The Phytobiomes Roadmap: A New Vision for Agriculture

Jan Leach
Colorado State University
American Phytopathological Society Public Policy Board & The International Phytobiomes Alliance
www.phytobiomes.org
Global Grand Challenges
A new paradigm for agriculture is needed ......
APS: Phytobiomes Initiative

American Phytopathological Society
Dec 2013 Directive to an international group of “thought leaders”:

Develop concepts that can contribute to doubling the amount of safe and nutritious food by 2050

In the year 2050, the world population will require 70% more food.
Phytobiomes Roadmap: A new vision for agriculture

Achieve sustainable crop productivity through a systems-level understanding of diverse interacting components
Phytobiomes focus on a plant ecosystem that may involve any number of different types of plants, organisms, and environmental components.
Phytobiomes: Systems in Context

Management Context

- Crop choices
  - Species
  - Cultivar
  - GMO/Non-GMO
- Cover crops
- Crop rotations
- Monoculture

- Site choices
  - Irrigation
  - Tile drainage
  - Livestock mgmt

- Inputs
  - Application method & timing
  - Herbicides
  - Insecticides
  - Organic/inorganic fertilizer
  - Fungicides

- Till/No-till
- Planting/Harvesting time

- Equipment
- Agriculture
- Agriculture equipment
- Agriculture tools
- Agriculture technology
"We have to remember that what we observe is not nature in itself, but nature exposed to our method of questioning." - Werner Heisenberg (Theoretical physicist)
Plants can select their microbiome

What are the principles and processes guiding phytobiome composition and dynamics?

Can we exploit that information to improve agroecosystem health and productivity?

- Plants regulate the entry of bacteria; this plant genotype-dependent selection fine-tunes the internalized microbial communities.
- Geographically distinct soils contribute taxonomically similar sources of bacterial endophytes.
- Plants can transmit bacterial endophytes from generation to generation through seed.

Johnston-Montje et al, 2014; Lundberg et al, 2012; Bulgarelli et al, 2012; Wagner et al., 2016; Edwards et al, 2015; Hirsch et al, 2012; and others
Embracing complexity

Phytobiome knowledge can guide predictions of crop health/status:
- early detection?

• Rhizosphere microbiome on trees with citrus greening are different from those on uninfected trees
→ Disease is associated with shifts in the microbiome composition
→ Diagnostic functional shift: away from use of easily degraded carbon sources to more recalcitrant forms – consistent with carbohydrate repartitioning during disease

Trivedi et al. 2012. ISME J 6:363
Citrus/ACP microbiomes...components of the phytobiome
Embracing complexity: Learning from citrus/insect microbiomes

• How is the microbiome community impacted by:
  – CLas infection?
  – Asian citrus psyllid feeding?
  – Insecticide/antimicrobial treatments?
  – Abiotic stresses?
  – Environmental changes?
  – Other management strategies?

• Are the microbiomes contributing to or mitigating HLB disease?

• Can the microbiomes of citrus or ACP be manipulated to benefit disease control?

Wang et al., 2015
More complexity:
Insects-microbes-plants

Herbivore exploits orally secreted bacteria to suppress plant defenses

Phytobiome knowledge can guide management strategies

PNAS 110:15728

Seung Ho Chung, Cristina Rosa, Erin D. Scully, Michelle Peiffer, John F. Tooker, Kelli Hoover, Dawn S. Luthe, and Gary W. Felton

Bacteria associated with the Colorado potato beetle manipulate plant defenses to facilitate beetle feeding

Should breeding programs/treatment regimes target the bacteria rather than the insect?
Embrace the complexity!

