09.11.2024

SOIL METAGENOMIC INSIGHTS – AN EMERGING FRONTIER IN SUSTAINABLE AGRICULTURE

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TRACE GENOMICS™

AGRO-ECOSYSTEMS: PRE-INDUSTRIAL TO CURRENT TIMES

Pre-industrial
(1700 to 1800)

Subsistence farming, crop rotations, small farms, labor intensive and low productivity

Soil tests – Visual observation, soil color, earthworms, yield

Industrial revolution
(1800 to mid 1900)

Mechanized farming, mono cropping, selective breeding, environmental degradation, rural displacement

Soil tests – OM, pH, basic soil texture

Green & biotech revolution
(1940s to 2000s)

High yielding varieties, reduced hunger globally, water scarcity, soil degradation, loss of biodiversity

Soil tests – OM, pH, basic soil texture, nutrients, salinity, moisture
Formal integration of weather data, yield maps, FMIS in 1980s

Regenerative and Climate Smart revolution (Current)

Precision farming, resource management, climate change, soil health and sustainability

Soil tests – In addition, water holding capacity, basic biology test, carbon, satellite imagery data analytics

Climate change,
water scarcity,
degrading soils
pests & diseases

The key data points for decision making has remained yield, soil physical and chemical properties over time

Holistic Soil Environment

Key Missing Element to Sustainable Change

TRACE GENOMICS™

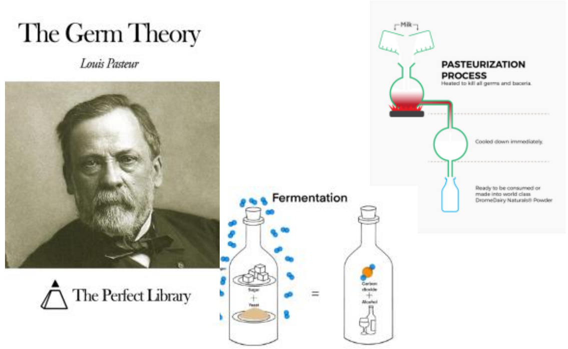
A Holistic View of the Soil Environment

Soil physical, chemical and biological features

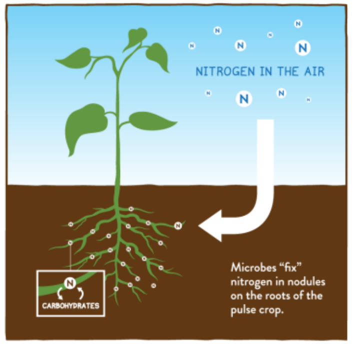
- PRODUCTIVITY
- TARGETED APPLICATION
- MICROBIAL DIVERSTY
- IMPROVED WATER QUALITY
- NUTRIENT CYCLING
- MICROBIAL DECOMPOSITION
- CARBON SEQUESTRATION
- REGENERATIVE PRACTICES

MILESTONES IN BENEFICIAL MICROBE STUDIES IN AGRICULTURE

1860s–1880s

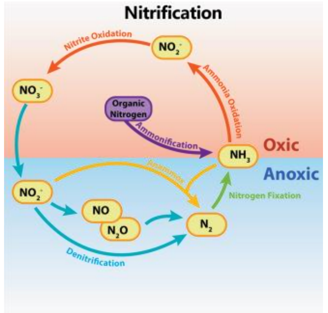


1880s



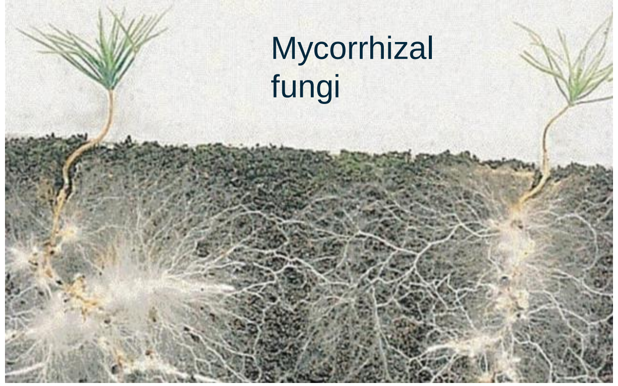
Late 1880s–1930s

Chemolithotrophy

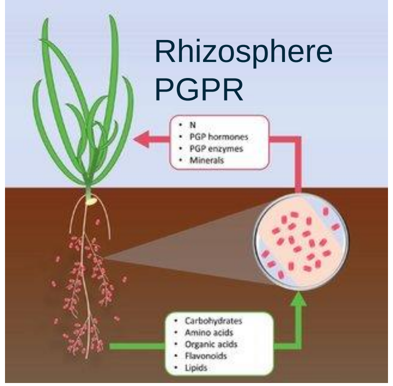


1950s–1970s

1960s–1990s

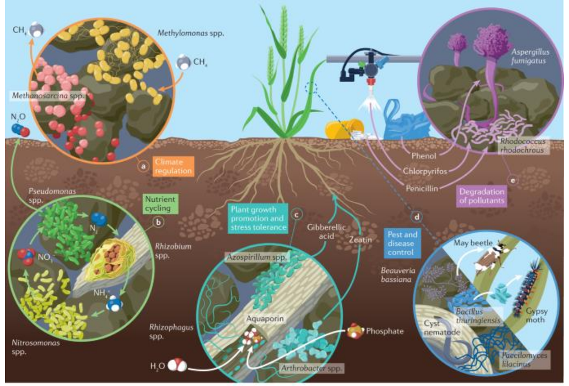


1970s–1980s



1980s–present

2000s–present



EVOLUTIONARY MILESTONES IN PLANT PATHOLOGY

1660s to 1830s Late 17th century to early 19th century

- Birth of Plant Pathology; Discovery of microorganisms; Plant pathogen interactions – rust fungi and potato blights

1820s to 1860s

- Discovery of fungal causing pathogens; *Phytopthora infestens* – potato blight

1860s to 1880s

- Germ theory

1880s to 1900s

- Chemical treatments; Sulphur and copper-based chemicals

1900s onwards

- Breeding for plant disease resistance

1890s to 1940s

- Viral discovery; Plant virology

1900s onwards

- Soil borne pathogens – Ex. *Fusarium*, *Verticillium* etc.; Nematodes

1970s to present

- IPM; Biological control

1980s to present

- Molecular plant pathology – molecular diagnostics, gene-for gene resistance, QTLs etc.; GM crops

