heliae
AGRICULTURE
SOIL IS THE KEY

Healthy Soil Yield Healthy Crops for Healthy Profits

PhycoTerra®

heliae®
AGRICULTURE

Revolutionary technology sourced from nature that drives yield and quality by activating soil microbes.

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Soil Health vs Soil Quality

Soil health - the interaction between organisms and their environment and the properties provided by such interactions.

Biological integrity of your field (e.g., microbial population and diversity) and a focus on **supporting plant growth**.

Soil quality –Refers to how well a soil functions **physically, chemically, and biologically** and does its “job” (e.g., crop production).

https://www.soilhealthpartnership.org/blog-posts/3-types-of-soil-health-indicators/

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Agricultural Impacts on Soil Health

- Widespread tillage & ag chem use
  (Hendrix et al. 1986)
- Loss of carbon inputs
  (Weil and Brady 2017)
- Reduced microbial community
  (Kraut-Cohen 2020)
- **Decrease in soil health & quality (Sanderman et al. 2017)**

Hendrix et al. 1986 - Detritus Food Webs in Conventional and No-Tillage Agroecosystem
Weil and Brady 2017 - The Nature and Properties of Soil 15th ed.
Kraut-Cohen 2020 - Effects of tillage practices on soil microbiome and agricultural parameters
Sanderman et al. 2017 - Soil Carbon Debt of 12,000 Years of Human Land Use

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What is Regenerative Agriculture?

FOUR BASIC PRINCIPALS

- **Minimize disturbance**
- **Keep soil covered**
- **Keep roots alive**
- **Diversity of plant inputs**

A holistic soil management plan is

CHEMICAL | BIOLOGICAL | PHYSICAL

https://phycoterra.com/2020/04/22/4-regenerative-agriculture-practices-increase-soil-health/

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Goal of Regenerative Agriculture

SOIL HEALTH

SOIL QUALITY

Microbial Partners are KEY!

https://phycoterra.com/2020/04/22/4-regenerative-agriculture-practices-increase-soil-health/

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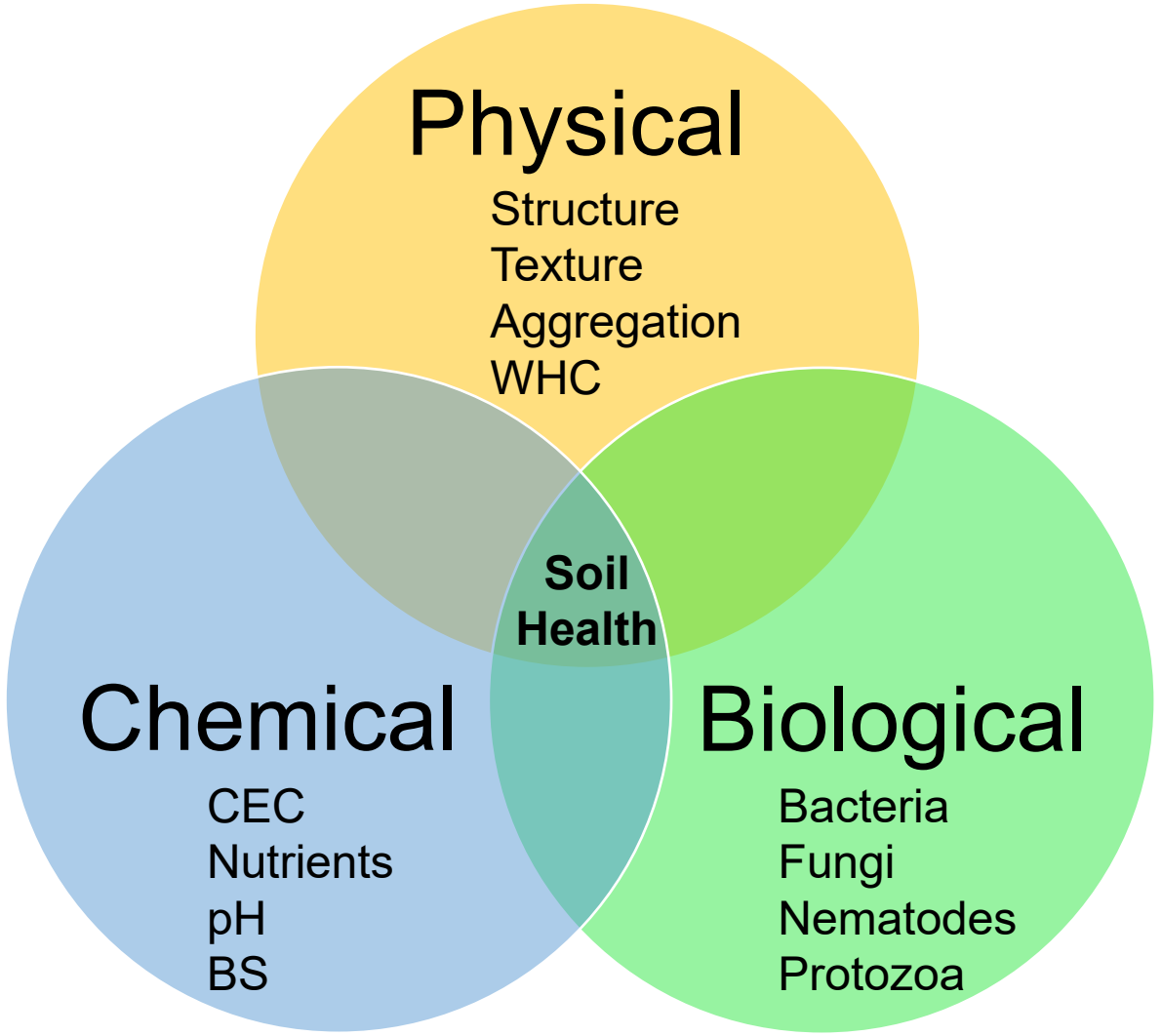
Holistic Approach for Managing Soil



https://www.soilhealthpartnership.org/blog-posts/3-types-of-soil-health-indicators/

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What Healthy Soils Do

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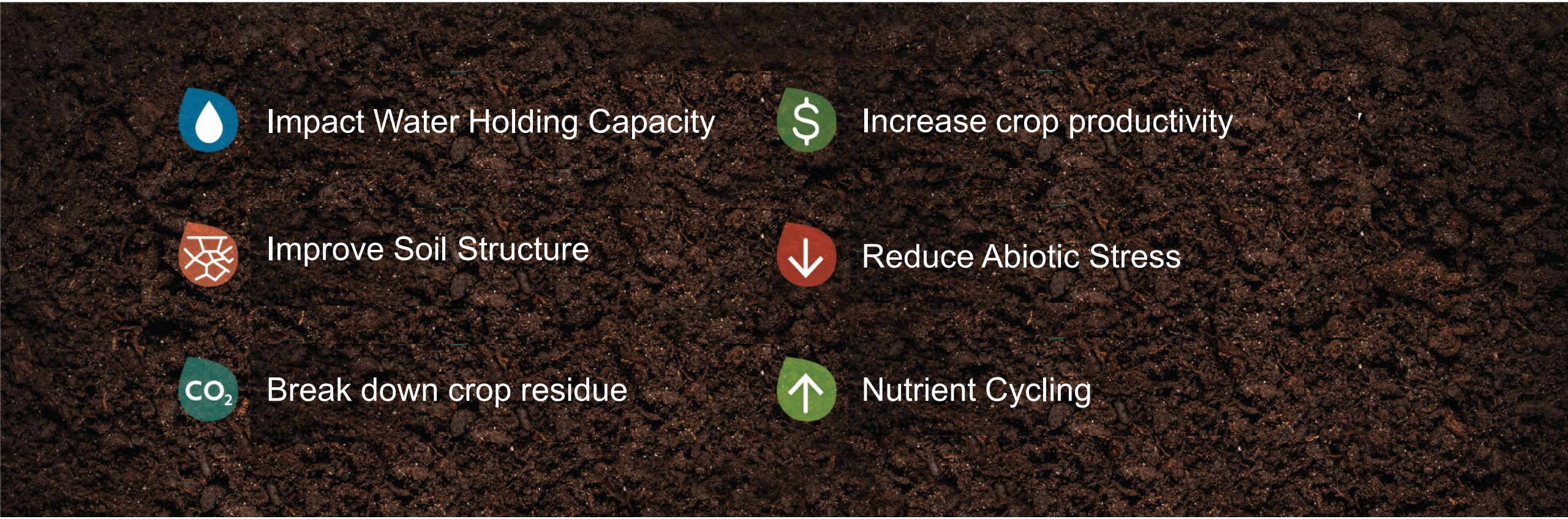
What Do Soil Microbes Do



Key indicator of soil health!

