Embracing the Complexity of the Phytobiome: Minding the Microbes

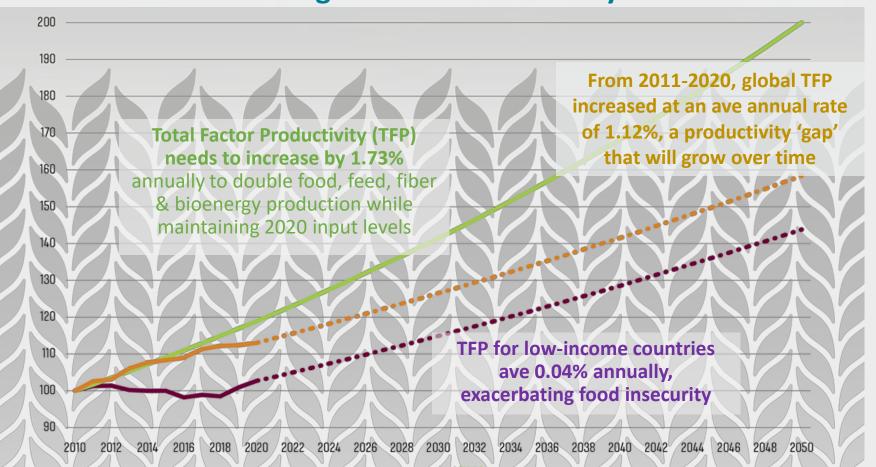
Jan E. Leach Colorado State University



Beyond the National Plant Genome Initiative:
New Frontiers and Grand Challenges in Plant Genomics
19 January 2023
PAG 30

Troublesome Trends

2022 Global Agricultural Productivity Index



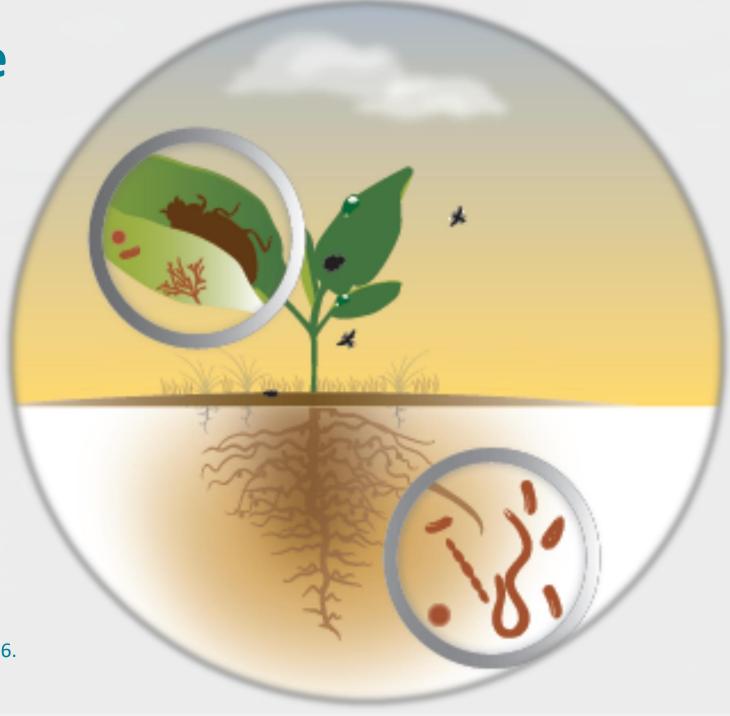


Phytobiomes Science as part of the solution

Phytobiome:

 Interactions of the environment and living organisms that influence or are influenced by plants

Phytobiomes: A Roadmap for Research and translation, 2016. St. Paul, MN: American Phytopathological Society, pp. 15



Holy Grail of Phytobiomes Science

To understand, predict, and control emergent phenotypes within specific phytobiomes for the sustainable production of food, feed, and fiber.



