Soilborne plant pathogen dispersal and assessment: Building a remote sensing-based global surveillance system for plant disease

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Disease causes 15-30% yield loss annually: $220 billion lost

>1.1 billion pounds of pesticide usage annually in US alone

Pesticides critical for modern agriculture, but overuse threatens biodiversity

No remote sensing!
**Fusarium oxysporum** *(F. oxy)*

- Causes Fusarium Wilt (FW)
- Endemic to all six crop producing continents
- 100+ susceptible hosts
- Survives in soil for 20+ years
- Annual yield losses ~10-60%
- Range expected to expand greatly under predicted climate change scenarios *(Shabani et al. 2014)*
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Preserving existing agroecosystems is critical to preserving natural ecosystems and global biodiversity
Soil dwelling fungi are capable of aerosolization and transport in global dust plumes.

Infectious *F. oxy* spores and DNA have been isolated from North African and Asian dust samples.
Remote Sensing

Comparative Genomics

Aerosol Transport

Pathogenicity Spore variability

F. oxy global surveillance system

Incidence Dispersal risk

Pathogenicity Incidence
Determine how remote sensing measurements and earth system models used to track atmospheric aerosols can be informed by comparative genomics to improve food security by developing:

1. Fusarium Wilt susceptibility assessment for current and future agricultural production zones under various climate change scenarios
2. A robust model for global *F. oxy* dispersion and survival
**Year One Goals**

**Remote Sensing:** Build susceptibility assessment for current *F. oxysporum* risk in agricultural zones from RS measurements.

**Comparative Genomics:** Assemble spore traits that impact dispersal and atmospheric viability.

**Aerosol Transport:** Adapt CAM6-MIMI model to include agricultural dust and spore transport.

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*Global dust current*  
*Fusarium oxysporum*
Susceptibility Assessment

1. Global pathogen distribution
2. Global cropland mapping
3. Conducive plant disease environment
4. Dust source regions modeling
5. Concordance evaluation: incidence locations vs. modeled source regions

Virulent Pathogen

Plant Disease

Conducive Environment

Susceptible Host

Global dust current
Fusarium oxysporum
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Aerosol Transport: CESM CAM6-MIMI

- Community Earth System Model (CESM)
  - Earth System Model linking land, ocean, atmosphere, and ice models
- Community Atmosphere Model (CAM6)
  - State of the art climate model, can simulate weather events
  - Includes: dust, sea salts, sulfates, soot, and organic carbon aerosols
- MIMI framework
  - MIMI = Mechanisms of Intermediate Complexity for Modelling Iron
  - Aerosol processing framework, makes it easy to simulate spore viability during transport
Incorporating ag dust and spores

1. Compare CAM6-MIMI to observations
2. Incorporate ag dust into model
3. Incorporate spores into model
4. Kill spores during transport
5. Spore differentiation by region
6. Run the model from 1980-2020
## Spore traits that influence dispersal and atmospheric survival

<table>
<thead>
<tr>
<th>Spore Type</th>
<th>Spore Information</th>
<th>Reference</th>
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<tbody>
<tr>
<td><strong>Ciceris</strong></td>
<td>Chlamydospore diameter 4.8-8.1 µm; Microconidia size 5.1-12.8 x 2.5-5.0 µm; Macroconidia 16.5-37.9 x 4.0-5.9 µm</td>
<td>Arvayo-Ortiz et al., 2011; Dubey et al., 2010</td>
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<tr>
<td><strong>General</strong></td>
<td>average ascospore size: 21 µm x 3.5 µm; 19–24 x 3–4 µm and macroconidia as 25–50 x 3–4 µm</td>
<td>Booth, 1971; Trail et al., 2002</td>
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<tr>
<td><strong>General</strong></td>
<td>long-distance ascospore dispersal will not be effective at relative humidity less than 50 %</td>
<td>Beyer et al., 2005</td>
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<td><strong>General</strong></td>
<td>Gravitational settling of 1-2 mm per s-1 in still air</td>
<td>Keller et al., 2014</td>
</tr>
</tbody>
</table>
Looking forward:
Climate change impacts on distribution

Remote Sensing: Map and integrate host and conducive environment range into susceptibility assessment

Comparative Genomics: Continue assembling spore traits of most abundant pathovars by region

Aerosol Transport: Experiment with different kill parameters for spores in the new CAM6-MIMI model

Next Steps
Evaluate concordance between susceptibility assessment and known incidence; modeled source/deposition regions

Compare relatedness between source/sink isolates

Incorporate spore variability by region into AT model

Global dust current
Fusarium oxysporum
Interested in more plant disease remote sensing?
Visit Fernando Romero Galvan’s NASA FINESST poster breakout room this afternoon!

Questions?
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