# Microbe-to-plant signals as a way to develop climate change resilient agriculture

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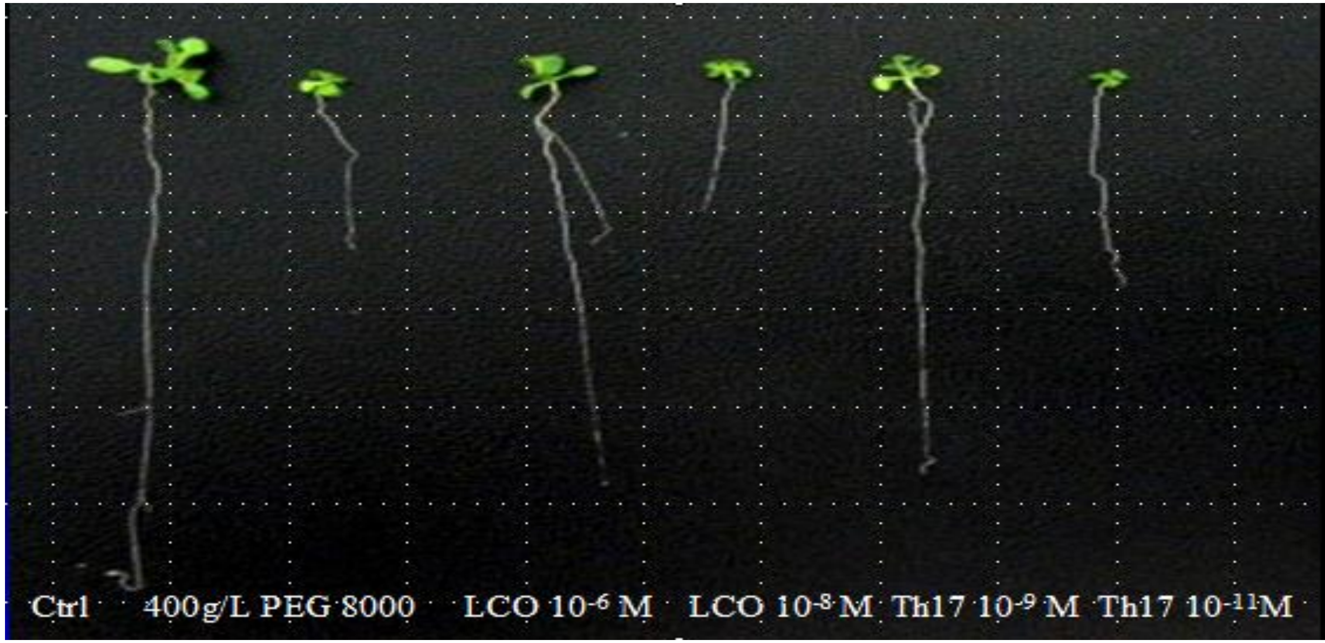
# Evolution – Individual and Community

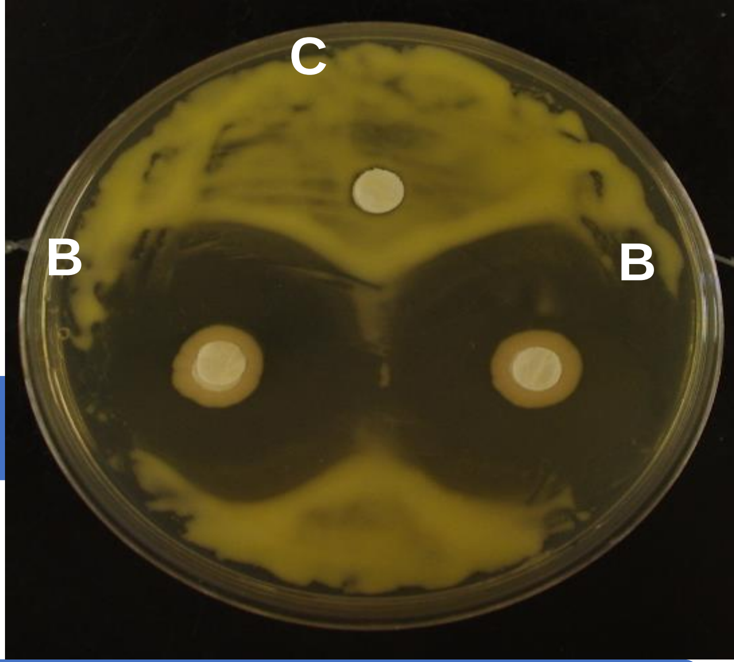
- It is now clear that pretty much all eukaryotes,  certainly all multicellular eukaryotes, have associated communities of microbes
  - for plants the phytomicrobiome
- The microbial community and the host organism interact in many ways
- It is this community (the holobiont) that evolution acts on

# Benefits to each other

- Microbes
  - Niche space
  - Supply of reduced C
  - Perhaps specifics to  allow growth
- Plants
  - Disease control
  - Nutrient supply
  - Stress mitigation




# Functions – plant perspective




## Nutrient supply

- $N_2$ fixation
- Siderophores – iron
- Solubilize and mobilize (mycorrhizae) P and Zn

## Water (root growth), stomatal aperture

## Pathogen resistance

- Antagonist to pathogen
- Induced resistance in plants

## Production of plant hormones

## Stress tolerance – microbe-to-plant signals

## Germination – eg. orchids

# Biomass Productivity

- **Biomass crops** on marginal agricultural lands (>class 3)
    - Little competition with food crops
    - Plants more stressed, plus climate change
- Perennial crops – stand can be harvested for 15 - 30 yrs.
- Fuel plus increase carbon/organic matter content of soil
- About 25 Mt biomass
- **Food crop residues**, take about 1/3 $yr^{-1}$
- About 48 Mt biomass
- PhytomicrobiomePGPR can help deal with stress and increase yield
- Climate change resilience, increase food ***and*** fuel