2010s to present

- CRISPR and gene editing; Microbiome and disease suppression

MODERN DAY AGRICULTURAL CHALLENGES

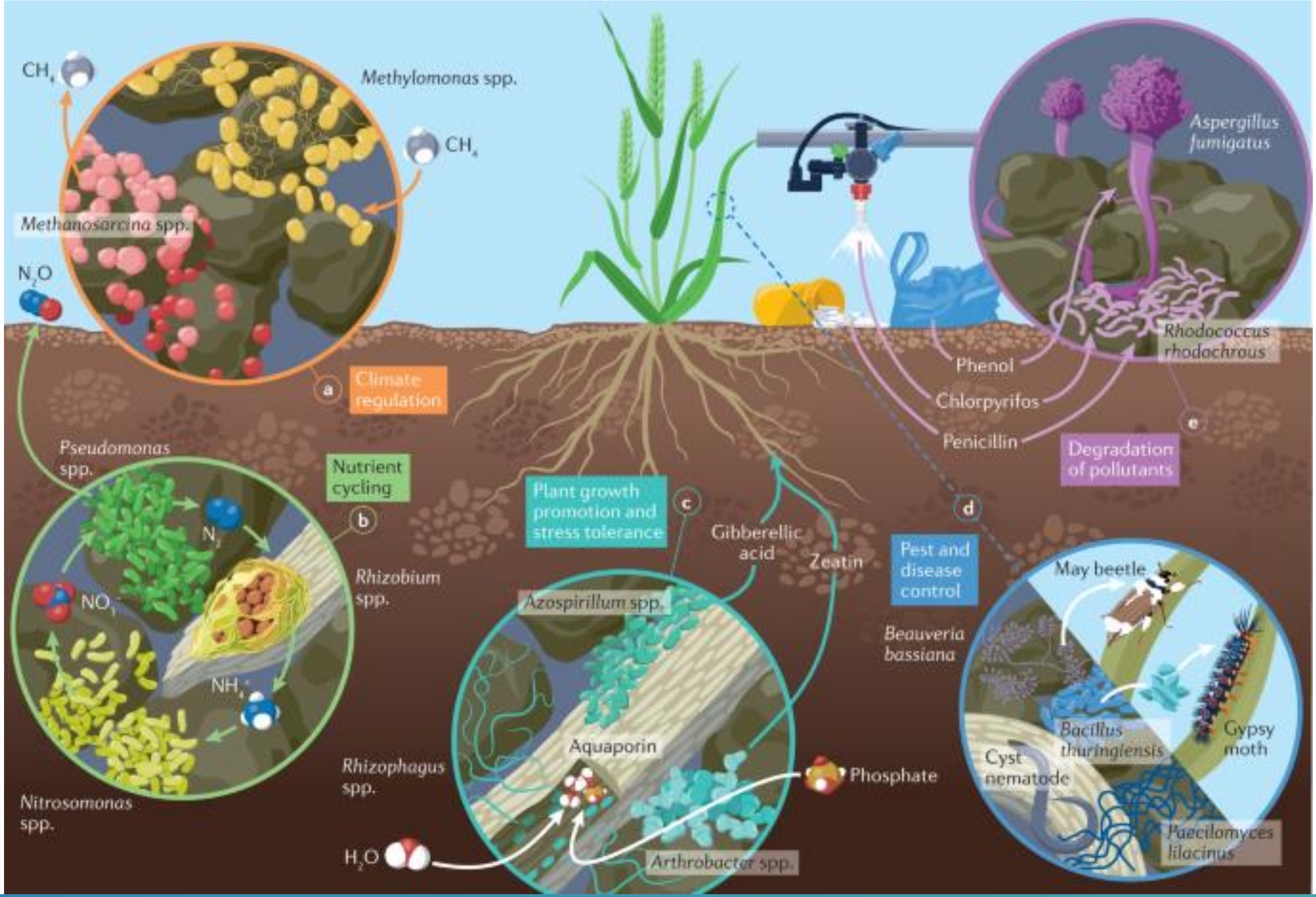
Excessive fertilizer uses – nutrient runoffs and eutrophication causing dead zones; nitrate contaminations in ground causing blue baby syndrome

Pesticides and herbicides – Environmental contamination, bioaccumulation, pesticide drift, resistance

Soil degradation – loss of microbial diversity, soil erosion, antimicrobial resistance