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Optimize Your Soil Biology

Table 1 – Practices to help improve soil biology and improve soil structure.

Component	Practice
Feed Existing Biology	Provides the soil microbiome a food source
Add Biology	Provide certain species of bacteria and fungi to soil
Utilize Carbon product and Biostimulants	Multiple Modes of Actions
Mulches and Compost	Provides a bulk carbon and nutrient source to the soil
Cover Cropping	Keeps living roots in the soil and protects soil from erosion
Reduce tillage	Helps keep soil structure and microbial communities intact

A holistic soil management plan is

CHEMICAL | **BIOLOGICAL** | PHYSICAL

Sound Advice is Key

http://progressivecrop.com/2021/05/managing-soil-structure-and-quality/

How do you maximize the most valuable asset at the farm?

75% of microbes (bacteria & fungi) found in soil are dormant. Without a proper food source, your soil cannot maximize nutrient availability & water retention, contributing significantly to crop growth & development.

Wake them up with … PhycoTerra®

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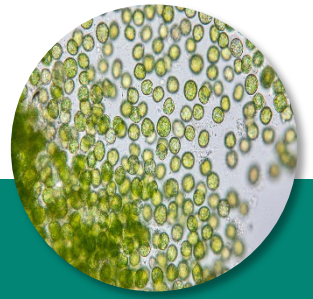
What is Microalgae?



Single-celled algae that converts sunlight, water, & carbon dioxide

Superior food source for the microbiome to support healthy crops

Applicable for various soil types to feed the microbiome

Application has proven beneficial impacts in various cropping systems

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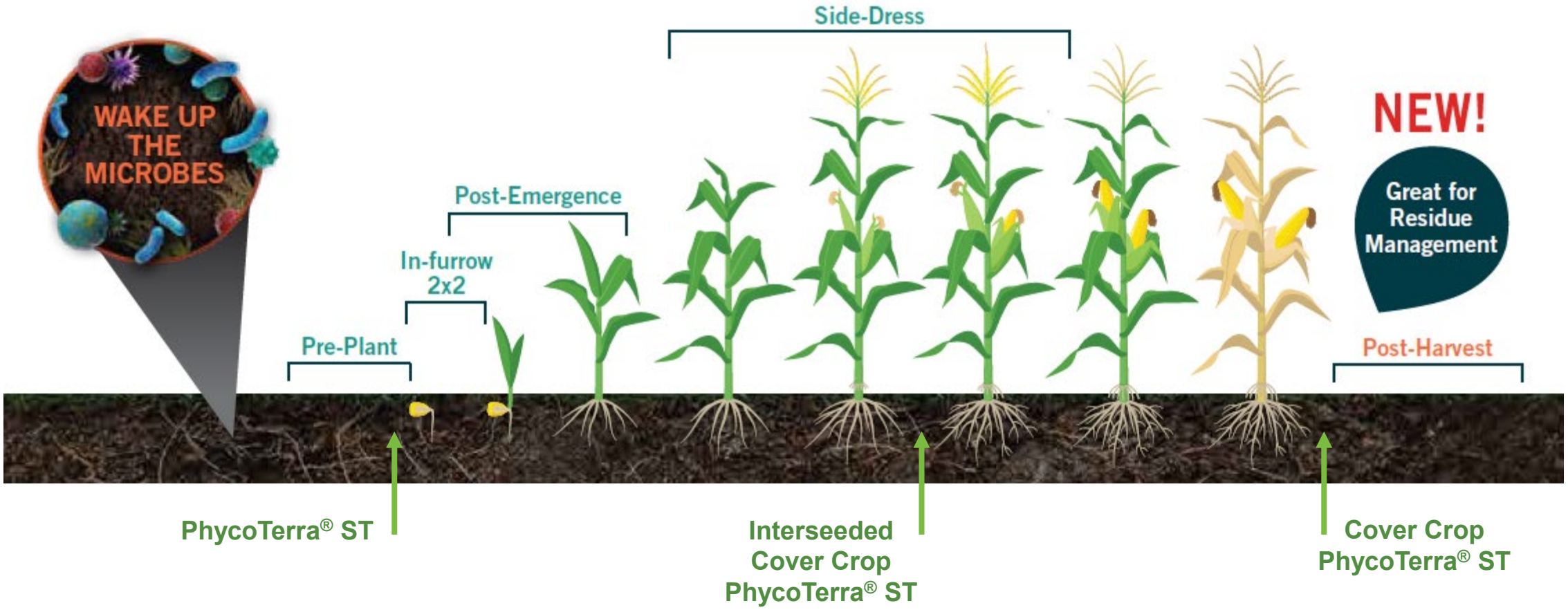
Start to Finish



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A Living Soil Promotes Healthy Soil

Limited Microbial Growth

Secreted Glues

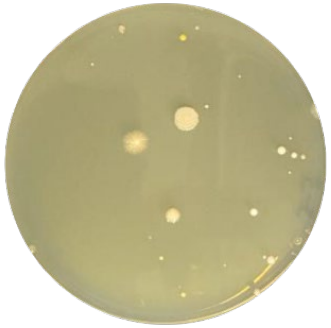
Typical Ag Soil
Limited Microbial Growth

Soil agar + PhycoTerra®
Excellent Abundance and Diversity

CONSISTENT MICROBIAL RESPONSE ACROSS SOIL TYPES

12X INCREASE

CFU/g soil | Sandy Loam
pH – 5.0 SOM – 1.0%



UTC

PhycoTerra®
8 Days

6X INCREASE

CFU/g soil | Loamy Sand
pH – 5.6 SOM < 1%

UTC

PhycoTerra®
12 Days

5X INCREASE

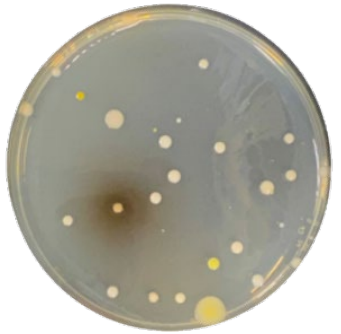
CFU/g soil | Clay Loam
pH – 6.9 SOM – 3.7%

UTC

PhycoTerra®
12 Days

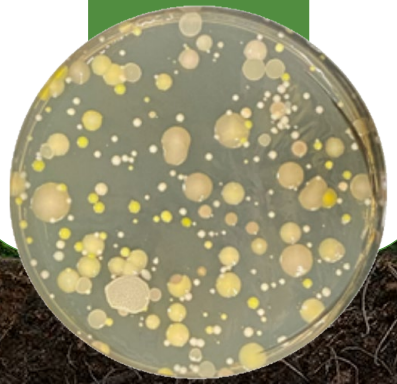
15X INCREASE

CFU/g soil | Silt Loam
pH – 5.6 SOM – 3.2%



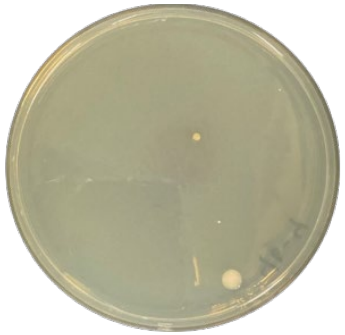
UTC

PhycoTerra®
21 Days



33X INCREASE

CFU/g soil | Sandy Loam
pH – 7.5 SOM – 2.2%



UTC

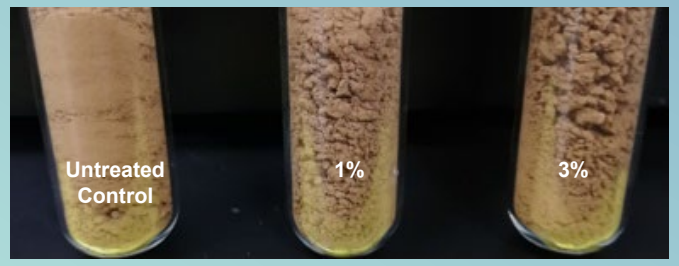
PhycoTerra®
21 Days

PhycoTerra®

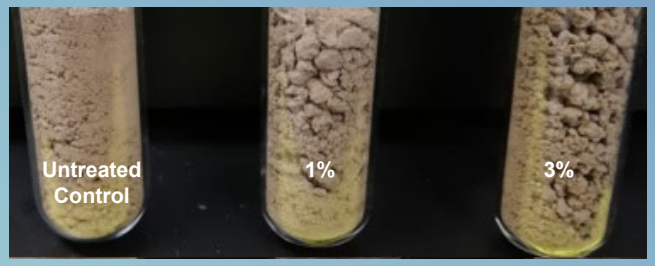
Significant soil changes with PhycoTerra® Soil Microbial food

