The Race Against Ug99 Stem Rust in Wheat

World Food Security at Risk?

C. James Peterson
Wheat Breeding and Genetics
W.E. Kronstad Endowed Chair
Oregon State University
Chair, National Wheat Improvement Committee
Wheat Stem Rust

- *Puccinina graminis* – Stem rust
  - Erratic, but devastating fungal disease
  - Obligate pathogen; wind dispersed

- **US wheat production losses**
  - 1917 to 1922 – total losses of 143 M bu
    - *Annual losses of 20% or more in ND, MN, SD*
  - 1935 - 23.9% of US crop
    - >50% of ND and MN
  - 1953 - 8.9% of US crop
    - >35% of ND and SD
  - 1954 - 8.8% of US crop
    - 43% of ND; >18% MN and SD
  - 1962 – 5.2% of US crop
    - 30% of NE; 26% of SD

- Since 1963 – *insignificant disease losses*
Why now the concern?

- Major resistance genes deployed in 1960’s have remained very effective – *but few in #*
  - Sr6, Sr17, Sr24, Sr31 (1B.1R), Sr36, Sr38 (VPM)

- New priorities for breeding, pathology, and funding

- Complacency, reduced funding for rust research

- Worldwide deployment of Sr31 (1B.1R)

- Instability of US and world wheat stocks
  - *Increasing demand for food production*
A highly virulent new race, Ug99 (Pgt-TTKS) appeared in Kenya in 1999.

Virulent on Sr31, Sr38, Sr17, Sr6
Spread of stem rust race Ug99

1998 – Uganda and Kenya

2003 - Ethiopia

2006 - Yemen and Sudan

Singh et al. 2008
Immediate Risk Areas – 19% of World Wheat Production

Key question is.... How quickly ??

Long-distance windborne dispersal
Or
Step-wise movement
Or
‘Assisted’ movement
Increasing virulence of Ug99 in Kenya

2006 - variant identified with virulence to Sr24, key resistance gene in Plains winter wheats
2008 – variant identified with virulence to Sr36, key resistance gene in Eastern wheat region
Migration of stem rust race Ug99

- 2008-09: Sr24 variant of Ug99 is now major race in Kenya
- 2007: Ug99 is confirmed in Iran
- 1998 to 2009

Map showing the migration of stem rust race Ug99 from 1998 to 2009.
Global Rust Summit, 2005
Njoro, Kenya
– Call to action by Dr. Norman Borlaug

Borlaug Global Rust Initiative
– CIMMYT, ICARDA co-organizers
– Coordinate funding, research initiatives
– International Conferences, Workshops

“If we fail to contain Ug99 it could bring calamity to tens of millions of farmers and hundreds of millions of consumers. We know what to do and how to do it. All we need are the financial resources, scientific cooperation, and political will to contain this threat to world food security”

Norman E. Borlaug, Nobel Laureate and Father of the Green Revolution
Initial Strategies, Gene Deployment

- **Immediate value - race specific genes**
  - Sr22, 26, 35, Tmp, 1A.1R, Sha7; Sr25/Lr19

- **Shuttle breeding (Kenya x Mexico)**
  - 2 cycles per year; screening worldwide germplasm

- **Worldwide distribution of resistance genes / parents**
  - CIMMYT international nurseries

- **New breeding targets, gene pyramids**
  - Multiple race-specific resistance genes
  - Minor genes, adult plant, durable resistance
  - Molecular marker development

- **Fungicides** – short term response
  - Availability, effectiveness, cost in developing countries??
Durable Rust Resistance in Wheat

- Bill and Melinda Gates Foundation – 2008
  - Led by Cornell University
  - $26.7M to international agencies over 3 yrs

- Resistant varieties for developing countries
  - Global awareness, coordinated response
  - Pathogen and race monitoring
  - Improved screening facilities in Africa
  - Applications of molecular markers
  - New sources of resistance
USAID Famine Seed Project
$5.1M for 2008-09 to 2010-11