Climate change – Greenhouse gas emissions

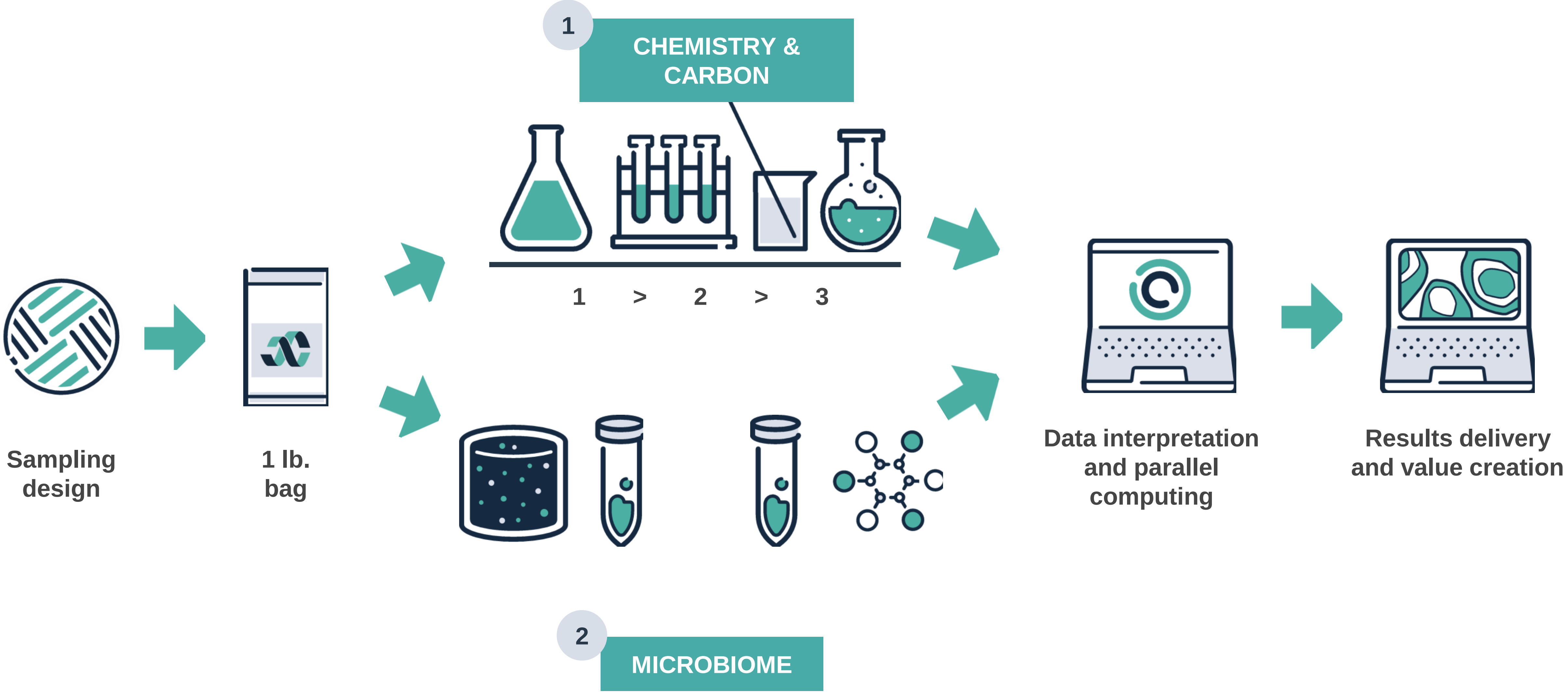
SOIL MICROBIOME IS AN IMPORTANT FACTOR IN SUSTAINABLE AGRICULTURE



https://www.nature.com/articles/s43017-022-00366-w

TRACE GENOMICS – COMPREHENSIVE SOIL DATA PLATFORM

TRACE GENOMICS – DIGITIZE AND DECODE SOIL DNA



1 CHEMISTRY & CARBON

1 > 2 > 3

Sampling design

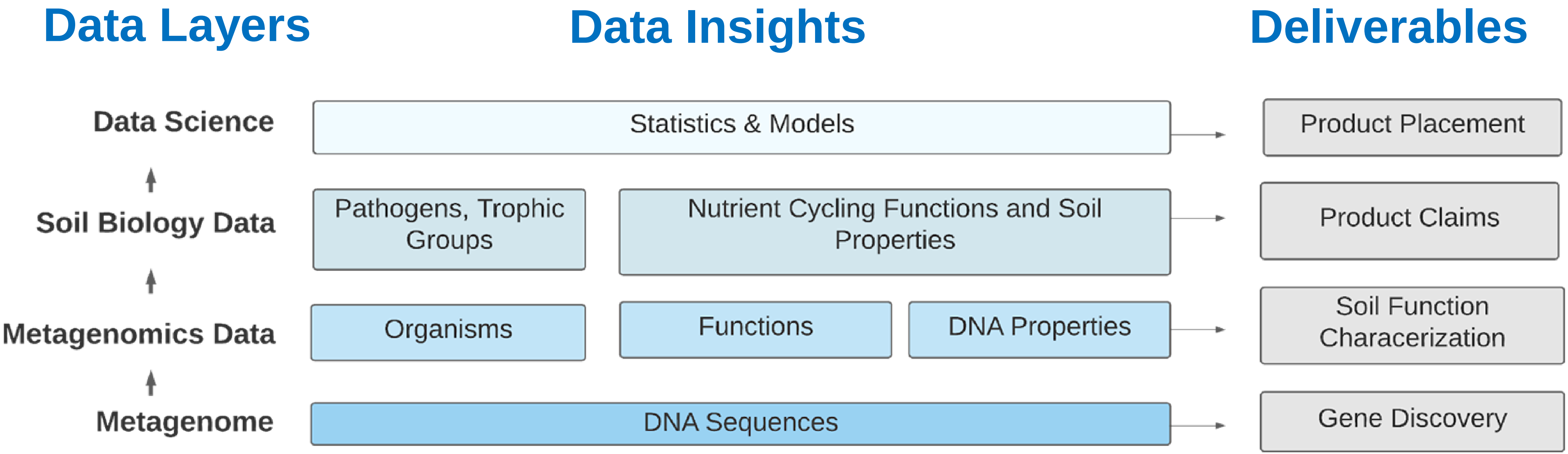
1 lb. bag

Data interpretation and parallel computing

Results delivery and value creation

2 MICROBIOME

TRACE GENOMICS – SOIL INTELLIGENCE PLATFORM



Data Layers

Data Insights

Deliverables

Data Science

Statistics & Models → Product Placement

Soil Biology Data

Pathogens, Trophic Groups

Nutrient Cycling Functions and Soil Properties → Product Claims

Metagenomics Data

Organisms

Functions

DNA Properties → Soil Function Characterization

Metagenome

DNA Sequences → Gene Discovery

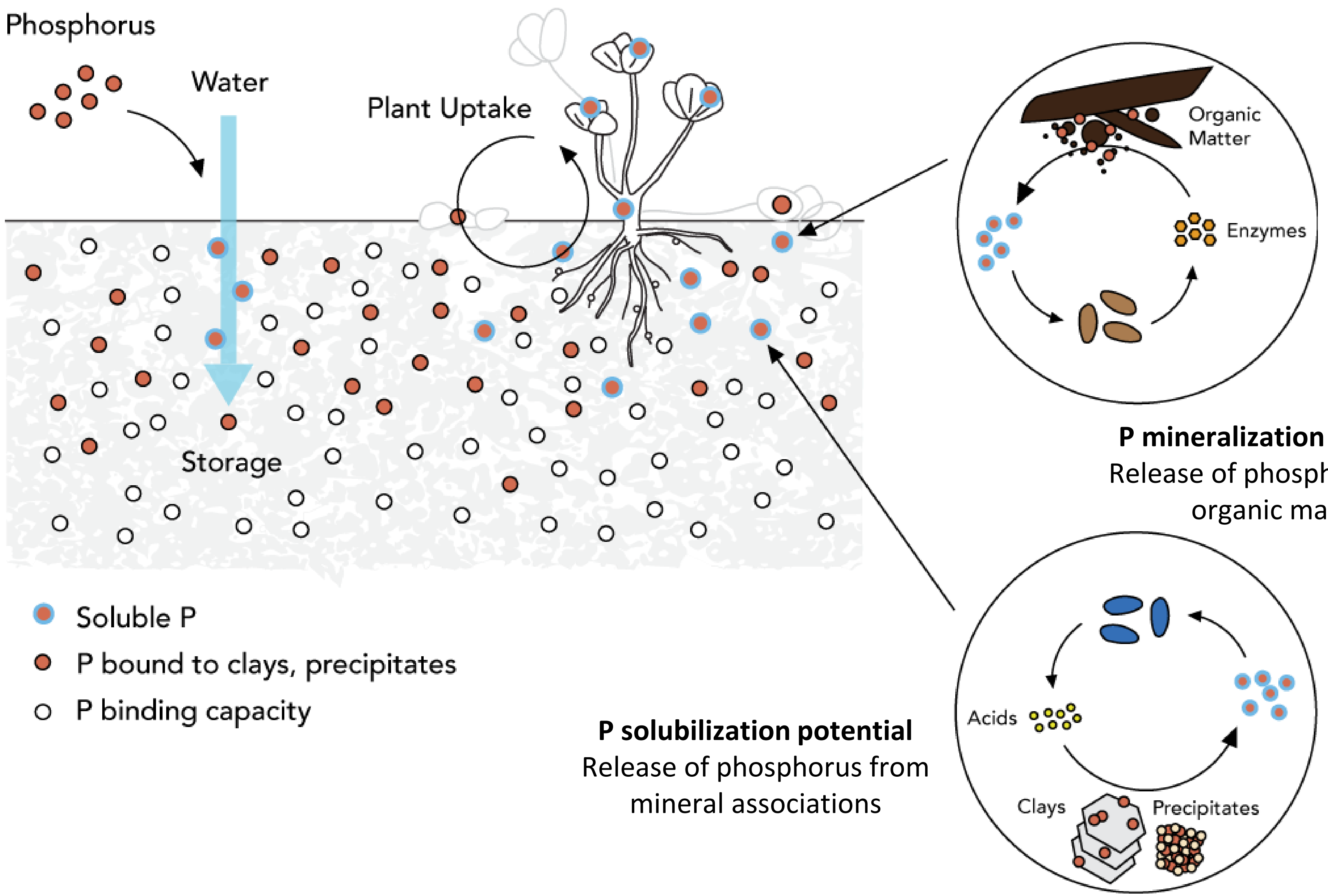
METAGENOMICS TECHNOLOGY

LESS THAN 1% OF THE MICROBES IN SOIL ARE IDENTIFIED.

METAGENOMIC SEQUENCING BRINGS TO LIGHT THE FUNCTIONS OF THE DARK DNA

METAGENOME INSIGHTS FOR ENHANCED NUTRIENT USE EFFICIENCY

TracePHOS – Systems based approach for P management



P mineralization potential
Release of phosphorus from organic matter

P solubilization potential
Release of phosphorus from mineral associations

P Storage Capacity

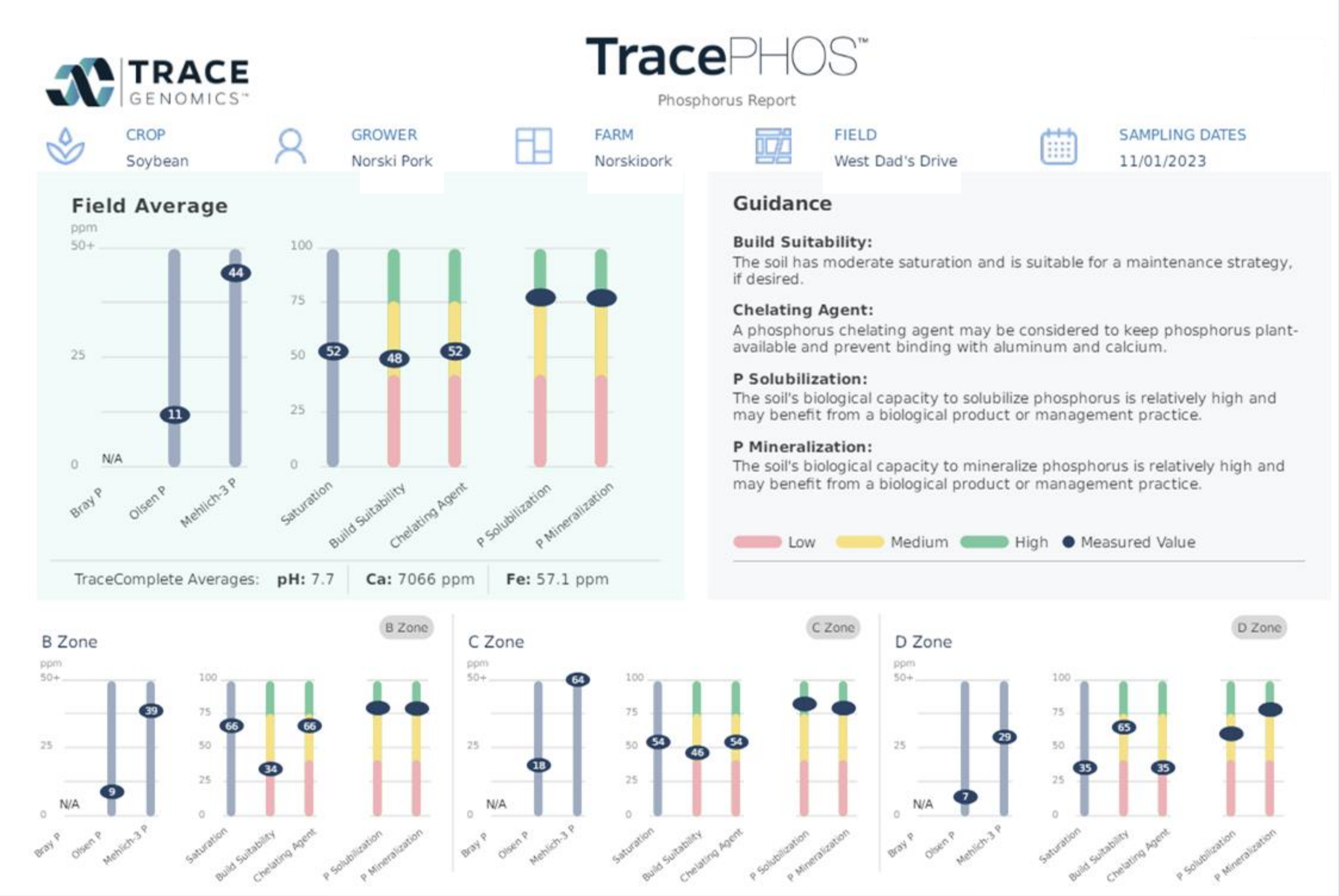
Every soil is different in its capacity to fix P, depending on the amount of Calcium and Aluminium in the soil.