Many examples emerging of complex interactions within phytobiomes:

- **High temperatures** increase plant susceptibility to pathogens
- **Soil pH and C sources** favor bacteria that inhibit fungal plant pathogens
- **Virus infection of plants** alters attraction and herbivory by insects
Phytobiomes approaches embrace complexity

Networks of interactions among the phytobiome components profoundly influence plant and agroecosystem health and productivity
Why now?
Convergence of need & opportunities

Technological advances in
Probing and understanding phytobiome components
Precision crop management systems
Big Data Analytics

www.phytobiomes.org
Phytobiomes Roadmap

...is a strategic plan for acquiring knowledge of what constitutes a healthy, productive and sustainable agroecosystem, and translating that knowledge into powerful new tools for crop management.
Phytobiome Roadmap identifies:

- Major gaps in
  - Knowledge
  - Technology
  - Infrastructure
- Challenges in educating and training a future workforce
- Short-, mid- and long-term actions and goals for the future
Roadmap highlights applications of Phytobiome knowledge

- What genetic linkages connect phytobiome components?
  - *Can we breed/engineer plants that select for beneficial communities of organisms?*

- What constitutes a “healthy phytobiome”?
  - *Can we use this information to develop effective biologicals and predictors of crop and soil health?*

- Can we exploit predictive and prescriptive analytics to design seeds, biologicals, and management practices that are site-specific and resilient to future environmental challenges?
Roadmap highlights applications of Phytobiome knowledge

- What are the mechanisms by which specific management practices promote ecosystem health and sustainability?
  - *Design novel or improved management practices*
Outcomes of this vision for agriculture

Managed or engineered phytobiomes that promote:

- Effective rehabilitation of degraded and depleted lands worldwide

*1.5 billion people depend on degraded lands for survival!

Source: UNEP
Outcomes of this vision for agriculture

 Managed or engineered phytobiomes that promote:

- Increased resilience of cropping systems to pests, pathogens, water and nutrient limitation
- Pest control practices that are best suited for sustainable productivity
- Full integration of biologicals into site-specific crop management (precision agriculture)
Outcomes of this vision for agriculture

• Adaptive, data-driven, on-farm systems for managing phytobiomes for optimal productivity

• Increased profitability of sustainable production to enable growers to meet demand

www.linkedin.com/pulse/foreign-affairs-precision-agriculture-revolution-ulrich-adam
• Forming linkages with other disciplines to recruit a broad base of expertise

• Integrating efforts to attract and strengthen a cross-trained workforce

• Defining standards and best practices relevant to specific crops, cropping systems, rotational practices, and precision agriculture
Actions: A New Journal!

• Launched a new open-access journal

• Editor-in-Chief: Carolyn Young (Noble Foundation)
Actions

• Advocating for new funding (national and international)

I agree. Let’s fund research!

PHYTOBIOMES are important…..

@phytobiomes
www.phytobiomes.com
Actions: Launched International Alliance for Phytobiomes Research

• **Alliance** of *industry and academic* entities committed to enabling a paradigm shift in agricultural production

• **Mission** - establish a science and technology foundation for phytobiome-based, site-specific enhancement of the sustainable production of food, feed, and fiber

• **Goals**
  – Coordinate research to address gaps in phytobiomes knowledge
  – Establish national & international private-public networks
  – Develop standards and reference materials for phytobiomes research
Phytobiomes Roadmap is endorsed by:
Upcoming Events

**Phytobiomes Think-Tank**, ISRFG, Sep 28, Montpellier, France

**Phytobiomes: From Microbes to Plant Ecosystems**, Keystone Symposium, Nov 8-13, 2016, Santa Fe, New Mexico

**American Meteorology Society Meeting**, Session: Applying a systems-level approach to the phytobiome, Jan 22-26, 2017, Seattle, WA

**American Geophysical Union Meeting**, Session: Non-linear System Interactions and Analysis Methodologies for Advancing Research and Applications in Phytobiomes, including Plants, Insects, Microbiomes, Soils, Hydrology, Aerosols and Other Atmospheric Properties, Jan 2017

www.phytobiomes.org
Your thoughts on Phytobiomes?

@phytobiomes

www.phytobiomes.com
Phytobiomes Roadmap: A new vision for agriculture

Achieve sustainable crop productivity through a systems-level understanding of diverse interacting components.