Phytobiomes: A whole-system approach to advancing plant agriculture

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Global Grand Challenge
To sustainably feed the world ......
To feed a global population of 9.6 billion in 2050

Need 70% more food (based on calories)

World Summit on Food Security (2013)
Doubling global crop production by 2050 will require ~2.4% increase per year in yields.

**GLOBAL YIELD GROWTH RATES (%)**

<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>Maize</td>
<td>1.8</td>
<td>2.2</td>
</tr>
<tr>
<td>Wheat</td>
<td>0.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Rice</td>
<td>1.0</td>
<td>2.2</td>
</tr>
<tr>
<td>Soybeans</td>
<td>1.1</td>
<td>1.8</td>
</tr>
</tbody>
</table>

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

→ Time is right for a systems approach
Phytobiomes: Systems in Context

Micro- and Macroorganisms
- Viruses
- Archaea
- Bacteria
- Amoeba
- Oomycetes
- Fungi
- Algae
- Nematodes

Plants

Arthropods, Other Animals and Plants
- Insects
- Arachnids
- Myriapods
- Worms
- Birds
- Rodents
- Ruminants
- Weeds

Their environment

Soils

All of the associated organisms

Biological and Environmental Context

Climate
Phytobiomes: Systems in Context

Management Context

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

**Site choices**
- Irrigation
- Tile drainage
- Livestock Mgt

**Inputs**
- Application methods
- Timing
- Herbicides
- Insecticides
- Organic/Inorganic fertilizers
- Fungicides

**Till/No-till**
- Planting time
- Harvest time
Phytobiomes - plants, their associated organisms, and their environment
Plant systems vs. Phytobiomes

**Plant systems** focus on a plant and then determine the interactions of that plant with all other components.

**Phytobiomes** focus on a plant ecosystem that may involve any number of different types of plants, organisms, and environmental components.

→ use information on all components and their interactions to identify the best plant(s) to grow at a given site in a given period.
Achieve sustainable crop productivity through a systems-level understanding of diverse interacting components.
Origin of the Phytobiomes Roadmap

- American Phytopathological Society meetings (2014-15)
- Interdisciplinary participants from academia, industry and government in
  - Workshop: Phytobiomes 2015 - Designing a new paradigm for crop improvement (>200 participants)
  - Interdisciplinary writing team
- Comments from the public and organizations endorsing the Roadmap
The Phytobiomes Roadmap has been endorsed by:
Reductionist approach to biology and agricultural science: Understand each component individually.

Reality: biological systems are complex and non-linear in their organization and regulation.
Develop a foundation of knowledge

Translate that knowledge into application
Why now?
Convergence of need & opportunities

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

Genome-enabled technologies
Computational biology and modeling

- **Amplicon sequencing**
  - PCR amplify (16S-18S rRNA, ITS, cpn60)
  - Species (taxa) number, abundance, composition
  - “Who is there?”

- **Metagenome sequencing**
  - Community function
  - “What can they do?”

- **Meta-transcriptome sequencing**
  - Community activity
  - “What are they doing?”

- **Metaproteome analysis**
- **Metabolome analysis**
Advances in precision management strategies in agriculture

Mid-1990’s: global positioning systems
Big data analytics
What genetic linkages connect phytobiome components?  
→ Breed plants that select for beneficial communities

What constitutes a “healthy phytobiome”?  
→ Develop biologicals and predictors of crop and soil health
What are the **mechanisms** by which specific management practices promote ecosystem health?

→ *Design novel or improved management practices*

Can we exploit **predictive and prescriptive analytics** to design site-specific solutions to environmental challenges?

→ *Incorporate biological information into the next generation of precision agriculture technologies*
The Phytobiomes Roadmap Offers ...

A strategic plan
Phytobiomes 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
Actions

- Forming linkages among disciplines to recruit a broad base of expertise to the field of phytobiomes
- APS is launching a new, open-access journal
- Advocating for *new* support for phytobiome research
Actions

- Establishing the International Alliance for Phytobiomes Research, a public-private alliance to enhance interdisciplinary networks

  Executive Director: Kellye Eversole

- Working to attract and strengthen a cross-trained workforce
Outcomes of this new 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
Managed or engineered phytobiomes that promote:

- Increased resilience of our 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 – moving us to the next-generation precision agriculture
Outcomes of this new vision for agriculture

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

- **Increased profitability** of sustainable food production to enable growers to meet demand

www.linkedin.com/pulse/foreign-affairs-precision-agriculture-revolution-ulrich-adam
Future Events

http://www.keystonesymposia.org/17S2