We measure the degree to which soil phosphorus absorption sites are filled.

Soil Biology

Soil microbes can alleviate P limitation by making fixed P available and by releasing P from organic matter.

We quantify the organisms in the soil that have the potential to liberate P and make it plant available.



TRACE GENOMICS™

TracePHOS™

Phosphorus Report

CROP Soybean

GROWER Norski Pork

FARM Norskipork

FIELD West Dad's Drive

SAMPLING DATES 11/01/2023

Field Average

TraceComplete Averages: **pH:** 7.7 | **Ca:** 7066 ppm | **Fe:** 57.1 ppm

Guidance

Build Suitability:
The soil has moderate saturation and is suitable for a maintenance strategy, if desired.

Chelating Agent:
A phosphorus chelating agent may be considered to keep phosphorus plant-available and prevent binding with aluminum and calcium.

P Solubilization:
The soil's biological capacity to solubilize phosphorus is relatively high and may benefit from a biological product or management practice.

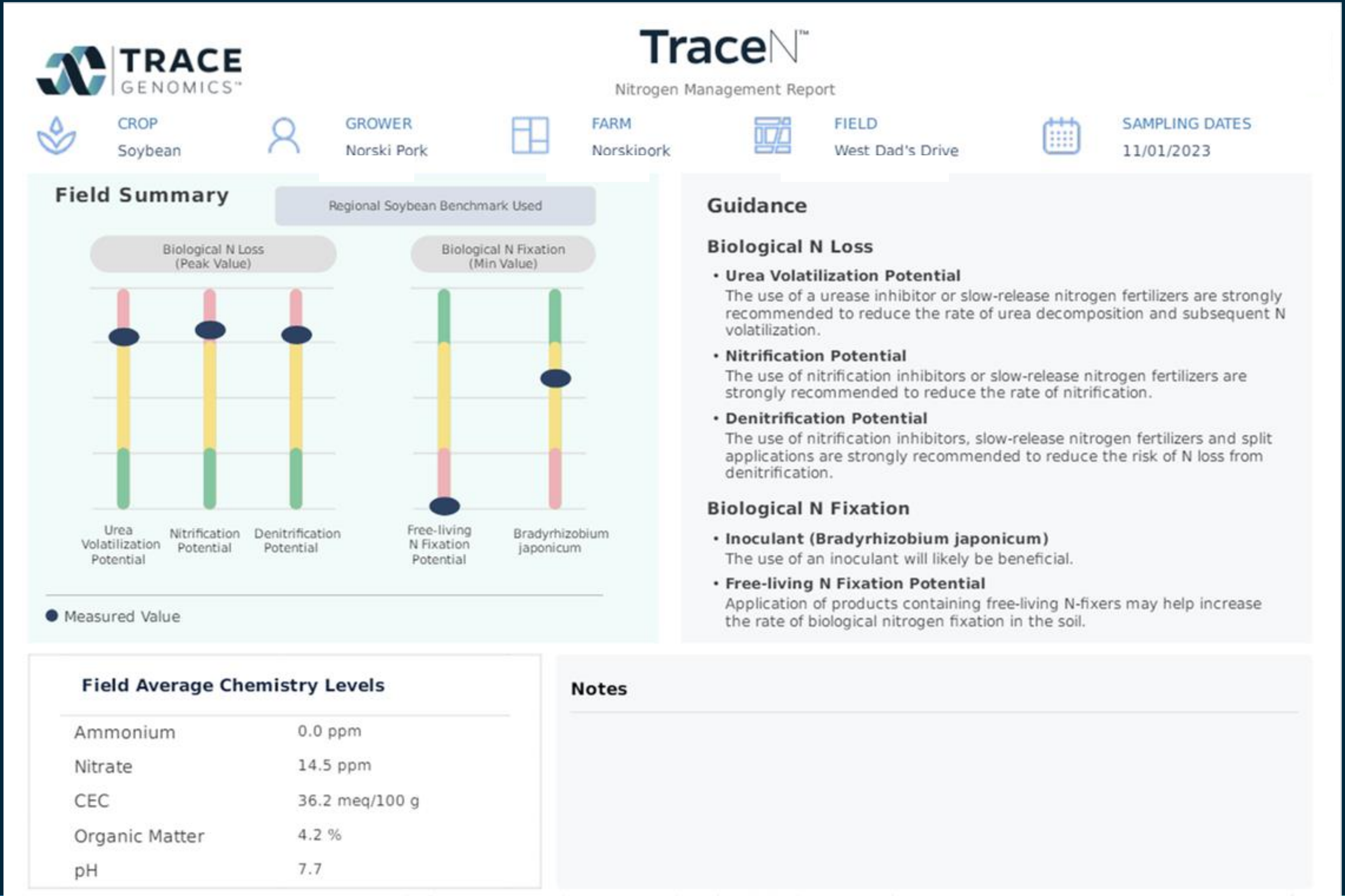
P Mineralization:
The soil's biological capacity to mineralize phosphorus is relatively high and may benefit from a biological product or management practice.

🟥 Low 🟨 Medium 🟩 High ● Measured Value

B Zone

C Zone

D Zone



TRACE GENOMICS

TraceN™

Nitrogen Management Report

CROP	GROWER	FARM	FIELD	SAMPLING DATES
Soybean	Norski Pork	Norskipork	West Dad's Drive	11/01/2023

Field Summary

Regional Soybean Benchmark Used

Biological N Loss (Peak Value)

Biological N Fixation (Min Value)

Guidance

Biological N Loss

- **Urea Volatilization Potential**
  The use of a urease inhibitor or slow-release nitrogen fertilizers are strongly recommended to reduce the rate of urea decomposition and subsequent N volatilization.
- **Nitrification Potential**
  The use of nitrification inhibitors or slow-release nitrogen fertilizers are strongly recommended to reduce the rate of nitrification.
- **Denitrification Potential**
  The use of nitrification inhibitors, slow-release nitrogen fertilizers and split applications are strongly recommended to reduce the risk of N loss from denitrification.

Biological N Fixation

- **Inoculant (Bradyrhizobium japonicum)**
  The use of an inoculant will likely be beneficial.
- **Free-living N Fixation Potential**
  Application of products containing free-living N-fixers may help increase the rate of biological nitrogen fixation in the soil.

