Soybean Rust Dispersal Prediction and Analyses in the US for 2005 Growing Season

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Acknowledgments

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Outline

- Spore and Rust Prediction
  - Model system
  - Prediction experiments 2005
  - Validation, mostly qualitative
- Analyses of disease spread - climate conditions
  - Transport conditions
  - Spread conditions
- Improvements for 2006
  - Source specification
  - Model improvements
ISU/SLU Rust prediction model – An climate-dispersal-disease integrated system

Global model – Scripps Institution of Oceanography

MM5 – National Center for Atmospheric Research

HYPLIT – NOAA Air Resource Lab

Disease model – Iowa State University
HYPLIT model

- Runs in trajectory or concentration modes
  - trajectory – forward/backward tracking
  - concentration – airborne and at surface
- Treats spores as particle or plume
  - particle passively moves along atmosphere
  - plume or puff dilutes, splits, merges according to advection and diffusion rules
- Considers dry and wet deposition
  - gravitational settling
  - rainfall washout
- Incorporate simple aerobiological viability criteria
  - VU-B radiation, temperature, etc.
Simulated spore dispersal from Africa to S. America
March 2004 prediction, showing a favorable pathway from S. America toward Cali, Columbia
Predicated spore dispersal showing the favorable pathway from Cali, Columbia to US in fall 2004

Soybean rusts detected by USDA, 2004
Two kinds of prediction – Lorenz theory

- First kind: day-to-day *weather* prediction based on initial conditions
- Second kind: long-term *climate* prediction based on boundary conditions
- First kind prediction is limited to 7-10 days whereas the second kind can be as long as *months to years*.
- Lower latitudes have more predictability than mid-latitudes due to long thermal memory of oceans
Spore counts which are visually inspected as SBR positive, but not confirmed by PCR because of low spore density (Courtesy of Syngenta)
Climatic dispersal pattern from hypothetical source in southern LA and western TX as denoted by the yellow dots (Kim et al.)
As of 7/7

Hindcast Instantaneous spore concentration for June 2 – 11, 2005 (one from per day)

Predicted Spore Concentration (log N/m³)
starting June 2, 2005

-4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0

ground

Predicted Spore Concentration (log N/m³)
starting June 2, 2005

-4.0 -3.5 -3.0 -2.5 -2.0 -1.5 -1.0 -0.5 0 0.5 1.0 1.5 2.0 2.5 3.0

500 meter
Spore dispersal handcast for first two weeks of July

Disease as of 8/31/05

500 meter

100 meter

Ground
Disease favorability outlook

- What does it mean if certain amount of rust spores have arrived and deposed on the ground?
- The disease model would determine the fate of these spores based on *in situ* environment conditions including host availability.
- As part of the disease model, we adopted an expert system originally developed for China to project the disease outlook.
- In 2005 the expert system used mainly rainfall frequency and amount, while spore concentration was used subjectively.
Sample of weekly instantaneous and cumulative spore concentration predicted during 2005

Early season

Mid-season

Season cumulative

As of end of Oct., 2005
Sample of predicted favorability for epidemics based observed and modeled rainfall

- Monthly climatic favorability
  - Jun 10 - Jul 10
  - 6/10-7/10

- Past monthly climatic favorability
  - June 23 - July 23
  - 6/23-7/23

- Past + forecast monthly climatic favorability
  - July 15 - Aug 13
  - 7/15-8/15

- As of end of Oct., 2005

Data source: NOAA Climate Prediction Center

Comprises 15 days observed weather data with 15-days weather forecast starting on June 23.
Some unfavorable **climate** conditions in 05

- Wind direction was less northward – possibly suppressing transport to central US
- Wind speed was lighter – likely reducing turbulent lifting
- West of Mississippi in coastal states was dry – contributing to local confinement of the disease
- Biological factors may also have contributed the limited rust spread this year.
Observed wind vector at ~1500 m height in summer

Mean climate

Anomaly: 2005 minus climatology

2005
Mean summer wind speed (m/s) at ~1500 m

Low-level jet

Soybean acreage (from: USDA)

Alternative hosts (from: USDA ?)
Illustration of wind pattern in southeastern US showing strong jet belt west of a relatively light wind zone where the rust exited.
Illustration of turbulent lifting that can carry spore clouds up high

**VERTICAL TRANSPORT OF HEAT BY CONDUCTION AND CONVECTION**

**Strong wind**

**Weak wind**
Correlation of rust map to rainfall distribution

Accumulated Rainfall Amount (mm)
May 01 to Aug 31 2005

As of end of Oct., 2005
Rust spore dispersal pattern with hypothetic source in western TX, LA

Projected Spore Concentration (log N/m^3)
starting April 30, 2005
Rust spore dispersal pattern with source in FL, GA, AL

Projected Spore Concentration (log N/m^3)
starting April 30, 2005

Week 1

Week 2

Week 3

Week 4
Summary and Discussions

- A spore and disease prediction model system has been established to forecast spore dispersal and disease development up to 2-4 weeks in advance.
- The integrated model system consists of spore dispersal and rust development sub-models.
  - Dispersal model is an integration of HYSPLIT with MM5 that is fed on by a global seasonal forecast model.
  - Disease model is an expert assessment system based on rainfall characteristics, among others.
- The 2005 season prediction suggests that the model system can predict the general dispersal patterns although it often overpredicted spore concentration.
Even if the predicted spore dispersal has large uncertainty, a well-adapted expert system of the disease model still appear to give a reasonable disease outlook, as seen this year.

Among other factors, the 2005 climate conditions were somewhat unfavorable for SBR widespread:
- Light wind speeds likely suppressed spore lifting
- Wind direction may have demoted northward transport
- Drier surface could limit the westward spread

Largest uncertainties in the rust prediction seem to lie in accurate determination of spore production and lifting, their viability, and disease biology, which need to be improved in the coming years.
Thank you!