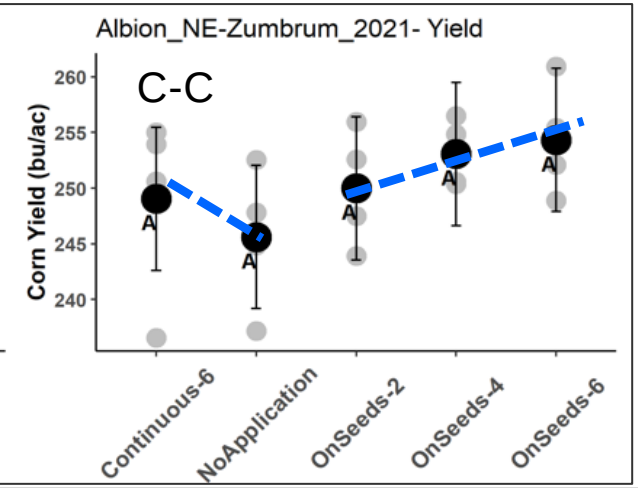


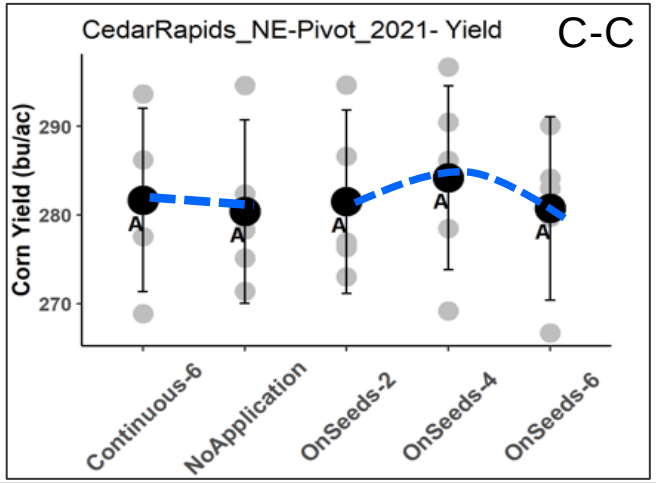


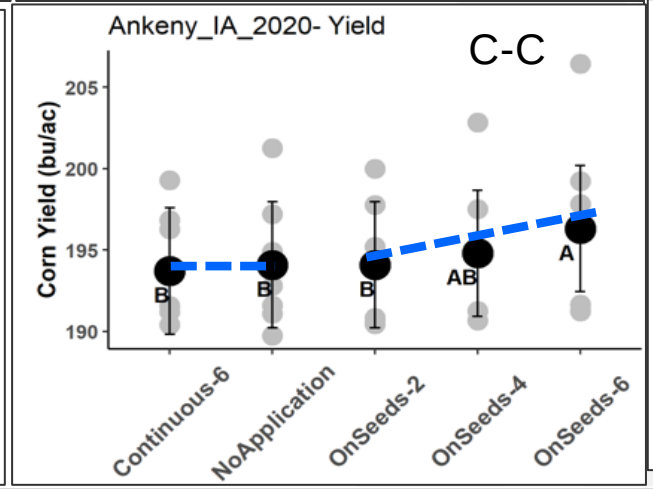


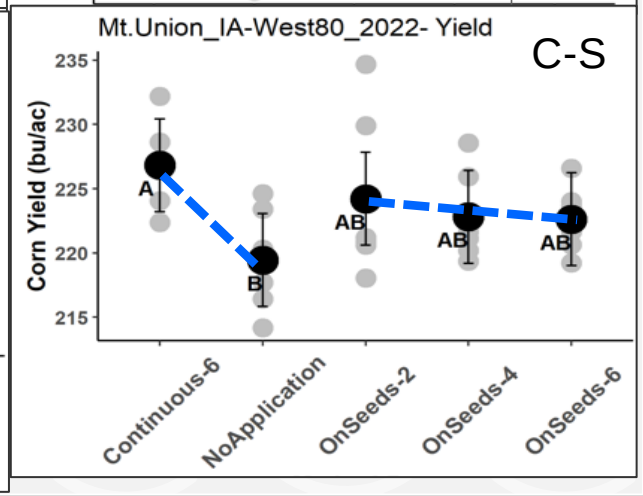




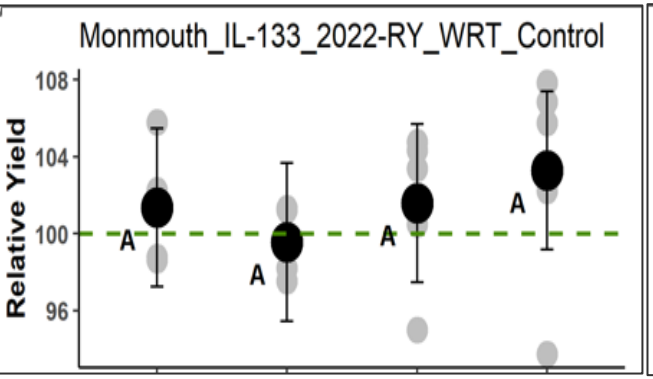