Field Average Chemistry Levels

Ammonium	0.0 ppm
Nitrate	14.5 ppm
CEC	36.2 meq/100 g
Organic Matter	4.2 %
pH	7.7

Notes

METAGENOME FOR PLANT PATHOLOGY INSIGHTS

ENHANCED PATHOGEN REPORTING TAKES THE GUESSWORK OUT

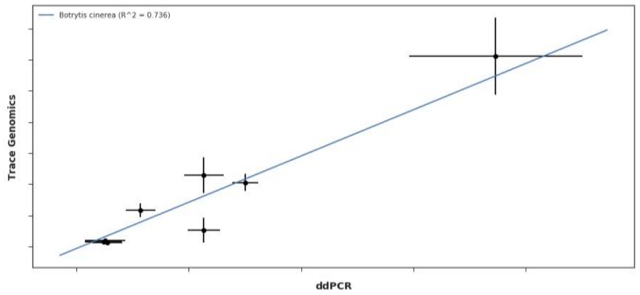
Soybean Charcoal Rot

Trace identified the first occurrence of charcoal rot by *Macrophomina phaseolina* Confirmed by NDSU plant pathology department

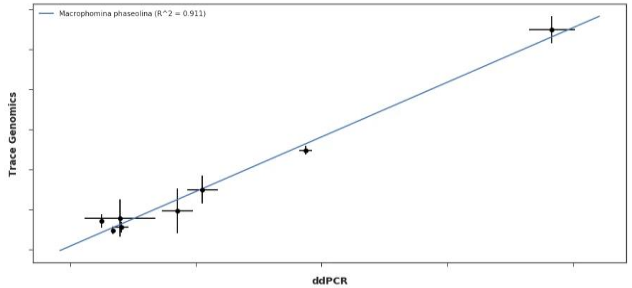
Soybean Stem Canker

Diaporthe phaseolorum was misdiagnosed at a customer location by agronomists. Trace identified the correct pathogen. Confirmed by University of Nebraska-Lincoln

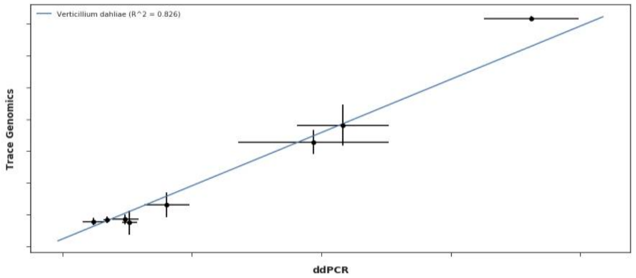
Validations – Trace vs ddPCR



Botrytis cinerea

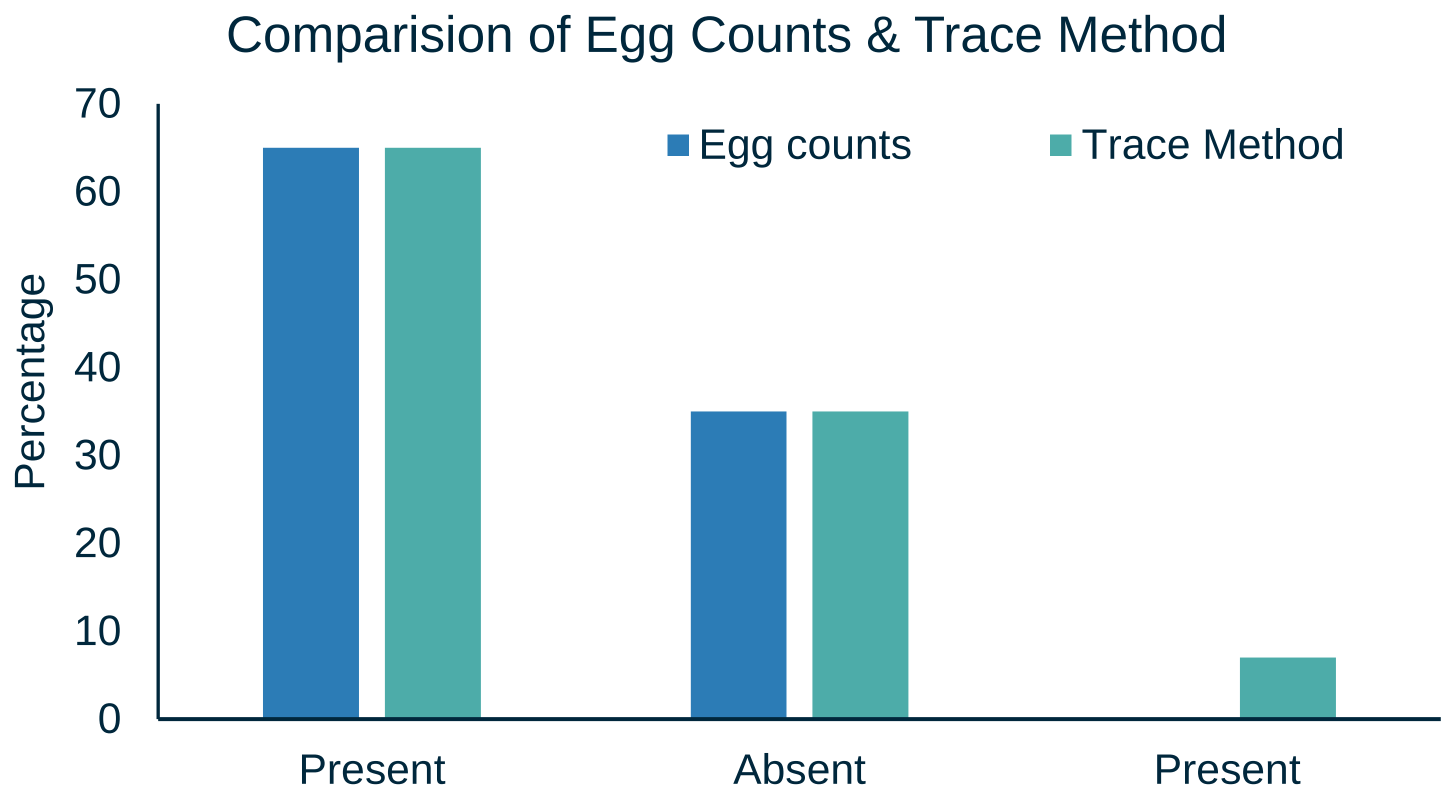


Macrophomina phaseolina



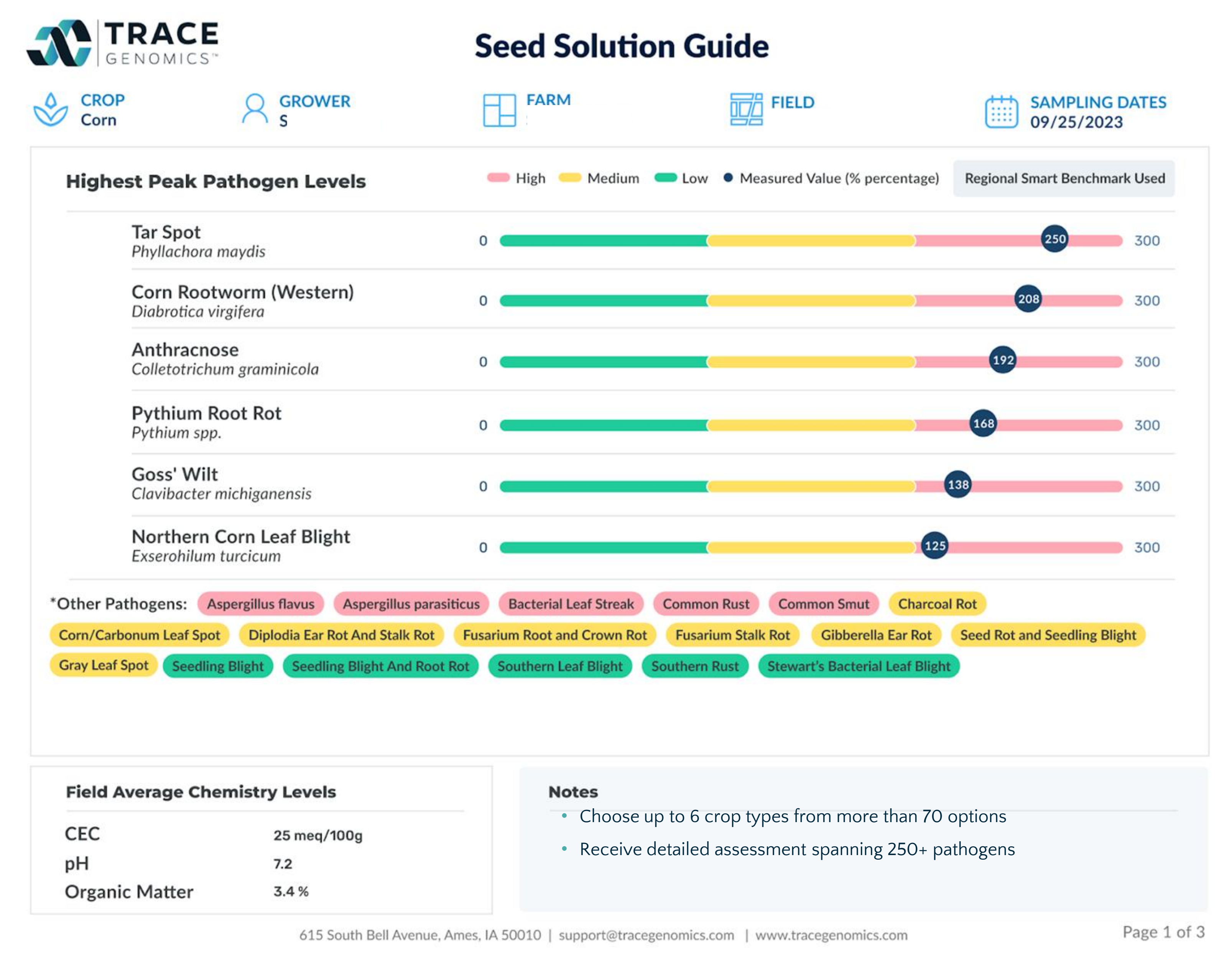
Verticillium dahliae

NEMATODE DETECTIONS WITH METAGENOMICS



Egg counts were done at Iowa State University

Trace method is sensitive to detect signatures of SCN presence in soils when egg counts are low or undetectable