Structure changes after 3 biweekly applications of 1 gal/acre or 3 gal/acre in greenhouse

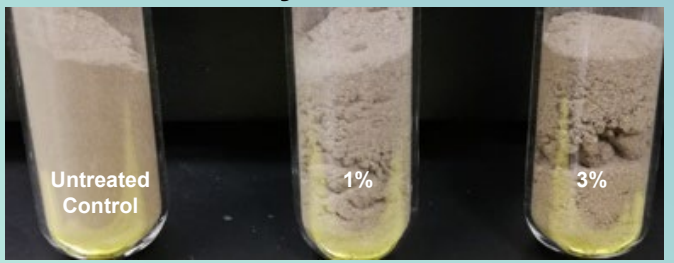
Silty Clay Loam



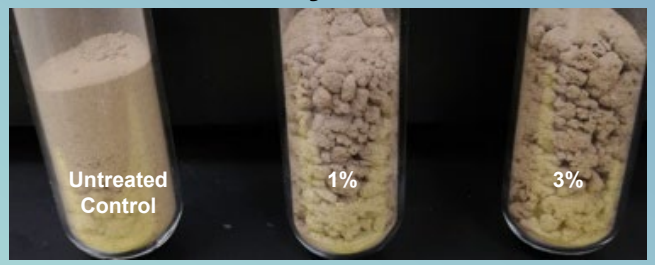
Loam



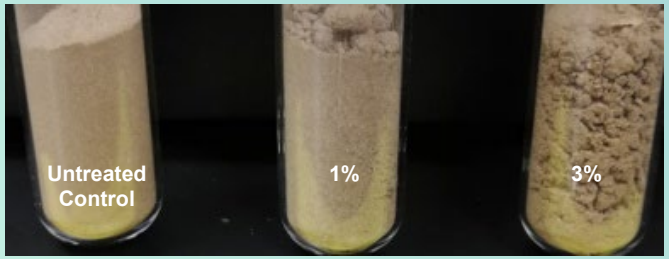
Loamy Fine Sand



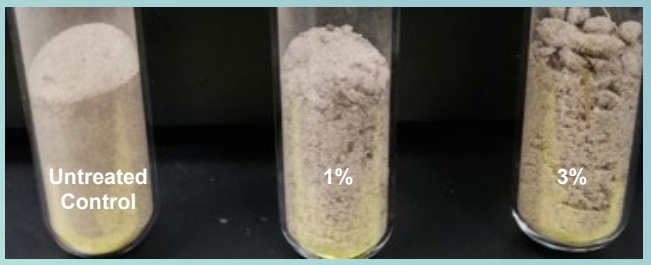
Sandy Loam



Loamy Sand



Fine Sand



Chenu and Cosentino 2011 - **Microbial Regulation of Soil Structure Dynamics**
Kallenbach et al. 2016 - **Direct evidence for microbial-derived soil organic matter formation and its ecophysiological controls**
Costa et al., 2018 - **Microbial Extracellular Polymeric Substances: Ecological Function and Impact on Soil Aggregation**
Wilpiszeski et al., 2019 - **Soil Aggregate Microbial Communities: Towards Understanding Microbiome Interactions at Biologically Relevant Scales**

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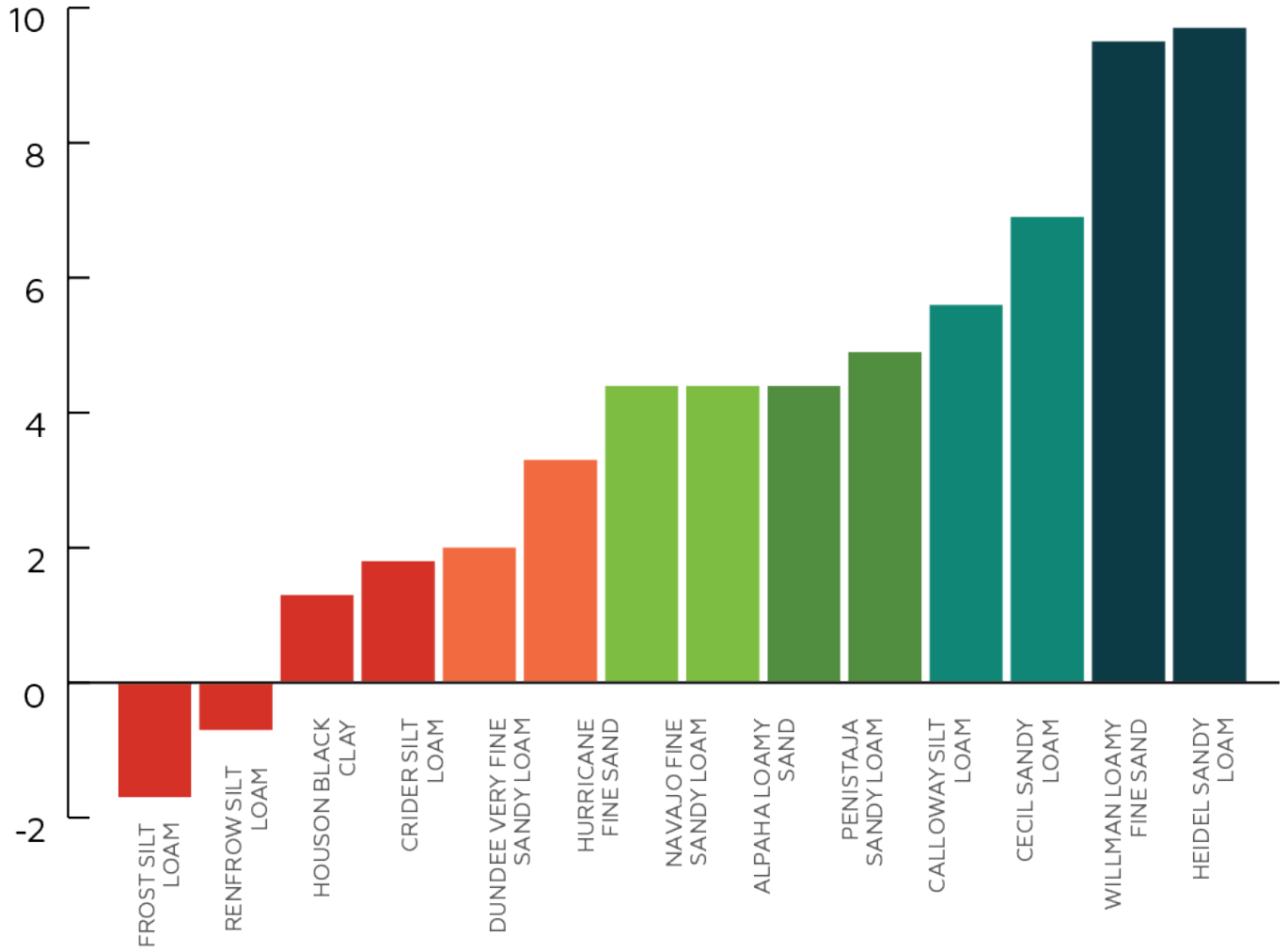
Water Holding Capacity Improvement

1% v/v for 40 days after three biweekly applications in greenhouse



Rabot et al., 2018 **Soil structure as an indicator of soil functions: A review**

