Advances in Predictive Modeling

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&

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USDA, ARS
Cereal Disease Laboratory

2009 National Soybean Rust Symposium
Collaborators

Charles Barnes - Equador
Albert Tenuta - OMAFRA
Sarah Hambleton - Agriculture and Agri-Food Canada
Joe Russo – ZedX Inc
Jeremy Zydek – ZedX Inc
Julie Golod - PSU
Annalisa Ariatti – PSU

and

The many U.S., Canadian, and Mexican Extension Pathologists and their assistants who collected data on soybean rust from sentinel plots and through mobile scouting

Funded by the USB and USDA
Focus of Presentation

Validation of short term forecasts of long-distance soybean rust spread
Integrated Aerobiology Modeling Systems (IAMS) output
NADP Rainwater spore collections
Sentinel plot and mobile scouting soybean rust observations

What we have learned about forecasting long-distance transport of soybean rust to the continental interior of North America

Expectations for 2010 season
IAMS is a deterministic model of soybean rust transport process.

- Synoptic Scale Airflows Govern Transport Direction and Speed
- Turbulent Diffusion and Wind Shear Govern Dilution
- Ultraviolet Radiation
- Temperature and Relative Humidity
- Vertical Distribution of Spores in Canopy
- Canopy Density & Structure
- Wind & Turbulence
- Time of Spore Release
- Soybean Plant Growth
- Stage of Disease
- Weather
- Escape of Spores from Canopy
- Spore Production
- Survival of Spores while Airborne
- Deposition of Spores into a Soybean Crop
- Colonization of Soybean Crop

Dry Deposition Due to Wind and Turbulence
Wet Deposition Due to Washout by Precipitation
Temperature & Leaf Wetness
Soybean Crop Growth Stage
Doppler Radar Data Sources

NOAA Models (winds, temperatures...)
- Rapid Update Cycle Forecast (RUC)
- North American Mesoscale (NAM)
- Global Forecast System (GFS)

NEXRAD stage-4 radar (precipitation)

NOAA satellites (precipitation)

USDA crop statistics (e.g., soybean acreage for counties)

Sentinel plot and mobile scout observations (e.g., crop stage, disease incidence and severity)

Epidemiology field studies (aerobiological and epidemiological relationships)
IAMS Output Maps

Wind speed and direction

Precipitation and humidity

Deposition of viable spores

Ensemble risk forecast
National Atmospheric Deposition Network

Rainwater collector

Potential collection sites
Time Series of Positive SBR Observations

Number of Positives

Month

May
June
July
Aug.
Sept.

2005
2006
Geographic Distribution of Positive SBR Observations

2005

2006

Frequency

0
1
2
3
4
> 4
The total number of observations were 22,176 and 26,103 in 2007 and 2008 respectively throughout the U.S., southern Canada, and Mexico from more than 2000 different geographic locations each year.
Map showing counties where soybean rust is present generated from sentinel plot and mobile scouting observations.
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (30 May - 06 June 2007)

Confusion Matrix

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

- very low
- low
- moderate
- high

SBR Spore Collections

- Positive, very few spores
- Low
- Moderate
- High
- Positive, # of spores unknown

Arbitrary demarcation of continental interior

Collection levels considered in analysis

Prediction levels considered in analysis

County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (06 - 12 June 2007)

May was a particularly dry month in the southeast reinforcing an on-going drought that continued until late August.
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(13 - 19 June 2007)

In contrast, rainfall was generally above normal in the southwestern portion of the Mississippi basin during late spring and early summer.
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(20 - 26 June 2007)

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SBR Spore Collections

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- Moderate
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- Positive, # of spores unknown

County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(27 June - 03 July 2007)
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (04 - 10 July 2007)

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

- very low
- low
- moderate
- high

County with SBR infected sites

Positive, # of spores unknown

First set of spatially clumped positive observations

IAMS predicted transport and deposition up the Mississippi River valley but not as far as the continental interior
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(04 - 10 July 2007)

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Spore Collections

- Positive, # of spores unknown
- Positive, very few spores
- Low
- Moderate
- High

IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

very low  low  moderate  high

County with SBR infected sites

NOAA HYSPLIT MODEL
Forward trajectories starting at 1700 UTC 05 Jul 07
GLAS Meteorological Data
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(11 - 17 July 2007)

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- **County with SBR infected sites**
  - Red

- **IAMS Wet Deposition Output**
  - Viable SBR Spores/Land Area (#/ha)
    - very low
    - low
    - moderate
    - high

- **SBR Spore Collections**
  - Positive, very few spores
  - Low
  - Moderate
  - High
  - Positive, # of spores unknown
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(18 - 24 July 2008)

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SBR Spore Collections
- Positive, very few spores
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- Positive, # of spores unknown

IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
very low  low  moderate  high

County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(25 - 31 July 2007)

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
- very low
- low
- moderate
- high

County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(01 - 07 August 2007)

IAMS predicted moderate spore deposition in 2 counties in Kansas
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (08 - 14 August 2007)

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

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SBR Spore Collections
- Positive, very few spores
- Low
- Moderate
- High
- Positive, # of spores unknown

42 infected counties in South, mostly west of the Mississippi River
Strong mid-latitude cyclone traversed Midwest advecting heat, moisture, and SBR spores from TX and LA
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(15 - 21 August 2007)

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

- very low
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- moderate
- high
- Positive, # of spores unknown