Seed Solution Guide

CROP
Corn

GROWER
S

FARM

FIELD

SAMPLING DATES
09/25/2023

Highest Peak Pathogen Levels

🟥 High 🟨 Medium 🟩 Low ● Measured Value (% percentage)

Regional Smart Benchmark Used

Tar Spot *Phyllachora maydis*	0	250	300
Corn Rootworm (Western) *Diabrotica virgifera*	0	208	300
Anthracnose *Colletotrichum graminicola*	0	192	300
Pythium Root Rot *Pythium spp.*	0	168	300
Goss' Wilt *Clavibacter michiganensis*	0	138	300
Northern Corn Leaf Blight *Exserohilum turcicum*	0	125	300

*Other Pathogens: Aspergillus flavus, Aspergillus parasiticus, Bacterial Leaf Streak, Common Rust, Common Smut, Charcoal Rot, Corn/Carbonum Leaf Spot, Diplodia Ear Rot And Stalk Rot, Fusarium Root and Crown Rot, Fusarium Stalk Rot, Gibberella Ear Rot, Seed Rot and Seedling Blight, Gray Leaf Spot, Seedling Blight, Seedling Blight And Root Rot, Southern Leaf Blight, Southern Rust, Stewart's Bacterial Leaf Blight

Field Average Chemistry Levels

CEC	25 meq/100g
pH	7.2
Organic Matter	3.4 %

Notes

- Choose up to 6 crop types from more than 70 options
- Receive detailed assessment spanning 250+ pathogens

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PATHOGEN MANAGEMENT—TRACE INSIGHTS VALUE STORIES

Illinois Retail Agronomist: Recommended grower switch to anthracnose-resistant corn hybrid.

YIELD INCREASED **32** BUSHELS/ACRE ($156.80/ACRE REVENUE)

Minnesota Grower & Regional Agronomy Manager: Switched seed variety based on presence of SCN.

YIELD INCREASED **10** BUSHELS/ACRE ($130/ACRE REVENUE)

SOIL MICROBIOME IS VARIABLE – MYTH OR REALITY??

FUNCTIONAL MICROBIOME IS NOT AS DIVERSE AS TAXONOMIC MICROBIOME

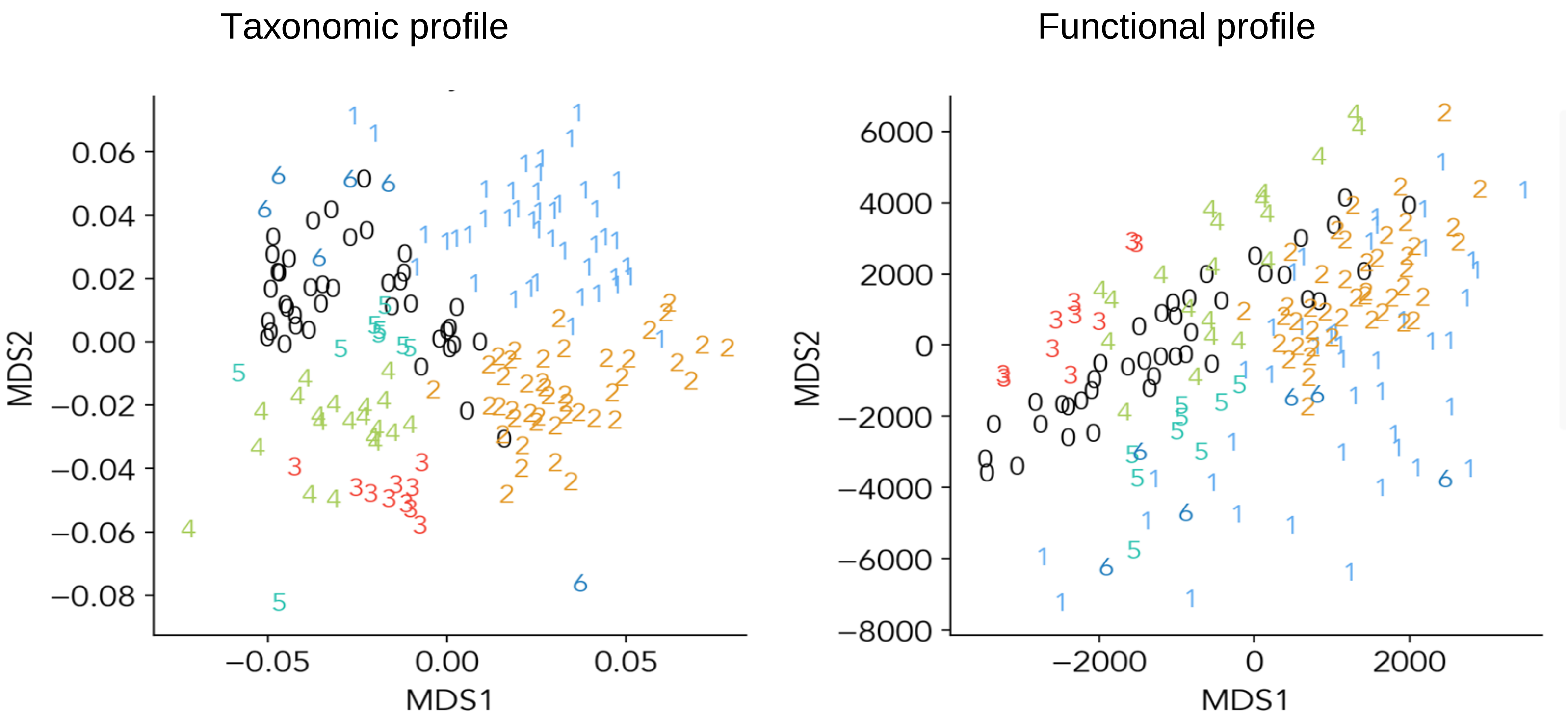
Trace conducted a study of soils in the corn belt across 7 different states

The soil biology was analyzed both taxonomically as well as with functional genes

The diversity of the soils was higher with taxonomic markers

The diversity collapsed using in the functional gene profiles

Agronomically the soil functions play a critical role in plant growth, nutrient use efficiency, and yield potential



0 – Indiana; 1 – South Dakota, 3 – Iowa, 4 – Ohio, 5 – Tennessee, 6 – Iowa, 7 - Nebraska