Interactions within the phytobiome are:

- interconnected
- dynamic
- complex

 HCN production SAM - ACC Hormone production synthase (IAA, GA, CK) Farm management ACC - ACC ACC Plant factors deaminase Genotype ISR Pili · Growth stage α-ketobutyrate Soil factors Ethylene • pH production Bacterial · Nutrient availability N source Moisture content Stress relief + Osmoprotectant **Endophytes** ROS detox Root exudates Root uptake of soluble Organic acid and · Organic acid 000 minerals and metals chelating agent Small molecules (e.g. Pi, Zn, Fe) production Secondary metabolites 000 · Signal molecules Acidification/ (3) Soluble Insoluble minerals chelation/ minerals and metals and metals exchange Rhizosphereassociated microbiome (2) Competition Recognition Signaling recruitment Antibiosis · Niche exclusion, **Bulk soil** Trivedi, Mattupalli, Eversole, & Leach cooperation Leach et al 2017 Cell microbiome 2021 New Phytol

Environmental factors

Light

Precipitation

UV

Temperature

Pathogen infection

Plant 4

Cell elongation

and root growth

Plant-associated

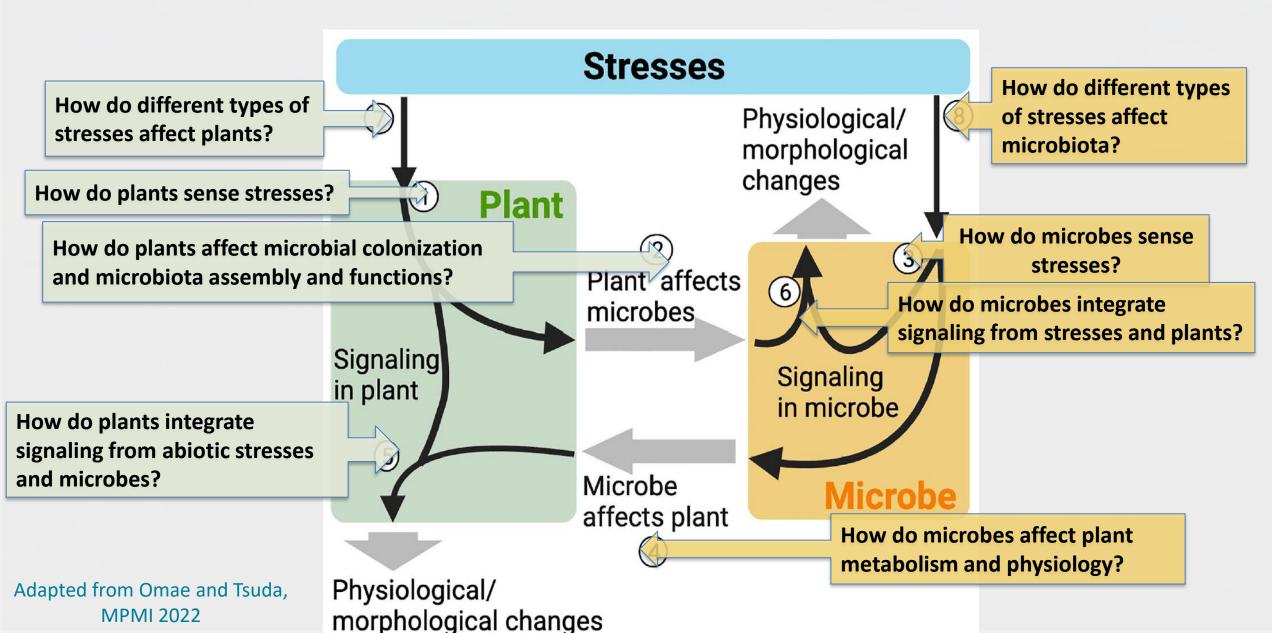
microbiome

Antibiotic

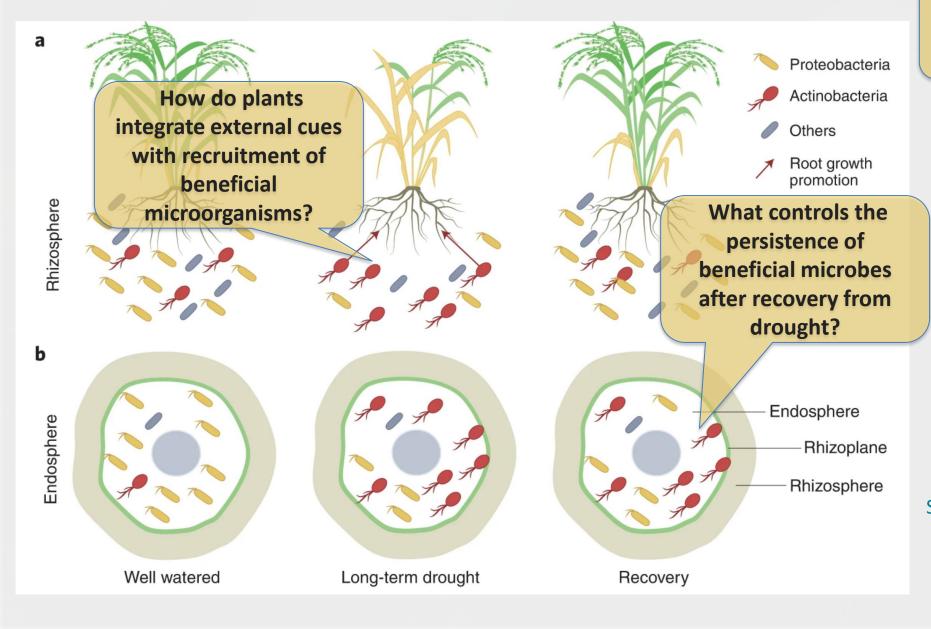
· VOC Bacteriocin

Trivedi et al 2021 New Phytol; Omae & Tsuda 2022 MPMI;

To exploit, we need a mechanistic understanding:



Plants 'cry for help' in response to stresses



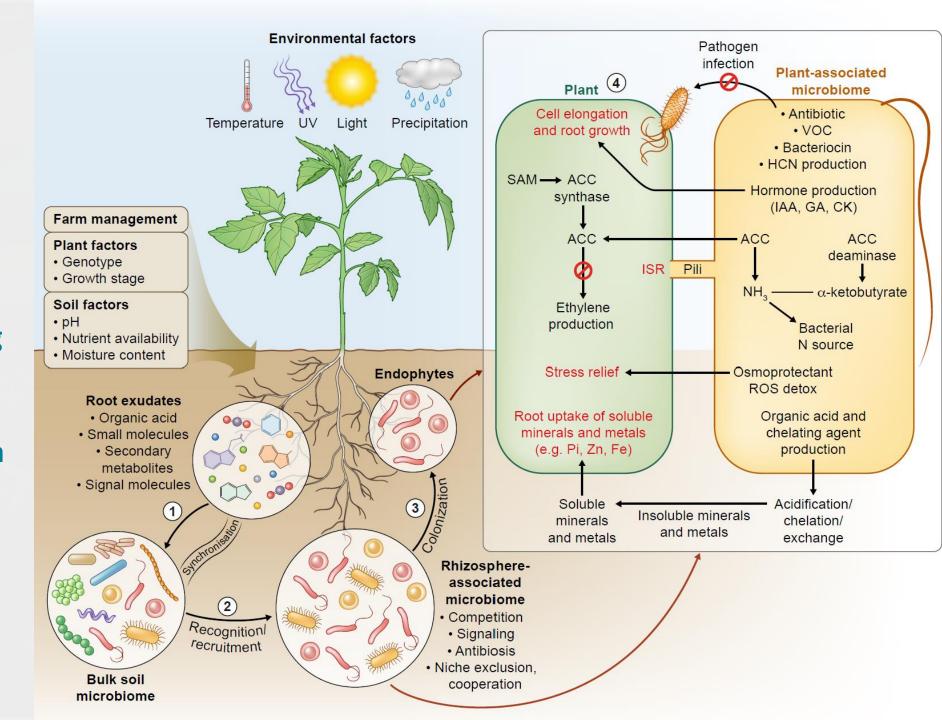
How can we exploit this to improve crop tolerance to stress?

"active recruitment
of beneficial
microorganisms
might be a common
evolutionary
strategy to enhance
plant fitness."