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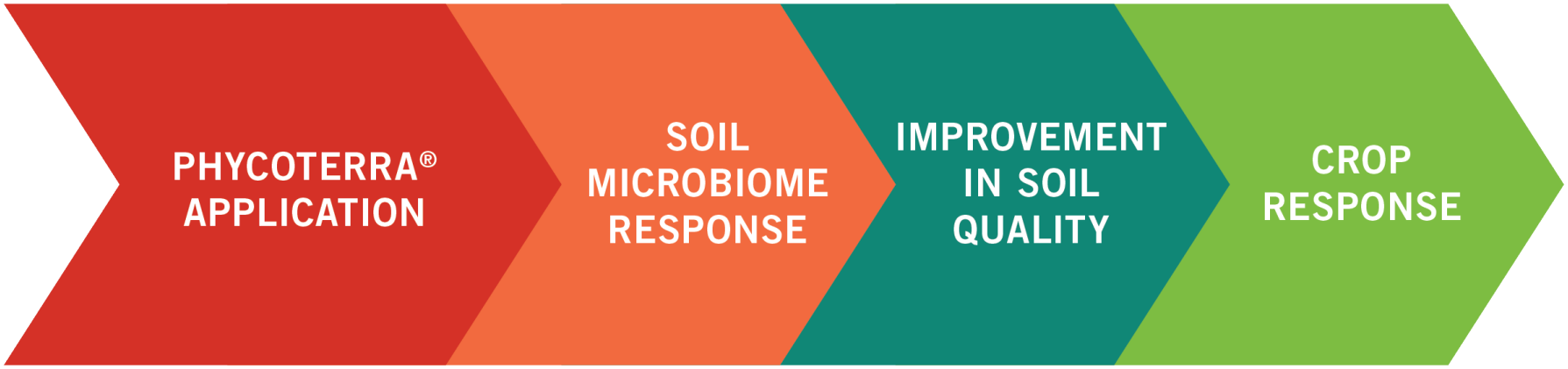
Optimize Production with Microbial Food



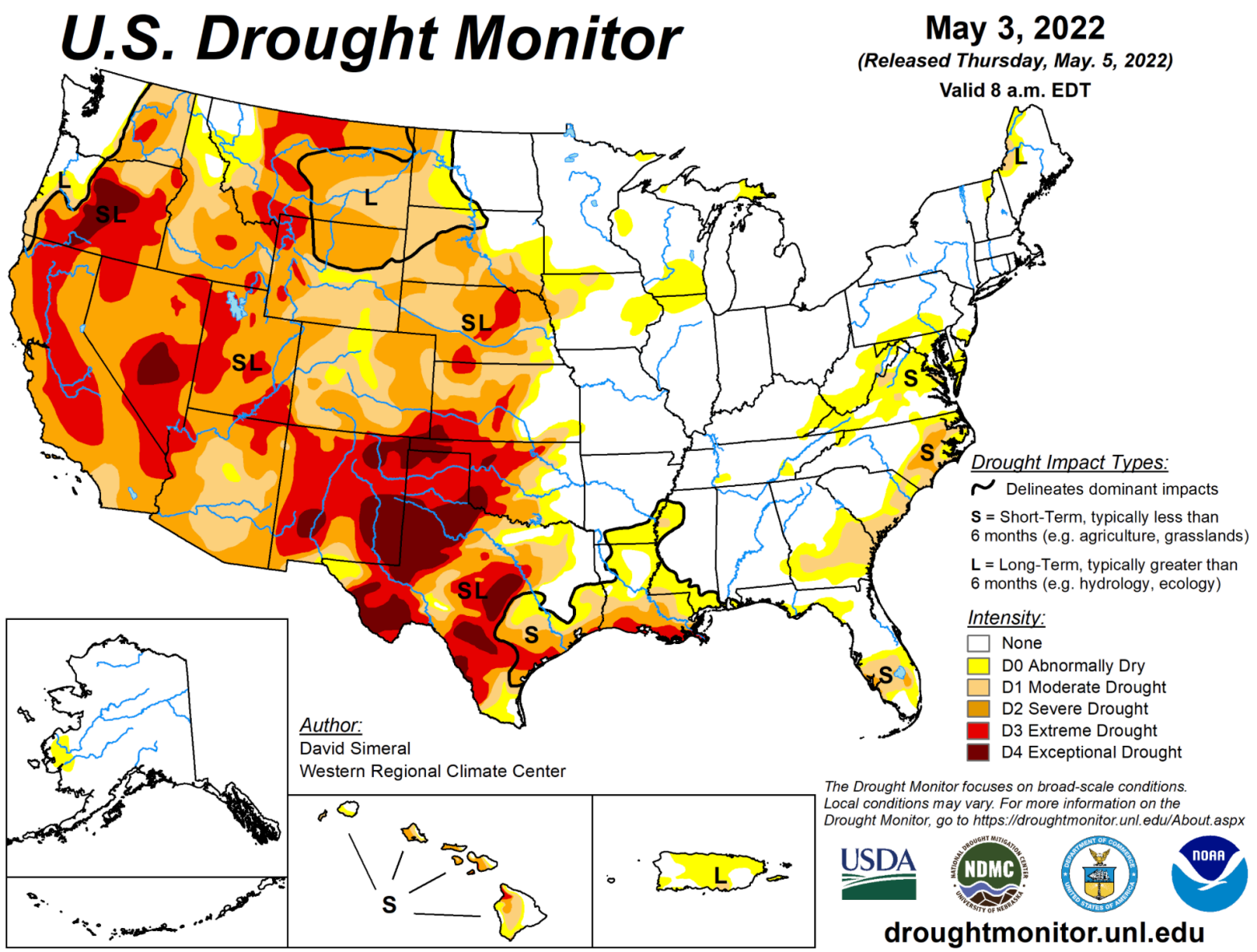
THE BENEFITS

- Improved NPK Availability
- Improved Soil Structure
- Improved Water Holding Capacity
- Abiotic Stress Relief

Kuzyakov 2002 – Review: Factors affecting rhizosphere priming effects
Jacoby et al. 2017 – The Role of Soil Microorganisms in Plant Mineral Nutrition—Current Knowledge and Future Directions
Bargaz et al. 2018 – Soil Microbial Resources for Improving Fertilizers Efficiency in an Integrated Plant Nutrient Management System
Olanrewaju et al., 2019 - Plant health: feedback effect of root exudates-rhizobiome interactions