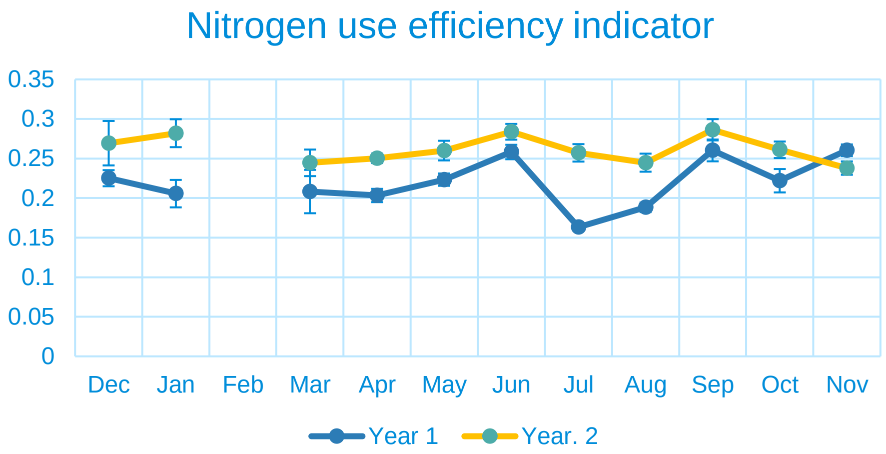
SEASONAL VARIATION ABIOTIC STRESS IMPACTS ON THE FUNCTIONAL BIOME

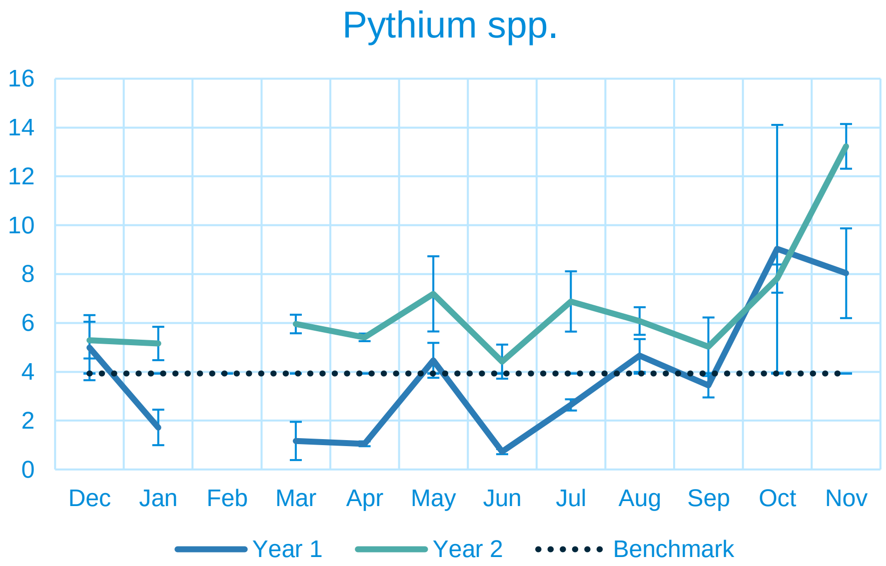
Study question – What is the best time to sample soils for biology? Does this vary by regions, by cropping systems etc.?

A 24-month study was designed in three states across the US in consultation with professors, agronomists and growers.

Soils were profiled every 4 weeks in these three regions and analyzed on Trace platform

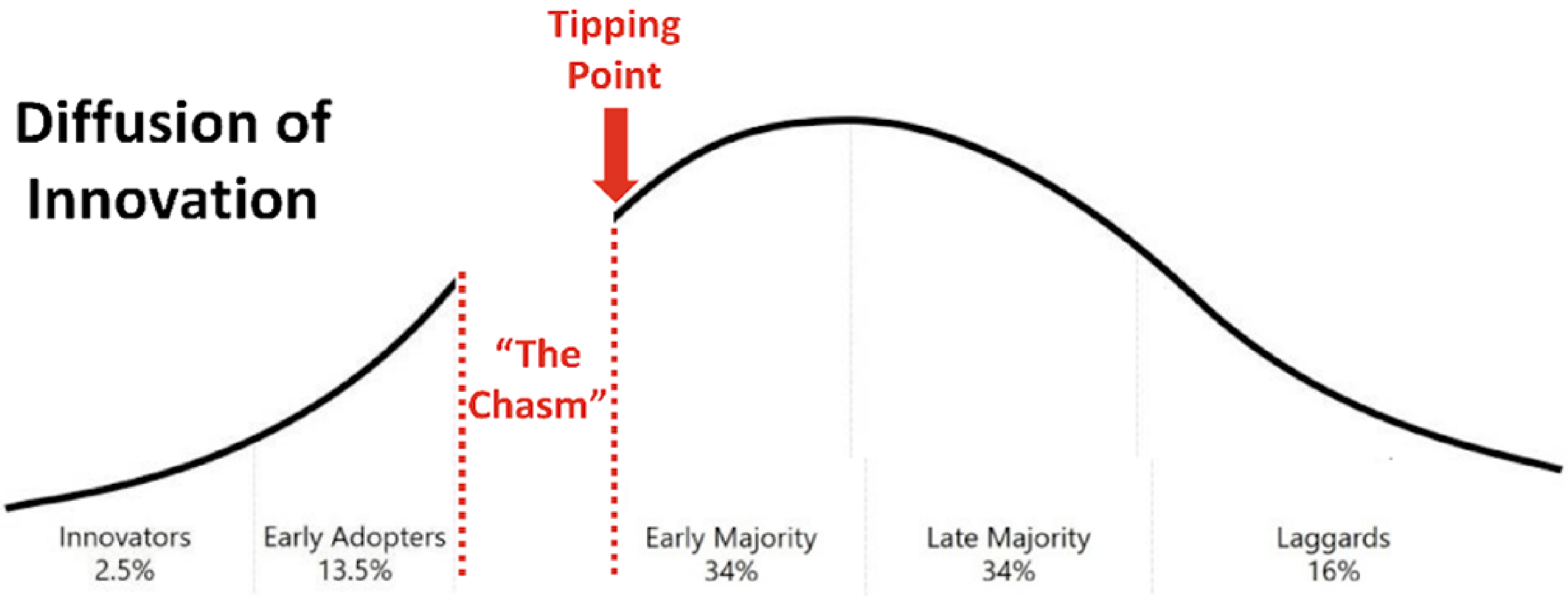
The findings of this study revealed that both management and environmental factors that impact biological functions



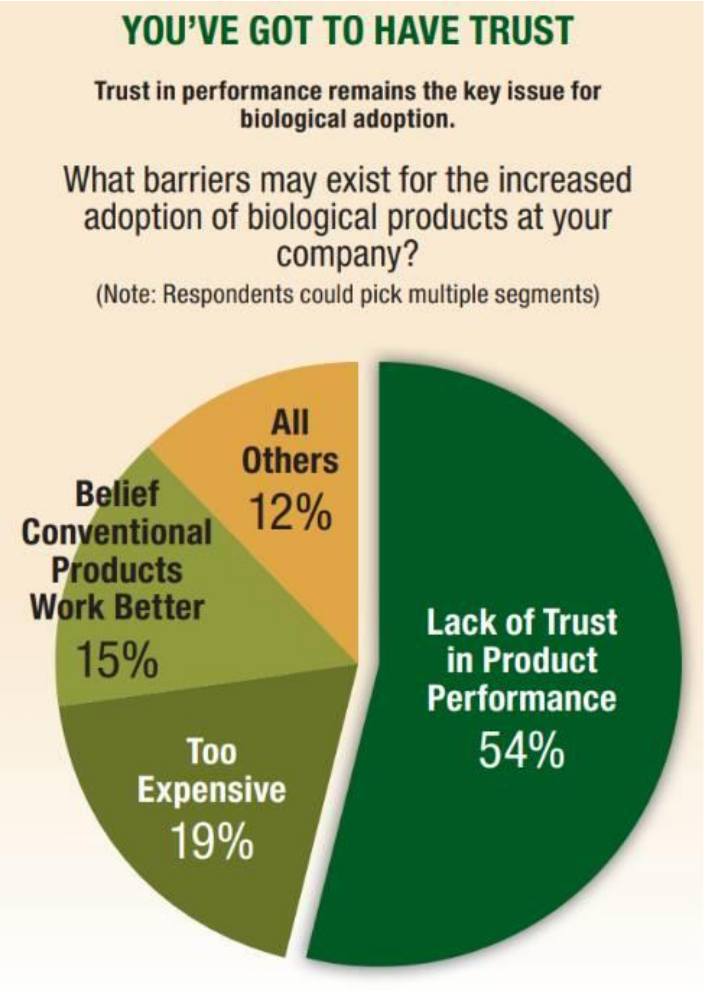


CAN METAGENOME DATA ENHANCE THE WINRATE OF BIOLOGICAL PRODUCTS?

ADOPTION BARRIERS – TRUST



SOURCE: Adapted from Diffusion of Innovation (Roger, 1962), Crossing the Chasm (Moore, 2002) and The Tipping Point (Gladwell, 2000)



YOU'VE GOT TO HAVE TRUST

Trust in performance remains the key issue for biological adoption.

What barriers may exist for the increased adoption of biological products at your company?