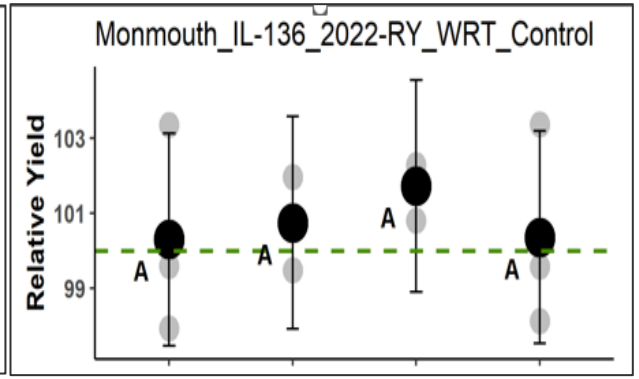


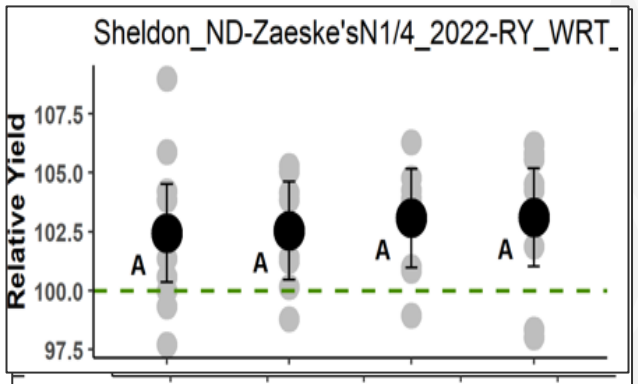


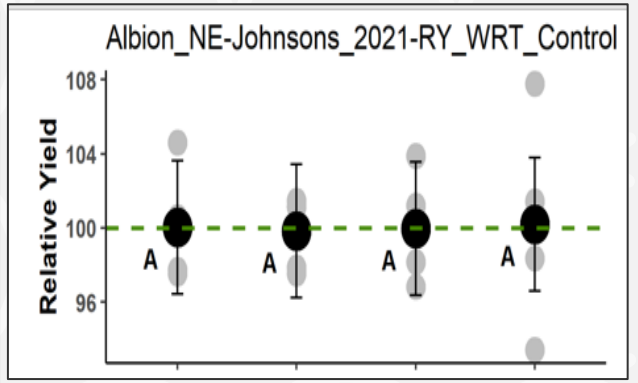


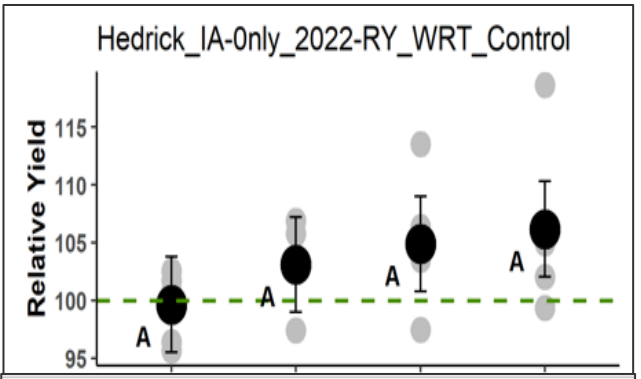
ExactShot OnSeed Fertilizer: 21 Site-Years Relative Yield vs Control