# The Problem/Opportunity

- There is a large area of potential land for biomass production in Canada
- Purpose grown biomass would be produced in a more stressful environment (marginal lands)

# The Supply Problem

- Uncertainties about biomass feedstock supply (drought, economics, etc.) can be a serious bioeconomy bottleneck
- In 2013-14 four large biomass plants opened in US
  - Three went broke, in large part over problems with biomass supply

**INEOS Bio - New Planet Energy -- Indian River BioEnergy Center**
- Vero Beach, Florida
- Opened July 2013
- Capacity: 32 M L $yr^{-1}$ and 6 megawatts (gross) of renewable power

**POET–DSM -- Project Liberty**
- Emmetsburg, Iowa
- Opened Sept 2014
- Capacity: 100 M L $yr^{-1}$

**DuPont -- Nevada Site Cellulosic Ethanol Facility**
- Nevada, Iowa
- Operational Date: Q4 2014
- Capacity: 120 M L $yr^{-1}$

**Abengoa -- Bioenergy Hugoton Cellulosic Ethanol Facility**
- Location: Hugoton, Kansas
- Operational Date: Q2 2014
- Capacity: 100 M L $yr^{-1}$ plus 21 megawatts of renewable electricity

INEOS Bio

POET | DSM
Advanced Biofuels

DUPONT®
The miracles of science™

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# Phytomicrobiome Signals and Stress

- Phytomicrobiome members can affect plant through signals
- Often help with stress response regulation
- Effective at very low concentration
    - Hormones of the holobiont
    - Makes inexpensive, low environmental impact
- Produce growth stimulating microbes in liquid medium, remove cells and test now cell free medium for growth stimulation
- Seeds on petri plates with signals
- Control and 150 mM NaCl
- Signals improved growth under stress

# Example - **Corn field trials**

- Corn and potato were grown in 2018, 2019 and 2020
- Microbial consortium (a group of 5 *Bacillus* strains), at various concentrations (1x recommended and 2x) and two seeding dates (recommended and late), three soil types (clay, clay-loam, sany-loam)
- **Key findings for corn** –
  - Biomass production average increases –
    - on clay soil **16.1%**
    - on clay loam soil 17**.4%**
    - on sandy loam soil **11.2%**
  - Both grain yield and starch content were significantly increased by microbial inoculation in corn

# Example - Potato field trials

- Consortium added at seeding
- Nutritional quality assessed (starch, protein, ascorbic acid and phenolics) in tubers
- Greatest increase in biomass was for treatments to which the consortium was applied at seeding
- Inoculation increased in-season biomass up to **27.9%,** tuber yield by **20%**

# Biomass crop field trials

- Trials planted up to 5 years ago
  - Switchgrass
  - Miscanthus
- Each grass treated with the phytomicrobiome based technologies
  - Consortium microbes
  - Single strains of microbes
  - Signal molecules
- Yield increases up to about **20%**


# Trials with Micro-to-Plant Signals

- LCOs, thuricin 17 and Biosignall
- Corn, soybean, potato, tomato, canola, etc.
- Seed or foliar application
- Yield and biomass increases depending on stress levels
- Often 10 to 20% increases in productivity
- LCO technology already going on 10s of millions of ha of agricultural land per year

# Example of Potential GHG reductions

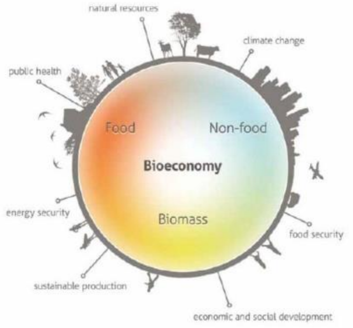
1. Food crop residue biomass production of 4 T $ha^{-1}$ aboveground non-grain biomass (corn is approx 10 T $ha^{-1}$, other crops less) plus 1.6 T $ha^{-1}$ root biomass (TOTAL 5.6 T $ha^{-1}$ biomass)
2. A new phytomicroiome signal technology applied to existing crop area (40 M ha)
3. 15% increase in biomass associated with application of new technology
4. New technology results in this increase 50% of the time
5. The biomass retained in the soil over the long term (after initial decomposition) is 10% of the total increase PER YEAR

- 5.6 T $ha^{-1}$ x 40 M ha x 0.15 x 0.5 x 0.1 = 1.68 M T $CO_2$
- Converting to $CO_2$ equivalents (correction of added oxygen) = 1.68 x 1.7 = 2.9 M T $CO_2$ equivalents PER YEAR
- If converted to biofuels instead of added to soils the value of reduced emissions is similar

# Relevance to Bioeconomy

- There is large potential impact of PGPR and their signal compounds, and the overall potential of the phytomicrobiome for increasing available biomass for the bioeconomy
- This could help remove the greatest bottleneck in the bioeconomy and help make the bioeconomy more climate change resilient

# Summary




- Phytomicrobiome members (PGPR) show promise in managing greenhouse gases
- New strains and products from them are being be isolated, and show promise
- Evaluation of other microbial plant-biostimulants is ongoing and there will be many new ones
- This approach shows the potential to enhance the production of biomass including in the presence of climate change related stresses that could negatively affect crop growth
- GHG levels reduced ($CO_2$ removal from atmosphere or reduced emissions) and enhanced crop resilience to climate change related stresses.

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# The End!

Questions?