Large-scale assessment of climate suitability for wheat blast in Asia

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1) Motivation

2) Objectives, methods and data used

3) Results
   – Spatial and interannual patterns
   – Drivers of interannual variability
   – Uncertainties and limitations

4) Concluding remarks
Motivation

Wheat blast today

- *Magnaporthe oryzae Triticum* (MoT)
- Spike infection during heading stage
- Partial to total grain loss (e.g. up to 90%)

Serious threat for food security in developing countries

Spread pattern?

- South America 1985 (3M ha)
- Bangladesh 2016 (15,000 ha)
- Zambia 2018

Cultural versus biophysical factors
Motivation

A big picture...

Climate (weather) a major driver of fungal diseases
How suitable are background conditions?

Increasing wheat yields and production
Motivation

A big picture...

In the context of the development of climate information services:

To provide a general overview of the spatial and temporal variability of climate suitability for the development of wheat blast in Asian wheat producing countries

Tools to address potential threat, research prioritization, risks assessments...
Approach

- Generic infection model
- Wheat phenology model
- Climate forcing data
- Boundary conditions data

Seasonal (heading stage) number of potential wheat blast infections (NPI)

Analysis: variability and drivers
Infection model

Generic fungal infection model* of potential wheat blast outbreaks

- **Temperature** response function

\[ f(T) = \left( \frac{T_{\text{max}} - T}{T_{\text{max}} - T_{\text{opt}}} \right) \left( \frac{T - T_{\text{min}}}{T_{\text{opt}} - T_{\text{min}}} \right)^{\left( T_{\text{opt}} - T_{\text{min}} \right) / \left( T_{\text{max}} - T_{\text{opt}} \right)} \]

- \( f(T) \) scaled to **wetness duration** requirements \( W(T) \)

\[ W(T) = \begin{cases} \frac{W_{D_{\text{min}}}}{f(T)}, & \text{if } \frac{W_{D_{\text{min}}}}{f(T)} < W_{D_{\text{max}}} \\ 0, & \text{elsewhere} \end{cases} \]

- Impact of critical **dry periods** (\( D_{50} \))

\[ W_{\text{sum}} = \begin{cases} W_1 + W_2, & \text{if } D \leq D_{50} \\ W_1, W_2, & \text{elsewhere} \end{cases} \]

\( W_{\text{sum}} \): sum of the wetting periods

\( D_{50} \): duration of a dry period with relative humidity < 95% that will result in a 50% reduction in disease compared with a continuous wetness period

\( \text{RH}, f(T) \rightarrow \text{infection event} \)

*Magarey et al. 2005*
Phenology model

Heading stage timing and duration: Wang and Engel (1998) model

Wheat phenology using only air temperature as forcing variable

- **Emergence day**: constant thermal time of 125 GDD after sowing date

- **Phenology** calculated as daily developmental rate for vegetative and reproductive phases

Response functions for **temperature** \( (T) \), **photoperiod** \( (p) \) and **vernalization** \( (v) \)

\[
R_v = R_{max,v} f(T) f(P) f(v) \quad \rightarrow \quad \text{Winter wheat varieties}
\]

\[
R_v = R_{max,v} f(T) f(P) \quad \rightarrow \quad \text{Spring wheat varieties}
\]
Data used: model forcing

ERA5 atmospheric reanalysis: hourly forcing, 1980 through 2019

- European Center for Medium Range Weather Forecasting (ECMWF)
- 31 km $\times$ 31 km spatial resolution, 137 vertical levels
- 4D-Var data assimilation scheme to combine climate model outputs and multiple observations sources

Air and dewpoint temperature for infection model
Air temperature for phenology model
Data used: boundary conditions

Spatial Production Allocation Model SPAM 2010 v1.0 global data

Wheat production to wheat grid presence

Crop Calendar Dataset of Sacks *et al.* (2010)

Spring wheat derived from Iizumi *et al.* (2019)
Probabilities of winter wheat = 0
Results: climatology of NPI

- From *low* to *high* pressure
- Range 1 (min) to 55 (max) NPI
- High spatial variability
- Hotspots of climate suitability

**Average NPI (1980-2019)**

- Indian *breadbasket* Indo Gangetic Plains
- Bangladesh
Results: climatology of NPI

Interannual variability by country

**Total** annual number of NPI by country

**Normalized** by infected area
Results: the relationship with climate anomalies

Percentile 66% of NPI

- Association with temperature not very clear
- Relative humidity: positive anomalies
- Precipitation: dry season
- Temperature response function (non linear)
- Air water content
Results: the relationship with climate anomalies

NPI during warm years (P66% of temperature)

Large area in India and Bangladesh with positive anomalies in NPI

Associated dynamical factors?

NPI during humid years (P66% of RH)
Results: the relationship with global drivers

**El Niño - Southern Oscillation (ENSO)**

Periodic fluctuation in sea surface temperature (El Niño) and atmospheric pressure (Southern Oscillation) across the equatorial Pacific Ocean.

**The Indian Ocean Dipole (IOD)**

Anomalous SST gradient between western equatorial and south eastern equatorial Indian Ocean.
Results: the relationship with global drivers

Oceanic ENSO index (ONI)

El Niño years

La Niña years

(+): anomalies in NPI

(−): anomalies in NPI
Results: the relationship with global drivers

Dipole Mode Index (DMI)

Positive years

Negative years

(+ ) anomalies in NPI

(− ) anomalies in NPI
Results: potential seasonal predictability

Can the *background* seasonal conditions be predicted?


**Bangladesh, mean DJF temperature**

**India, mean DJF temperature**
Uncertainties and limitations

Some relevant parameters not easy to measure or not available in the literature

**D50**: duration of a dry period that will result in a 50% reduction in infections

Sensitivity to dry interruption:  
- **Sensitive**: 1-2 h  
- **Moderate**: 4-20h  
- **Insensitive**: >= 24 h

**D50 = 1 to 10-15**

**D50 = 15 to 30**

Reliable range of values?
Uncertainties and limitations

Other sources of uncertainties:

• Other parameters for infection model
  • Sensitivity analysis
• Parameters for phenological model
  • Large domain, high uncertainty
  • Most parameters generated for other latitudes
• Fixed planting dates
Conclusions

- High **spatial and temporal variability** in climate suitability for wheat blast
- **Hotspots** concentrate in India and Bangladesh
- High interannual variability: variable suitable conditions
- Clear relationship with **ENSO and IOD anomalies**
- **ENSO** influences NPI anomalies over an area larger than IOD
- NPI anomalies associated with **IOD** phases are stronger
- Potential seasonal **prediction** of favorable conditions
  - Bias correction of GCMs (NMME)
  - Empirical statistical forecasting of NPI using SST indices
Thank you

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