• Emergency support for ‘pre-release’ seed increase
  – Initial resistant wheat germplasm from CIMMYT
  – 11 lines, 2275 kg of seed in 2008; target 10-100 tons for release

• Seed produced 2009 – 52.6 ha; 142 tons
  – Egypt 21 ha 81 tons 3 lines
  – Ethiopia 6 ha TBA 8 lines
  – Nepal 7.5 ha 18 tons 8 lines
  – Bangladesh 7 ha 12 ton 3 lines
  – Pakistan 9 ha 24 tons 3 lines
  – Afghanistan 2 ha 9 tons 6 lines
  (+1.5 tons of ‘Misr 1’ from Egypt)

• Other increases of CIMMYT lines (self-supported)
  – Iran >300 ha; multiple lines
  – India 700 ton; multiple lines
Vulnerability of Production to New Races of Wheat Stem Rust

Acreage based on 2009* Variety Survey Data

- Red: Susc. to Pgt-TTKS
- Orange: Susc. to Sr24 variant
- Green: Resistant
- Black: Unknown

Potential production losses of 200 to 500 million bushels

*Note: Eastern region are % of cultivars grown in 2008, as variety survey data are unavailable
Reaction of Wheat Germplasm in 2008-09 USDA-ARS Regional Nurseries to Stem Rust

- Susc. to Pgt-TTKS
- Susc. to Sr24 variant
- Susc. to Sr36 variant
- Resistant

The map depicts the distribution and reaction of wheat germplasm across the United States in 2008-09 USDA-ARS Regional Nurseries, with different colors and pie charts indicating susceptibility to various stem rust variants.
US Strategies and Response

- **USDA-ARS initiates screening in Kenya**
  - Over 14,000 lines screened since 2005
    - 28 Universities; 11 companies; 8 ARS Res. Units
  - Seedling evaluations in containment facility in MN

- **Immediate value, deployed in US**
  - 1A.1R; TMP, Thatcher, Sr2 (partial, rare)

- **Gene discovery, enhancement underway**
  - Exotics, synthetics, weedy relatives, Int. sources
  - Regional ARS Markers labs; identify, track genes
  - Support for international germplasm exchange

- **Action plans / Initiatives**
  - Cereal Rust Disease Initiative, NWIC / NAWG (2006)
  - Ug99 Action Plan, USDA-ARS (2008)
  - National Plant Disease Recovery Plan (2010)
US Progress on Stem Rust

• New appropriations for Ug99 Research
  – $1.50M to USDA-ARS in FY09
  – $1.58M to USDA-ARS in FY10

• Increased USDA-ARS Rust Pathology and Support
  – New scientist, technical support
    • Cereal Disease Laboratory, St. Paul, MN
  – Additional technical staff, lab and field support
    • NC, KS, ND, ID, WA
  – Enhanced field and laboratory capacity, screening
  – Support for application of molecular markers
  – Gene discovery, pre-breeding

• DNA Sequence of rust organism - 2007
  – New insights into pathogen, genetic control
How much time do we have??

- Dozens of major US varieties must be replaced
  - All regions, all market classes at risk (except PNW)
- Variety development takes time, $’s
  - 8-12 years from cross to release (+ seed increase)
- Few effective resistance genes remain
  - Rust evolves quickly; how long will these last?
  - Many genes in unadapted, weedy backgrounds
- Need for added support, infrastructure
  - Pathology, entomology, end-use quality, molecular markers, doubled haploid, agronomy, management
Increasingly aggressive new races of stripe and leaf rust diseases also have appeared since 1998 costing US growers millions in lost production.

**Leaf rust**

*Production losses:*
- US: 100M bu ($400M) for 2000-04
- KS: 50M bu ($200M) for 2007

**Stripe rust**

*Production losses:*
- US: $360M in 2004
- KS: $240M for 2001-03

Stem rust is not the only rust problem...
Time for a Renewed Commitment to US and International Agricultural Research

‘It’s not just about productivity and economics, it’s now an issue of world food security’……..

For additional information:
www.wheatworld.org/issues/research