Soil Microbes are Key for Drought Management

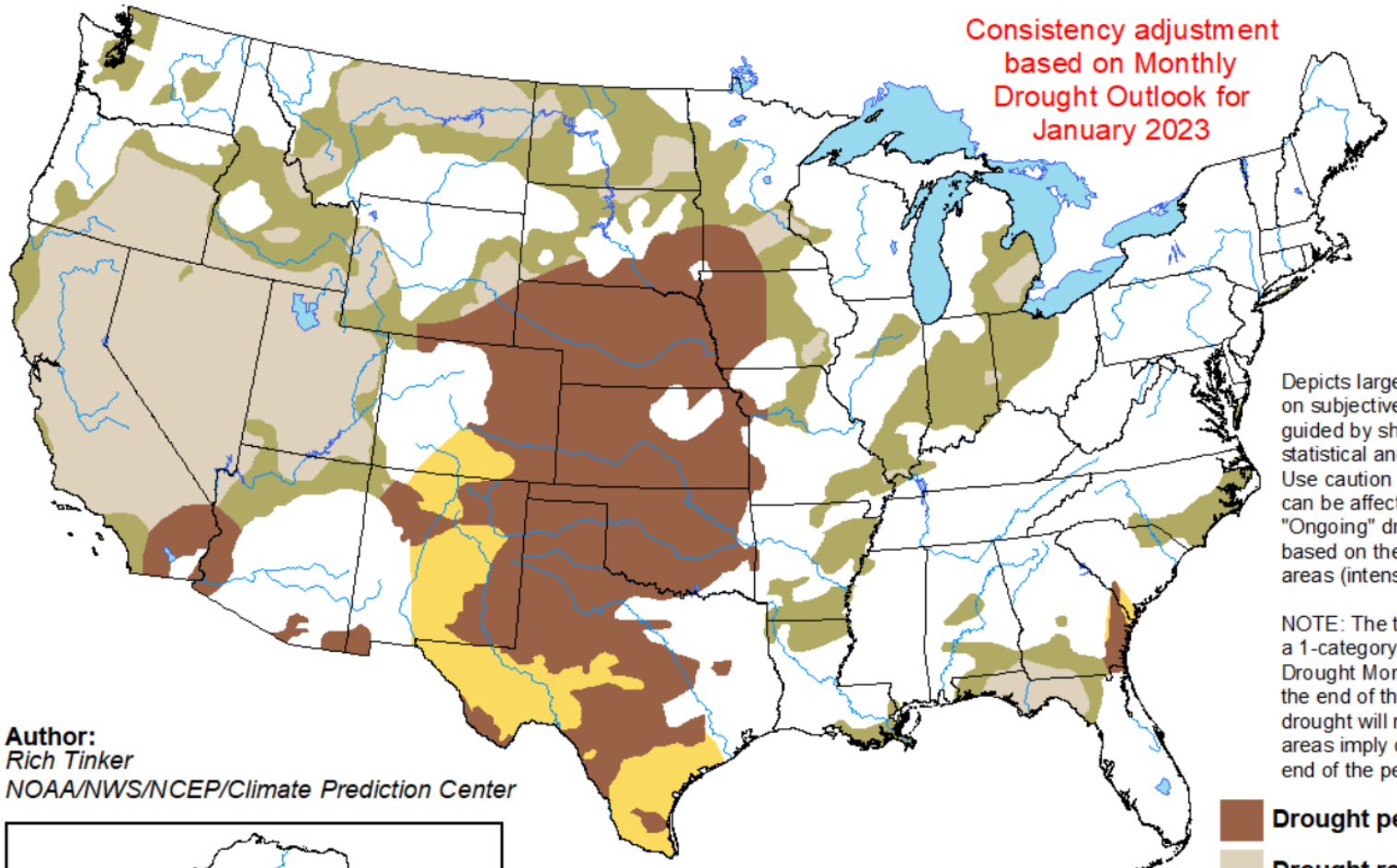
Soil Health & Drought Management



U.S. Seasonal Drought Outlook

Drought Tendency During the Valid Period

Valid for January 1 - March 31, 2023
Released December 31, 2022

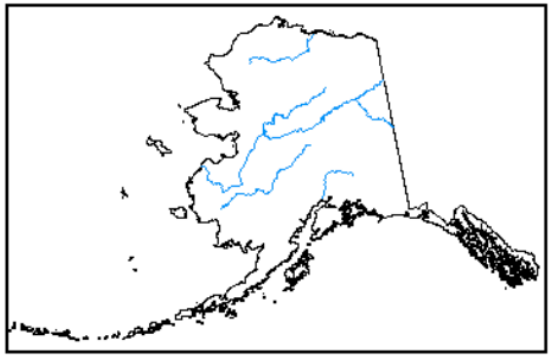


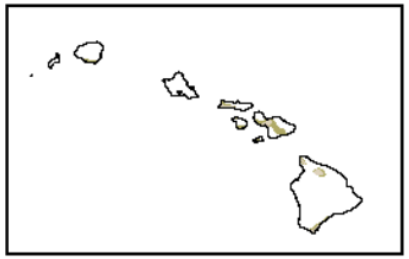
Depicts large-scale trends based on subjectively derived probabilities guided by short- and long-range statistical and dynamical forecasts. Use caution for applications that can be affected by short lived events. "Ongoing" drought areas are based on the U.S. Drought Monitor areas (intensities of D1 to D4).

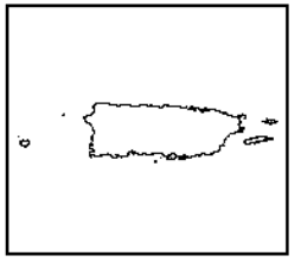
NOTE: The tan areas imply at least a 1-category improvement in the Drought Monitor intensity levels by the end of the period, although drought will remain. The green areas imply drought removal by the end of the period (D0 or none).

Drought persists
Drought remains but improves
Drought removal likely
Drought development likely

Author:
Rich Tinker
NOAA/NWS/NCEP/Climate Prediction Center







http://go.usa.gov/3eZ73

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Soil Health & Drought Management

Rule 1

Improved penetration and infiltration of moisture events recharges the root zone

Rule 2

Longer term storage of soil moisture occurs in pore spaces and water films around aggregates