Song & Haney 2021 Nat Plants; Santos-Medellin et al 2021 Nat Plants

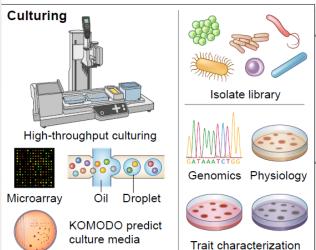
Embrace the complexity!

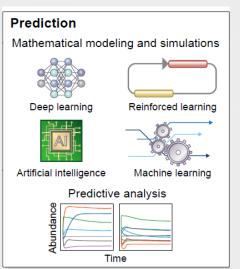
Understanding phytobiomes and using that knowledge to improve plant performance requires a systems approach.

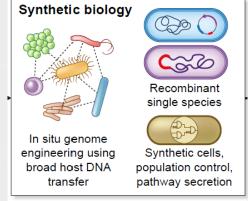


Trivedi, Mattupalli, Eversole & Leach 2021 New Phytol 230:2129

Going Forward: Continued Advancement in Enabling Technologies







Genomics & Transcriptomics & Metaproteomics Metaproteomics

Metaproteomics Bioinformatics and statistical analysis

Validation

Evaluation

Stakeholder-operated sequencer

UAS

3D LIDAR scanner

Nanospectral sensor

Microclimatic sensors

Root phenotype radar Soil moisture sensors

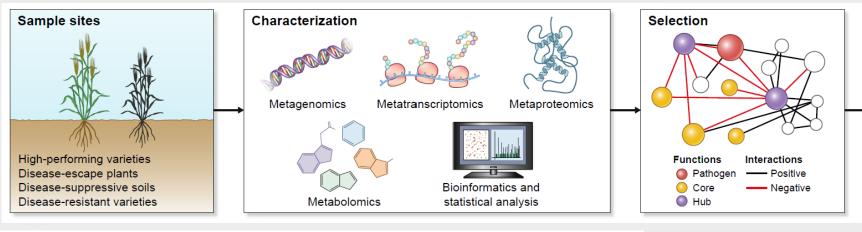
Characterization

EcoFabs

Microfluidics



Application: Development of synthetic communities (SynComs) for Smart Farming Systems



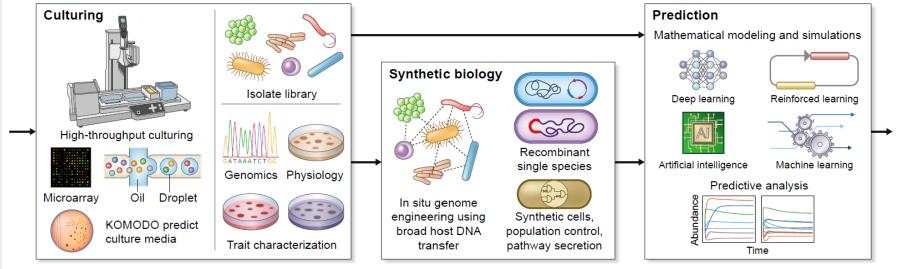
Evaluation

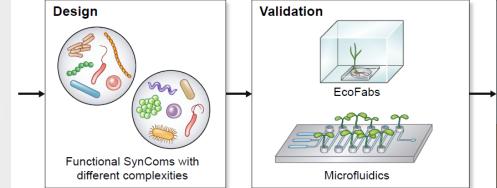
3D LIDAR scanner

Nanospectral sensor

Root phenotype radar Soil moisture sensors

Stakeholder-operated





Trivedi, Mattupalli, Eversole & Leach 2021 New Phytol 230:2129

Going forward......Embrace the Complexity!

- **Determine the makeup and functional potential** of plant-associated microbiomes to unravel complex interspecies ecological interactions and metabolic networks.
- Move beyond correlation to causation: get to mechanisms.
- Model and predict host genotype, microbiome genotype, environment, and management ($G_H \times G_M \times E \times M$) interactions to tailor solutions.
- Develop and adopt standardized procedures for collecting, classifying, and reporting consistent and well-annotated metadata (Dundore-Arias et al., 2020).
- **Develop globally accepted standards** for plant-associated microbial products to ensure rapid translation of innovations in real world conditions.
- Train the next generation of collaborative phytobiome scientists with skills in integration and sharing of best practices across relevant disciplines.



Join us at PAG 30!