(Note: Respondents could pick multiple segments)

Base = 112 | Source: 2023 Biologicals Survey

Biologicals have been in market since 1980s, but adoption challenges still exist

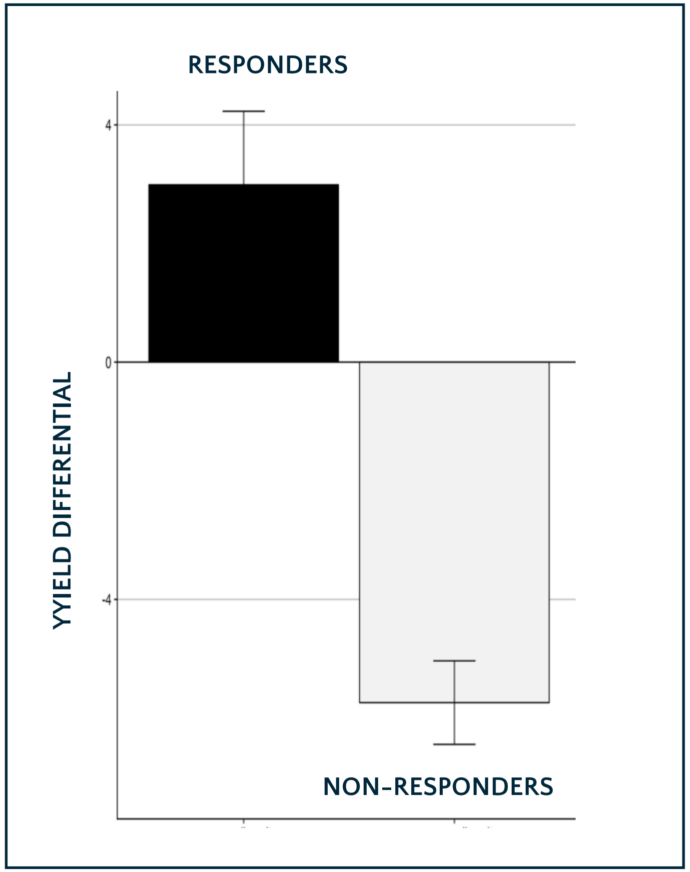
TRACEEDGE: BIOSTIMULANT PLACEMENT FOR ENHANCED WIN RATE

Field trials – A yield trial was conducted in corn fields across 6 states for a biostimulant product applied in-furrow

Product function – Enhanced phosphorus use efficiency

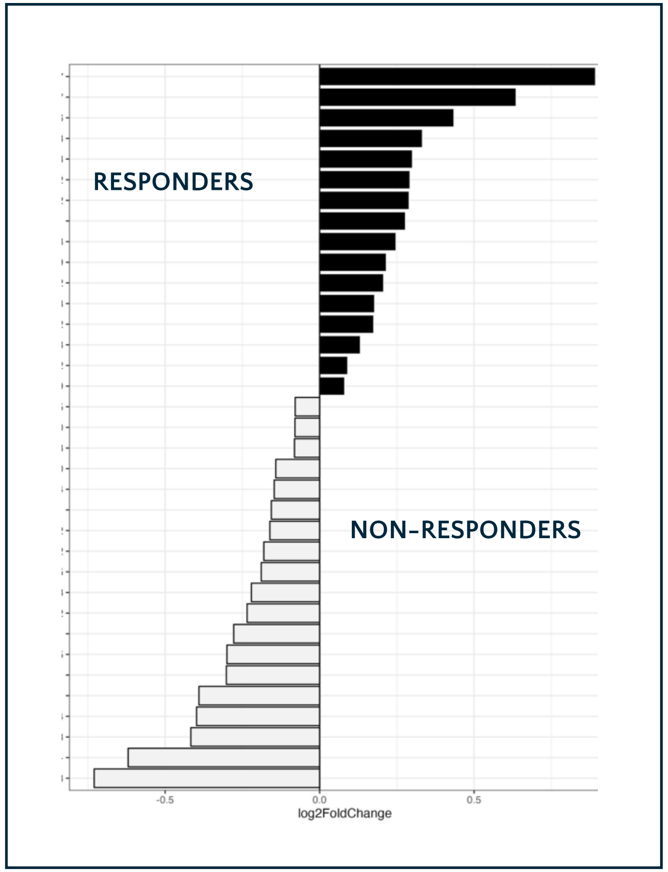
Findings – there were distinct functional features in the soils across states that had increased yields

Biostimulant – Yield benefit



Yield benefit corresponded to the soil that responded to the product application

Biostimulant placement



The responders with yield benefit had several distinct soil features in the baseline soils

METAGENOME ANALYSIS FOR SOIL RESILIENCE

CASE STUDY: VALIDATING SOIL HEALTH BASED ON TILLAGE PRACTICES

Problem

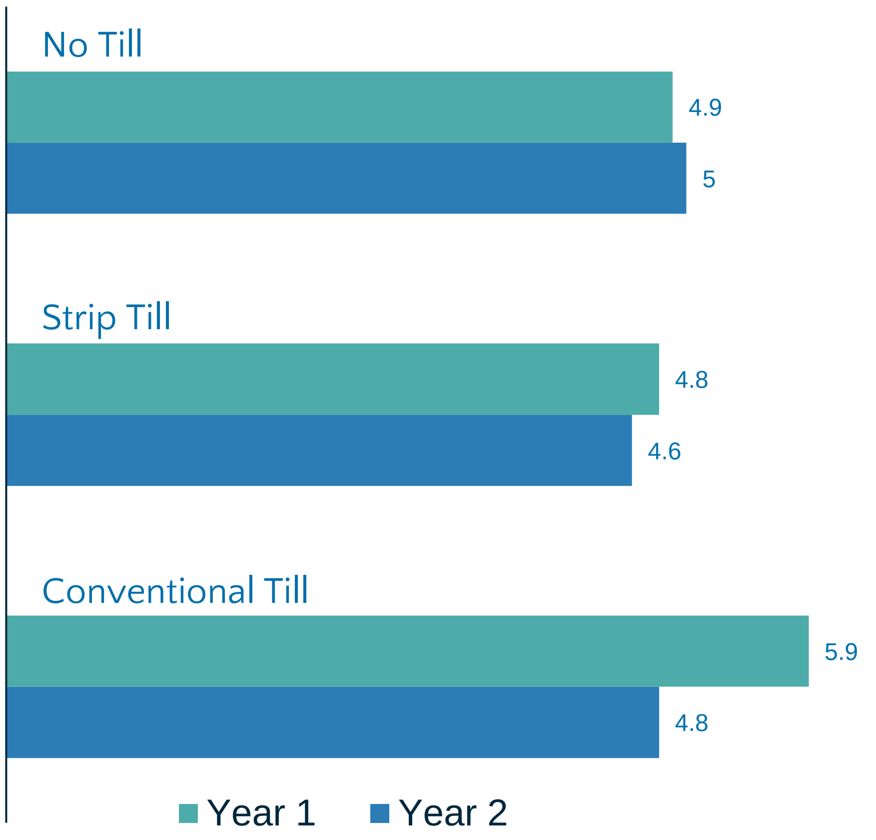
- Hypothesis: Soil health and sustainability metrics will be better with no till compared to conventional till practices
- The customer wanted to test their hypothesis using soil DNA measurement – evaluated several DNA technologies in the marketplace

Solution

- The samples were blindfolded for Trace evaluation
- The sampling was done for two consecutive years in the fields that were managed with different tillage practices
- The soil samples were run on Trace platform

Results

- Trace results validated customer hypothesis.
- The sustainable rating of the soils dropped year over year in conventional till fields while the sustainability rating of no till farms maintained its rating



CONCLUSIONS

APPLICATIONS OF SOIL METAGENOMIC INSIGHTS

✓ Soil metagenome is an emerging frontier in sustainable agriculture

✓ Place the right product on right acre to enhance win rate and increase ROI for growers

✓ Important data layer to revert soil degradation and build healthy soils

✓ Soil microbiome plays an important role in combating climate change impacts in agriculture and develop a resilient agricultural systems

✓ We are just now scratching the surface. It is important to enhance this knowledge base with transdisciplinary collaborations

THANK YOU

Trace Team

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Pat Dumstroff*, David Cruz*
Julian Trachsel*, Kim Vanous
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Past and present members of Trace Agronomy Network, Scientific and Industry Advisors

International Phytobiomes Alliance

Trace Customers