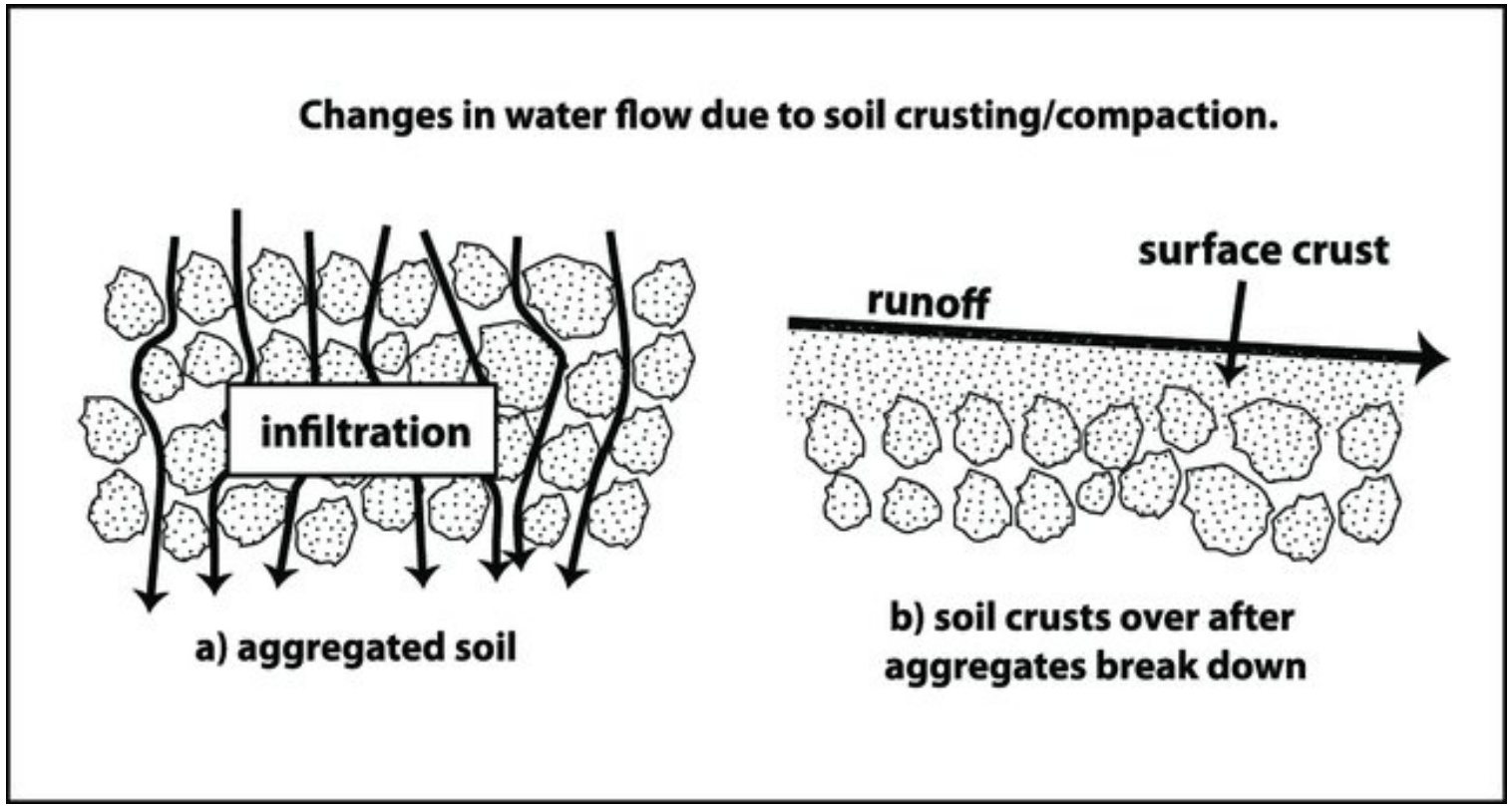
Rule 3

Microbes help mitigate abiotic stress

Rule 1 - Infiltration

Grower Standard

Phycoterra



Rule 2 - Storage

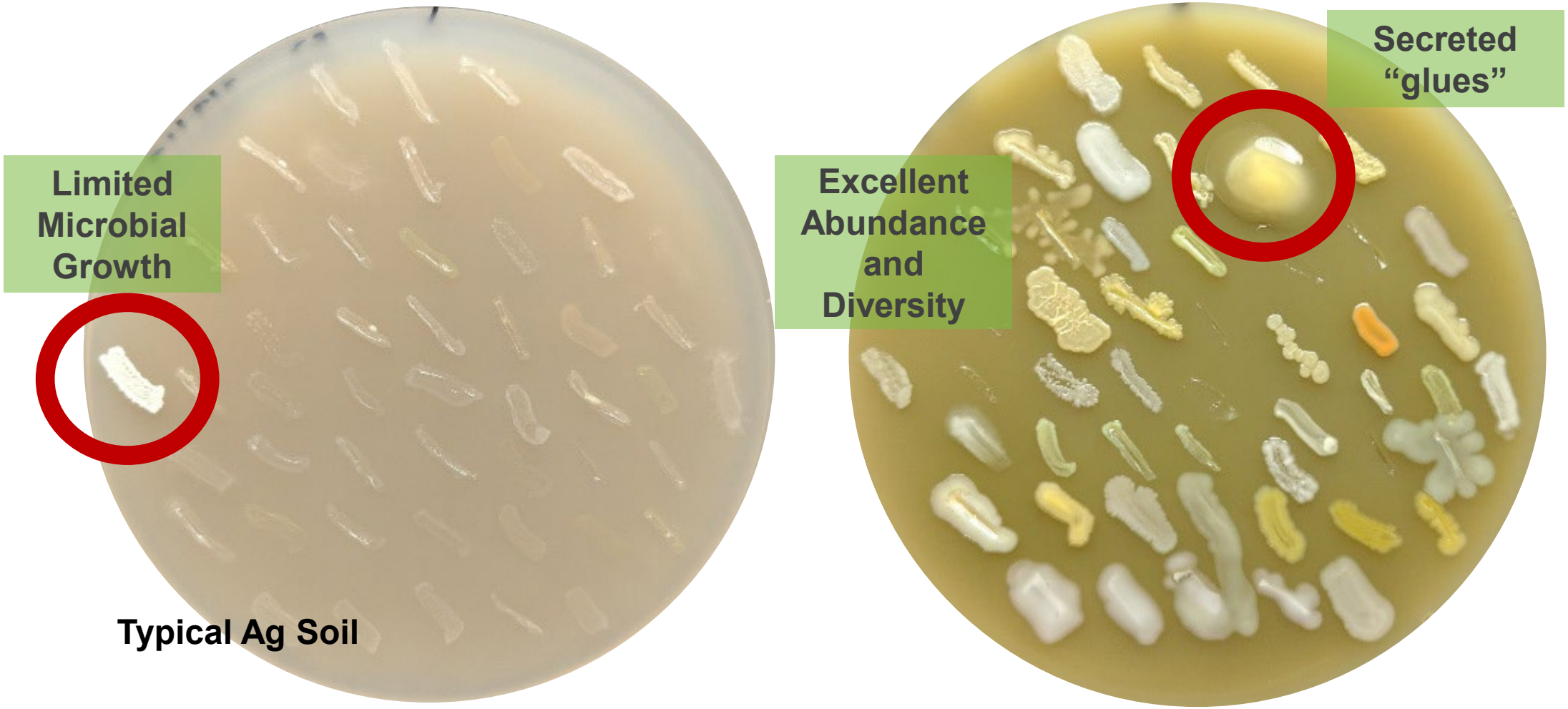
Grower Standard

Phycoterra

Soil pores between soil particles filled with water

Films of water around soil particles

PhycoTerra® Rule 3 – Microbes Mitigate Stress



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Crops Need Microbes for Drought Stress Mitigation

REVIEW

Harnessing rhizosphere microbiomes for drought-resilient crop production

Franciska T. de Vries[1,2]*, Rob I. Griffiths[3], Christopher G. Knight[1], Oceane Nicolitch[1], Alex Williams[1]

EPS for Soil Structure

Osmoprotection & Antioxidants

https://science.sciencemag.org/content/368/6488/270/tab-pdf

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Improvements in FUE

Corn	**6.8%**
Soybeans	**5.9%**
Wheat	**5.1%**
Canola	**4.5%**
Potatoes	**15.5%**

$$\frac{\text{Yield/ac}}{\text{lbs./ac of applied fertilizer}}$$

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What Healthy Soils Do

Store Water

Resist Erosion

Improve Profitability

Optimize Land Use

Improve Nutrient Use

PhycoTerra®

Does Soil Health Pay?

3rd Party CRO; treatments applied ~1 qt/A

Up to 10% increase in WHC

31% increase in soil aggregate diameter

ROI 5:1 Average Corn, Soybean, Wheat

Increased production

Corn: 15.3 bu/a
Soybean: 4.7 bu/a
Wheat: 5.3 bu/a

5.9% Avg. increase in NUE

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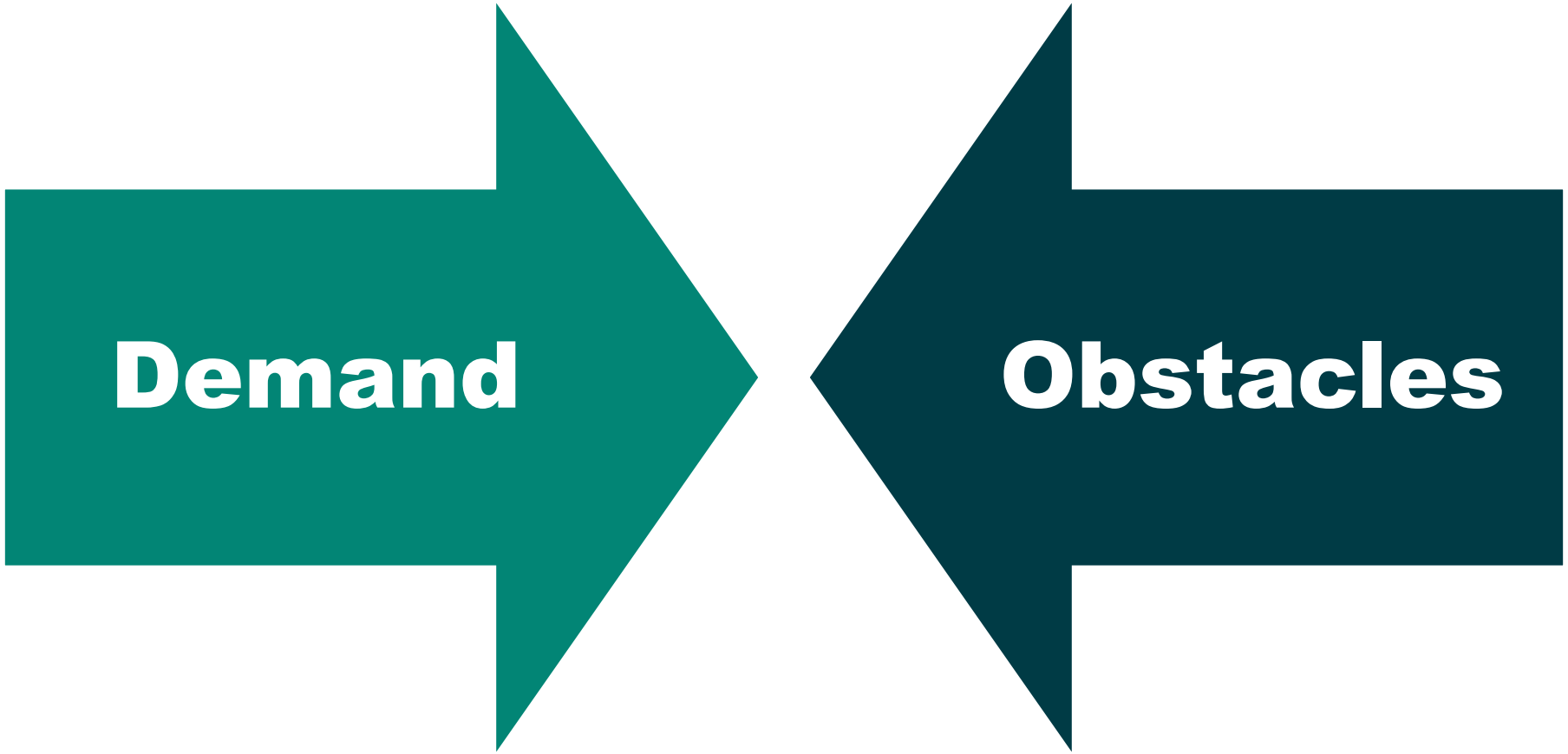
Ready for the Challenge?



Soil health is key!

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Regenerative Conundrum

THE IDEA

Decreasing tillage & increasing residue (cover crop and cash crop) are popular options for building soil health.

THE PROBLEM

Crop residue clogs equipment & delays spring warm up (cool/moist soil), ↑ pathogens, ↑ NPK immobilization.

THE NEED

In corn, ~ **95% residue cover remains** after harvest. Winter decomposition alone has been found to drop coverage to **roughly 86%.**

THE SOLUTION

Use products to decompose crop residue more quickly.

