Global Wheat Rust Monitoring Systems

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Food System Impacts of Pests & Pathogens in a Changing Climate, August 19-23, 2019, Aspen, CO
An Increasing Threat
– Transboundary Pathogens & Pests

• Rate of spread, appearance in new areas, detection of new races (diseases) is increasing
  – Drivers: Globalization (trade, travel), Selection pressure (uniform cropping systems), climate change

Pathogen Surveillance & Monitoring Systems increasingly needed.
Pathogens without Borders

- Wind-borne dispersal of fungal spores (e.g., wheat rusts) across or even between continents [Wheat Stem Rust: Southern Africa – Australia]
- Accidental travel/trade-borne transmission – increasing with globalization [Wheat Stripe Rust: Western Europe – Australia]
The Problem: Combating Cereal Killers

- **Wheat Rusts:** Highly mobile, extremely destructive and constantly changing!
  - Stem rust – most destructive disease on wheat, historically the most feared disease
  - Under favourable conditions, capable of causing 100% crop loss within weeks
  - Yellow rust currently the biggest global biotic threat
  - Stem Rust – the “defeated disease”, a major agricultural success story of 20th century
  - New race: Ug99 (Uganda 1999) – realization that large % of world’s wheat suddenly susceptible
  - Re-emergence of stem rust + rise of yellow rust
SURVEILLANCE AND MONITORING

DRRW/DGGW partners operate one of the world’s largest international crop disease monitoring systems.

As of 2019, over 35,000 geo-referenced survey records and 9000+ rust isolates records have been collected in 40 countries.

The surveillance system provides early warning of potential rust epidemics to scientists and farmers.

CIMMYT senior scientist Dave Hodson teaches field survey protocols to SAARC trainees.
Global Wheat Rust Monitoring

2005
Global Wheat Rust Monitoring

2018

- 35,000+ survey records
- Covers 40+ countries: large % of developing world wheat
- Most comprehensive, operational monitoring system for major crop diseases
Evolution and spread of races belonging to Ug99 lineage of stem (black) rust fungus

- Ug99 is mutating and migrating
- 14 races now known. Presence in 13 countries confirmed
- 80-90% wheat varieties/germplasm susceptible or with inadequate resistance in 2006
- Launch of Borlaug Global Rust Initiative in 2005 (DRRW project in 2008)
- Global stem rust threats now extend beyond Ug99
Stem Rust is re-emerging as a disease of concern
- Clade III (TTRTF) and IV (TKTTF) races now dominating over Ug99 races in East Africa
- High Race Diversity (Sexual populations): Georgia, Siberia/Kazakhstan, Sweden
- Caucus region – important role?

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Visual Content:
- World map highlighting regions affected by Stem Rust
  - UK (2013)
  - Sweden (2017)
  - Germany (2013)
  - Siberia/Kazakhstan (2015+)
  - Ethiopia (2013, 20-50,000 ha)
  - Italy (2016+)
  - Ecuador (2016)
  - 3 Million ha

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Source: Nature article on Stem Rust.
Recent Stripe Rust Races Spreading Across Globe

- New Emerging Genetic Groups of Yellow Rust
- Spreading Extremely Quickly
- Large Scale Epidemics

Yellow rust spores released when harvesting triticale for forage in the Huesca province, Spain. Source: Lluís Xanxo / Dolors Villegas, IRTA, Spain May 2019
New Technologies

Models to MinIONs
Advanced Spore Dispersal Model (NAME model, UK Met Office)

Big Data Approach (20TB Data + UK Met Office supercomputer)

First quantitative estimates of spore dispersal to different regions and continents

Models give a risk assessment framework e.g., how likely stem rust to move into South Asia?

Real-time forecasting part of an early warning system – Ethiopia

Predicting many of movements we now seeing globally

Quantifying airborne dispersal routes of pathogens over continents to safeguard global wheat supply

M. Meyer et al. 2017 Nature Plants
Real-time, Mobile Pathogen Diagnostics

- First field testing of Nanopore sequencing in Ethiopia – Sept 2018
- First ever application on a rust fungal pathogen
- It works! Field samples to diagnostic in 2 days!!
- Results already incorporated into national rust early warning system

NB: Only detects genetic group. No replacement for pathotyping.
Ethiopia: Rust Early Warning Framework

Partnerships to create one of the most advanced crop disease forecasting / early warning systems in the world

- 7 day forecast models for dispersal and risk
- Dispersal + Suitability $\rightarrow$ Risk
- Survey Data (automatic)
- 7 day forecast (automatic)
- Field Survey (17 centres)
- AI Phone Detection (in development)
- Near real-time data (ODK)
- Crowdsourced Phone Surveys 4+ million subscribers
- Weekly Advisories

EIAR Central Early Warning Unit (Integrated Data hub)

- Near Real-time Diagnostics
- Wheat Rust Toolbox Global Data Management System
- Reach (SHF/Extension): Advisories >150,000 ; SMS >500,000
- Early warning for action
- “Control ahead of disease in key areas”

MoAL
- Regions
- Ext

Targeted SMS alerts 4+ million subscribers

Weekly Advisories

MinION

Ethiopian ATA

Crowdsourced Phone Surveys
4+ million subscribers

4+ million subscribers

Survey Data (automatic)
Concluding Remarks

• Made advances regarding rust surveillance. Probably most comprehensive, operational monitoring system for major crop diseases
• Ug99 race group investments / learning now being applied to other important races (and other rusts)
• New races continuing to evolve / future incursions likely – **we must have long-term effective monitoring, sharing of information + strong connections to breeding programs** (role of durable resistant cultivars critical)
• New technologies playing a key role – Molecular diagnostics, dispersal / epidemiology models
• Advanced disease forecasting / early warning
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Partners in national programs in over 35 countries