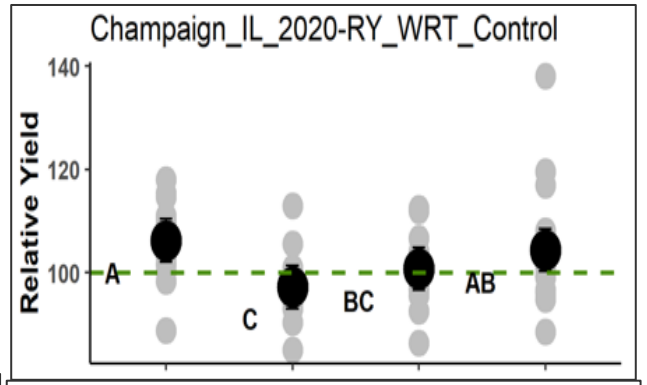


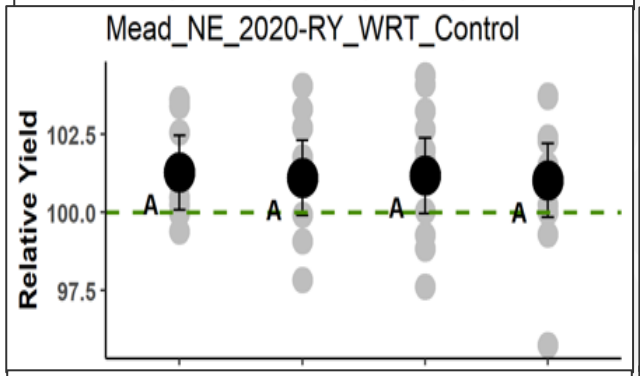


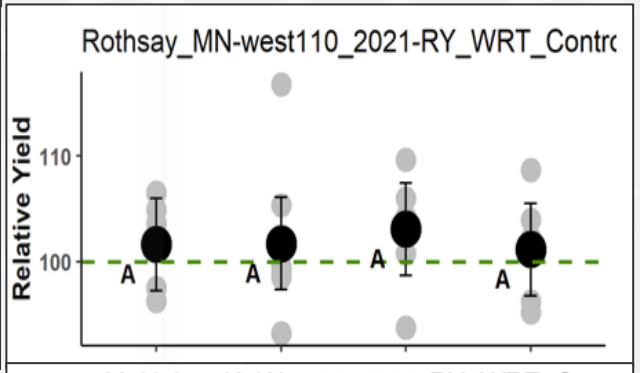


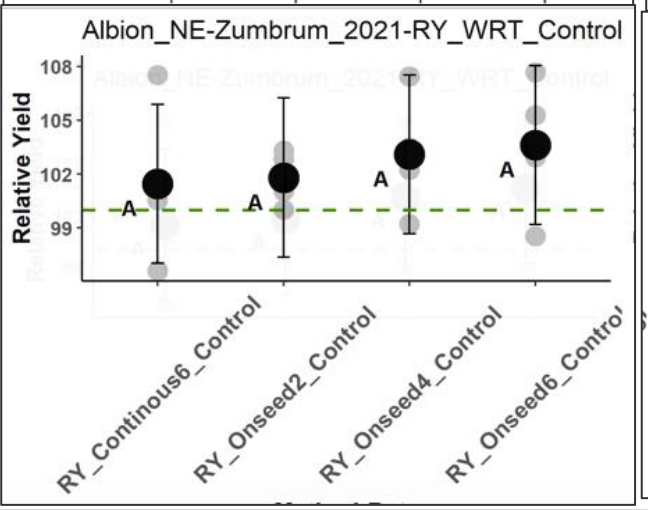


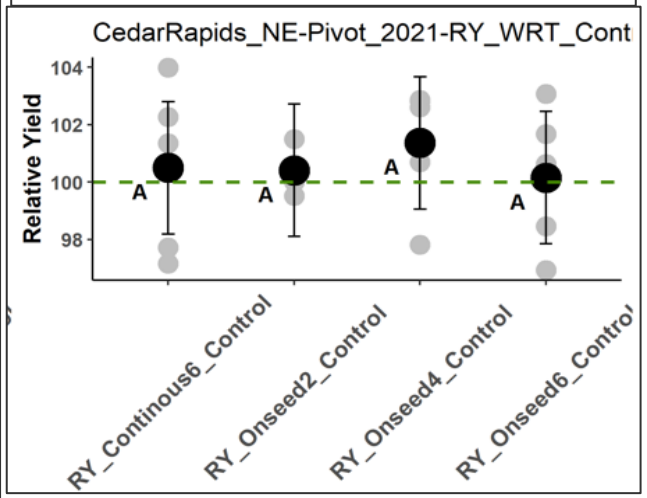


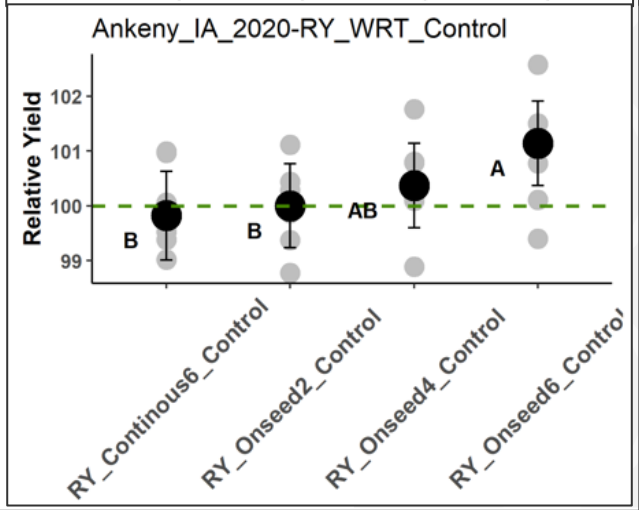


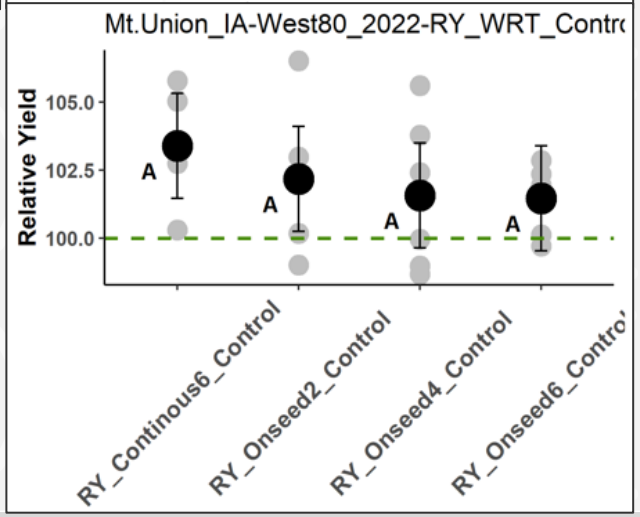