Source: Channel – Crop Residue Decomposition & Nitrogen Mobilization

Impacts of Residue

Impact crop residue has on soil:
- Wind and water erosion
- Maintaining soil productivity by recycling of plant nutrients
- Improving soil physical properties

Impact crop residue has on subsequent crop:
- Seed bed conditions: seed placement
- Disease potential
- Soil temperatures
- N availability

Too much residue at planting:
- Risk that soil conditions are too cool & moist
- Increase disease pressure
- N availability for the crop

Not enough crop residue:
- Soil erosion
- Decrease infiltration, loss of moisture
- Decrease soil quality

Myths & Facts: Residue Management

THE MYTHS

1. Tillage can accelerate residue breakdown by cutting crop residue into small pieces or by burying residue.

2. Nitrogen fertilizer application post-harvest can speed up residue breakdown process.

THE REALITY

1. Tillage has no direct effect on the residue breakdown.

2. Applying nitrogen fertilizer post-harvest does not effectively improve the rate of decomposition.

THE SOLUTION

1. Residue breakdown is controlled by biological processes influenced by environmental & soil conditions.

2. Crop residue decomposition is highly controlled by soil moisture & temperature.

3. PhycoTerra® can help leverage the microbial community for influencing residue decomposition by providing a superior microbial food source, when applied to the residue post-harvest.

Source: Iowa State University – Myths & Facts

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Microbes are necessary for effective residue management

Main Components of Crop Residue		Enzymes that degrade	
Hemicellulose	15-25 wt%	Endoxylanases, endomannanases, xylosidases, glucosidaes, and galactosideases	Bacteria/Fungi
Cellulose	40-50 wt%		
Pectin		Pectinase	Bacteria/Fungi
Lignin	20-30 wt%	Laccase and tyrosinase	Fungi/bacteria

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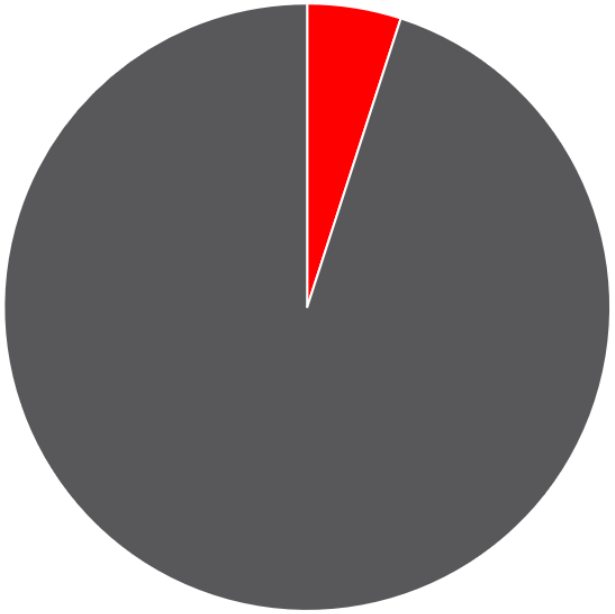
Reality of Decomposition

- C:N ratio, time, temperature, and moisture influence rates of decomposition
- Crop residue is highly complex (lignin, cellulose, hemicellulose & nutrients)
- Crop residue takes place under challenging conditions:
  - Dry/Wet & High UV
  - Short daily decomposition windows
  - **Food desert (system is limited by lack of labile carbon)**



- **Active: 5% of SOM**
  - Fuels microbes
  - NPK release
  - Strong Aggregation & Structure
  - WHC & Infiltration
  - Strong CEC & Chelation
- **Slow/Passive: 95% of SOM**
  - Soil color
  - Weak CEC & Chelation
  - Weak Aggregation & Structure
  - WHC & Infiltration

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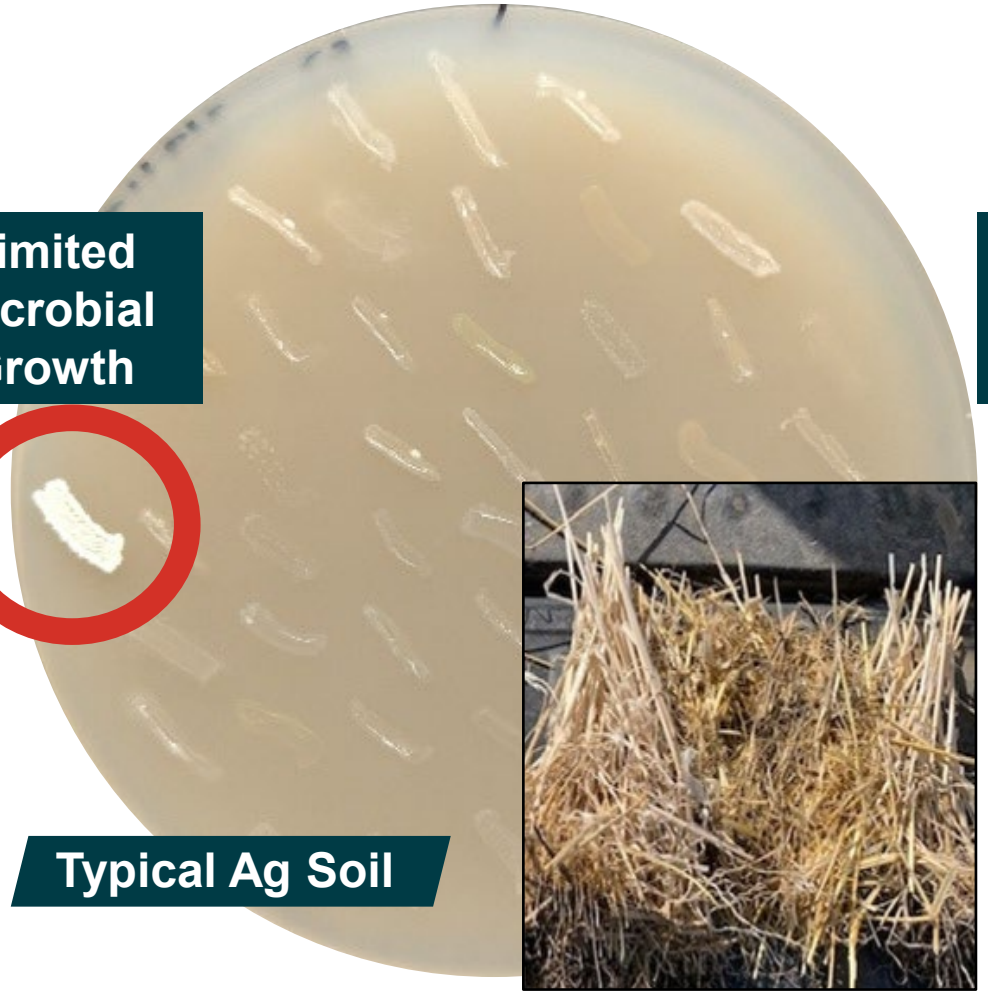
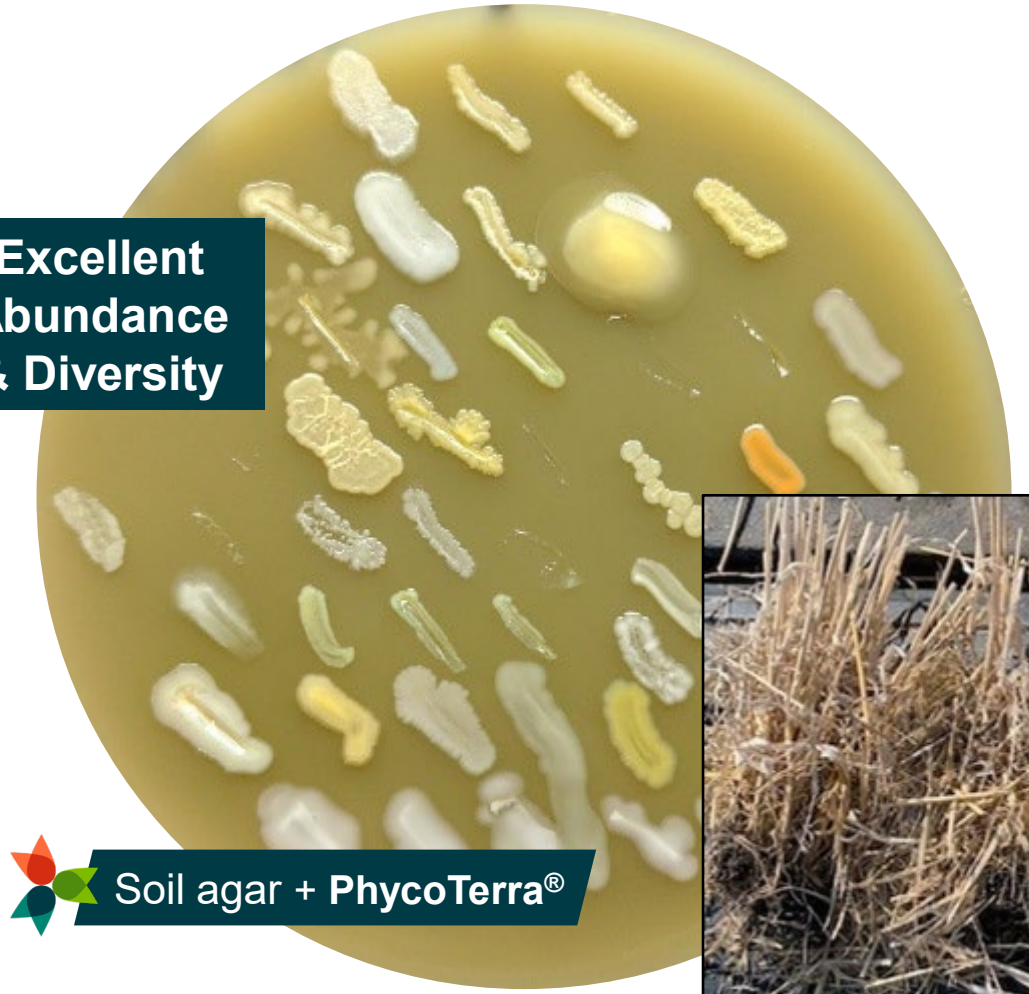
A Living Soil Promotes Decomposition