Tropical Storm Erin made landfall in TX traversed 20 counties with fields infected with SBR
SBR found in continental interior about 5 weeks later
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(22 - 28 August 2007)

Confusion Matrix

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Low pressure center became established over the Great Lakes with strong winds blowing from northern TX and OK northeastward
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections  
(29 August - 04 September 2007)

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SBR Spore Collections
- Positive, very few spores
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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
- very low
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County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(05 - 11 September 2007)

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SBR Spore Collections
- Positive, very few spores
- Low
- Moderate
- High
- Positive, # of spores unknown

County with SBR infected sites

Lack of correspondence

Last week in 2007 for which we have spore collections
Disappeared from the winter monitoring sites in coastal LA and eastern TX
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(14 - 20 May 2008)

Weather was generally dry throughout the South
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(21 - 27 May 2008)

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SBR Spore Collections:
- Positive, very few spores
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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

- very low
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County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(28 May - 03 June 2008)

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IAMS Wet Deposition Output
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SBR Spore Collections
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County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(04 - 10 June 2008)

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Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(11 - 17 June 2008)

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SBR Spore Collections
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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
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County with SBR infected sites

Map showing the distribution of SBR infected sites and IAMS wet deposition output.
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (18 - 24 June 2008)

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IAMS Wet Deposition Output
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- very low
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SBR Spore Collections
- Positive, very few spores
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- Positive, # of spores unknown

County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(25 June - 01 July 2008)

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SBR Spore Collections
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County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (01 - 08 July 2008)

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SBR Spore Collections
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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
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County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(09 - 15 July 2008)

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SBR Spore Collections
- Positive, very few spores
- Positive, moderate
- Positive, high
- Positive, # of spores unknown

IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
- very low
- low
- moderate
- high

County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(16 - 22 July 2008)

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

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- high

SBR Spore Collections
- Positive, very few spores
- Low
- Moderate
- High
- Positive, # of spores unknown

County with SBR infected sites
By the end of July, outside of the state of FL, SBR was only known to be present in 3 counties west of the Mississippi River, 1 county in extreme southern GA, and in 2 counties along the AL coast.
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(13 - 19 August 2008)

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Confusion Matrix:

- IAMS: Very low
- IAMS: Low
- IAMS: Moderate
- IAMS: High

SBR Spore Collections:
- Positive, very low
- Positive, low
- Positive, moderate
- Positive, high
- Positive, # of spores unknown

IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)

- Very low
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County with SBR infected sites
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections (20 - 26 August 2008)

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IAMS Wet Deposition Output
Viable SBR Spores/Land Area (#/ha)
- very low
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- moderate
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Tropical storm Fay brought abundant rain to the southeast in late August
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(27 August - 02 September 2008)

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SBR found in west-central Mississippi and shortly thereafter in other counties in the Delta
Hurricane Gustov made landfall in Louisiana
SBR found in continental interior about 1 month later
Comparison of IAMS Spore Deposition Predictions and SBR Spore Collections
(10 - 16 September 2008)

Hurricane Ike made landfall in eastern Texas

Last week in 2007 for which we have spore collections
Weeks when IAMS predictions and rainwater spore collections caused confusion.
Scenario for SBR Long-Distance Aerial Spread into Continental Interior

1. Pathogen overwinters on kudzu (and perhaps other hosts) along Gulf Coast and perhaps on islands in the Caribbean basin

2. Disease spreads into commercial soybean fields in South
   Appears to occur when 3 conditions are met:
   • Host is available
   • Prolonged periods of wet weather
   • Temperatures not too hot
3. Inoculum levels increase to high levels in commercial soybean fields in South. Combination of conditions occur:
   • continuation of wet weather
   • onset of cool weather
   • maturation of crop beyond stage that requires fungicide application for maintaining yield

4. *P. pachyrhizi* spores are blown to commercial fields in the interior of North American. Requires:
   • large scale southerly airflow associated with either tropical or mid-latitude storm system
Plenty of inoculum in MS but no transport event for over 1 month
Animation constructed by Arnalisa Ariatti, Penn State University
Week of initial transport event

2006

2007

SBR already found in continental interior

2008

2009

Week of initial transport event

Days on the calendar below are clickable

Animation constructed by Arnalisa Ariatti, Penn State University
SBR is found in continental interior 5 wks after likely transport event.
SBR is found in continental interior 3 wks after transport event
SBR is found in continental interior 6 wks after initial transport event.
Complementary Nature of Aerobiology Models and Rainwater Spore Collections

Aerobiology models are strongly dependent on knowing the geographic distribution and strength of inoculum sources. Rainwater spore collections are not.

Rainwater spore collections cannot distinguish between viable and non-viable spores. Aerobiology models keep track of spore viability.

Rainwater spore collections are point measurements of spore deposition. Aerobiology models predict geographic patterns of spore deposition.
Summary

1. Correspondence between IAMS model predictions and rainwater spore collections for continental interior is good.

2. We are able to predict long-distance transport of SBR spores into North American continental interior with reasonable accuracy.

3. Length of time between predicted deposition of viable spores and detection of SBR symptoms in continental interior is many weeks and variable (3 wks in 2006, 5 wks in 2007, and 6 wks in 2008)
Prospects for SBR Monitoring/Prediction Components in 2010

Reduced funding for sentinel plots

No funding for SBR rainwater spore trapping

No funding for SBR ensemble forecasting program

No funding for SBR national coordinator/data manager position
Thank You