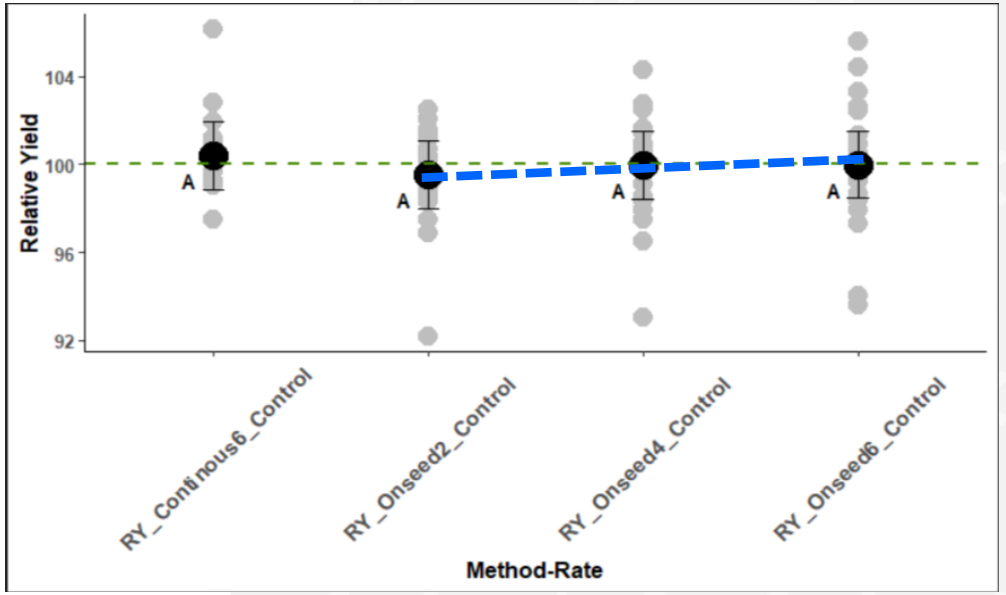


Relative Yield Aggregate Summaries

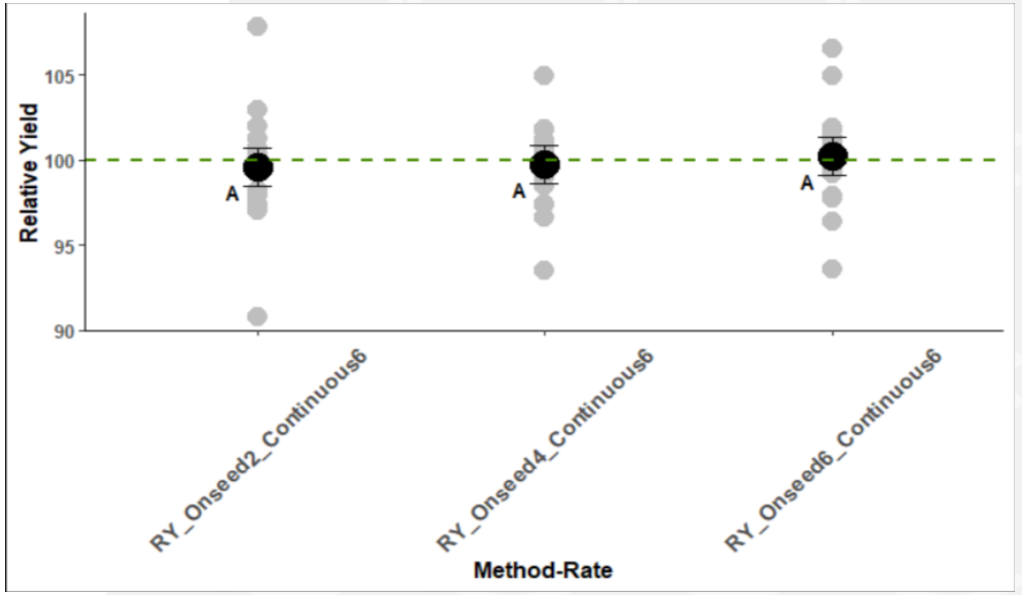
- **Relative Yield vs Control Treatment**
- All treatment comparisons were around 100%.
- A slight tendency to increase relative yield from OnSeed2 to OnSeed6.
- Two locations had significant yield increase from OnSeed treatments
- One location had a significant lower relative yield with OnSeed treatments

- **Relative Yield vs Continous6 Treatment**
- All treatment comparisons were not statistically different and were around 100%.