Limited Microbial Growth



Typical Ag Soil

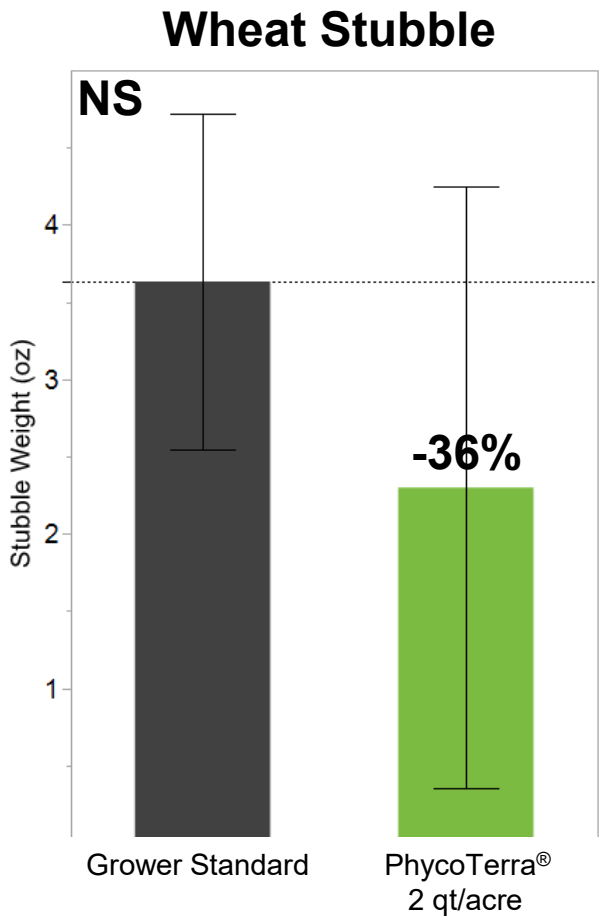
Excellent Abundance & Diversity



Soil agar + **PhycoTerra®**

Decomposed Plant Residue

*Location: **North Dakota***



PhycoTerra® was applied after harvest along with burndown chemical at 2 qt/acre in October 2020.

PhycoTerra® 2 qt/ac **Grower Standard**

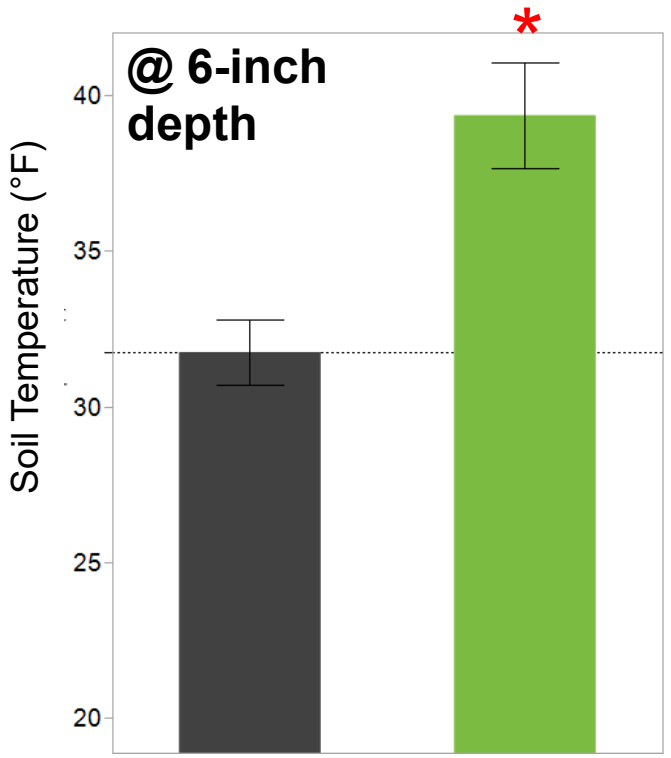
Minot, ND - Photos were taken 5 months after application.

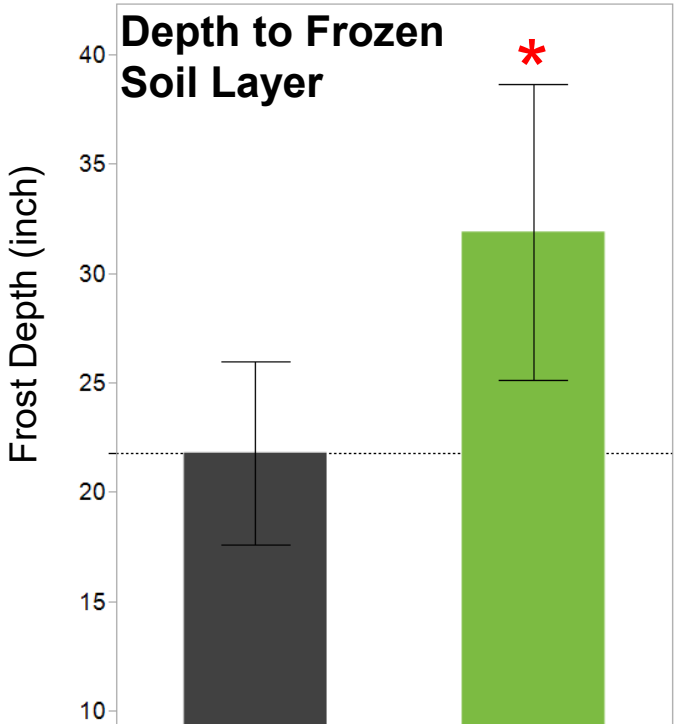
Asterisk shows significant difference after Dunnet's analysis p<0.1. Stubble weight with PhycoTerra® p=0.1552

Samples were dried at 275 °F for 30 minutes and weighed. Samples were wet during collection due to snow and in a 12"x10" area.

Increased Soil Temperature

October 2020 application – March 2021 Soil Temp measurements





Grower Standard
PhycoTerra® 2 qt/ac

PhycoTerra® was applied after harvest along with burndown chemical at 2 qt/acre in October 2020 near Minot, ND. Data from graph was obtained 5 months later.

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Incremental ROI of Residue Management

NPK RELEASE
$22-42/ac

WARMER SOIL AT PLANTING
$10/ac

TILLAGE SAVINGS
$17-22/ac

REDUCED TILLAGE CARBON CREDIT
$10/ac

PhycoTerra®

Proper Residue Management and Soil Health

Increase soil structure, texture, moisture

Increase population of soil organisms

Protection from Erosion

Improves water infiltration and reduces runoff

Makes nutrients more available

Improve soil productivity and crop production by maintaining SOM

Aid in cover crop establishment or fall crop

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Soil Health, Microbial Activity & Regenerative Agriculture

- Microbes **drive a key component of a healthy soil system** – *the feedback between the plant and the soil microbial system*.
- Feeding the native soil microbiome, which leads to *regenerated* soil functions such as increased water holding capacity and plant nutrient availability.
- Aboveground, we also show consistent positive crop yield response with the the increase of microbial communities and increased soil health.

PhycoTerra®

Dr. Cassidy Million
Director of Ag Science
Heliae® Agriculture
cmillion@heliae.com

PhycoTerra.com