Relative Yield (%) vs Control



Relative Yield (%) vs Continous6



Probability of Relative Yield vs Control

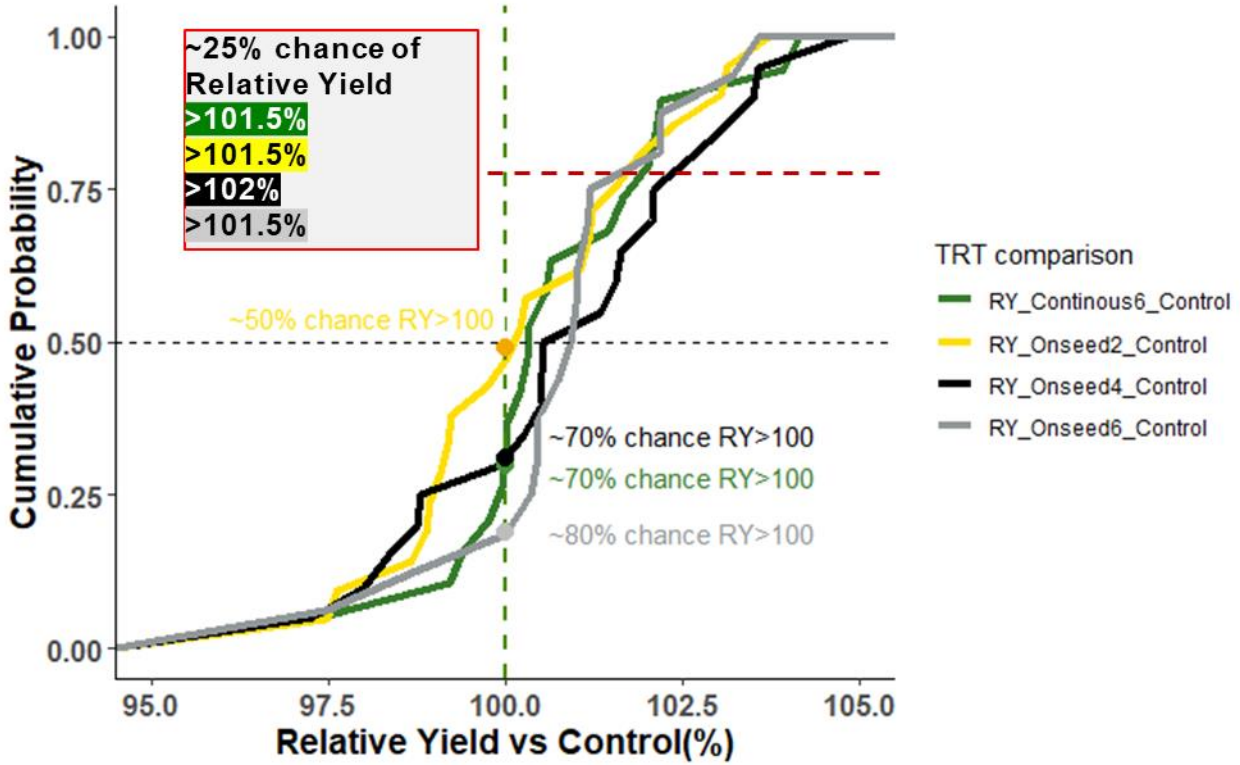
- ~50% of fields had Relative Yield > 100% for OnSeed2 vs Control
- ~70% of fields had Relative Yield > 100% for Continuous 6 and OnSeed4 vs control.
- ~80% of fields had Relative Yield > 100 % for OnSeed6 vs Control
- **~25% of fields had Relative Yield**

>101.5% for Continuous6 vs Control

>101.5% for OnSeed2 vs Control

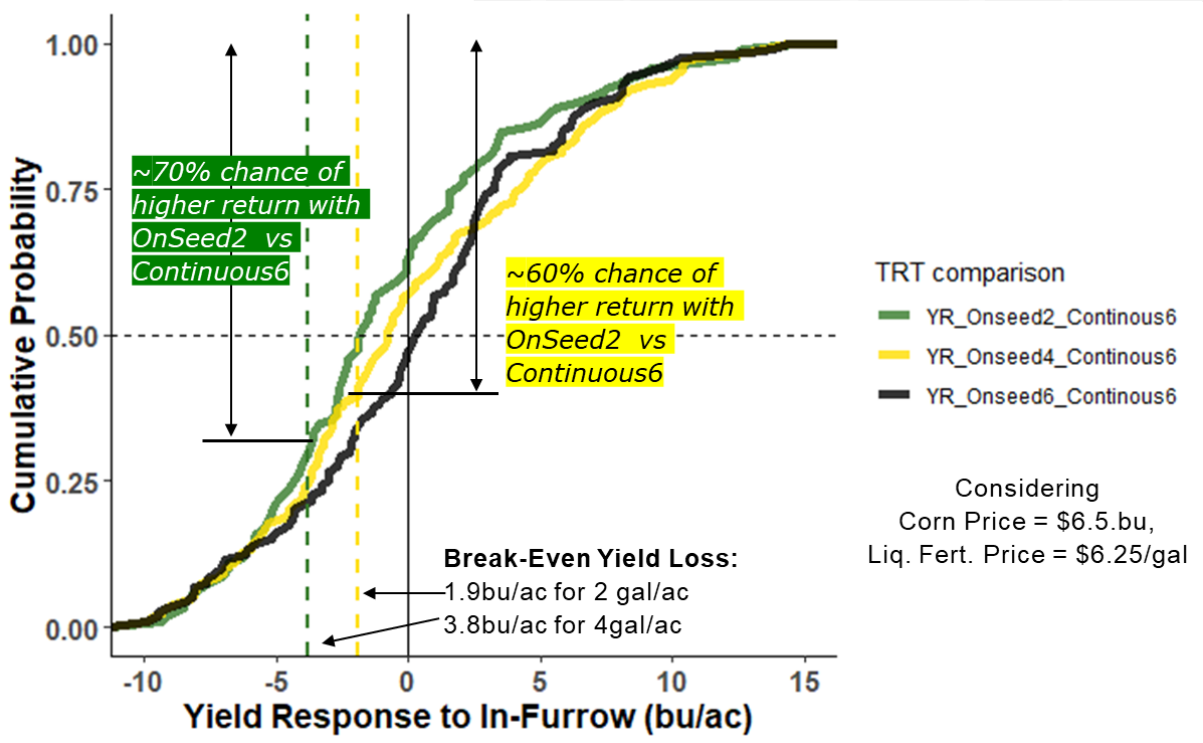
>101.5% for On-Seed6 vs Control

>102% for OnSeed4 vs Control



Economics of In-Furrow Fertilizer

- Considering corn price of $6.50/bu and liquid fertilizer cost of $6.25/gallon
- ~*70% chance of higher return with OnSeed2 vs Continuous6*
- *~ 60% chance of higher return with OnSeed4 vs Continuous6*
- The likelihood of cost saving increases with lower fertilizer price and higher corn price.
- * no fee for technology



Key Takeaways

- Agronomic research is driving innovation in the solutions Deere delivery into the marketplace
- Field trials building a database to quantify probability of response/ROI
- Next step is predict outcomes with some level of probability


JOHN DEERE