# Current status of Ug99 stem rust and plans to mitigate the threat to wheat production losses

**Financial resources to CIMMYT work:**

**DRRW Project, Cornell**
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Presented by: Ravi P. Singh


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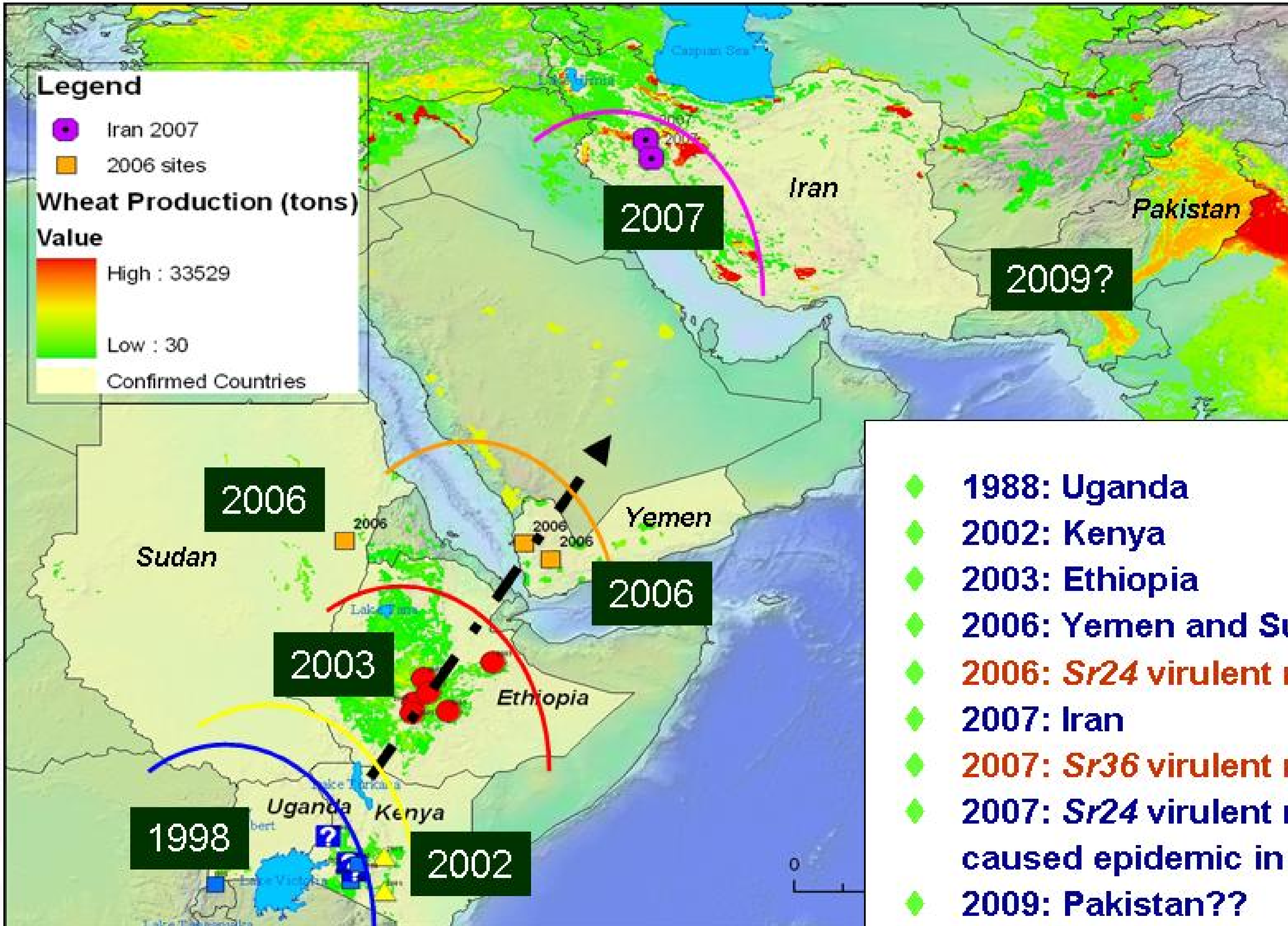
# Green Revolution and the Control of Stem Rust over four decades

- High yielding semidwarf wheat varieties
- Resistance to stem and other rusts
- Photo-insensitivity
- Responsiveness to fertilizer and water

# Returning back of stem rust as Ug99

- A race of *Puccinia graminis tritici*
- Causes stem (or black) rust disease on wheat, barley and triticale and disease spreads through wind transmitted spores (urediniospores)
- First found in Uganda by Dr. William Wagore in 1998 on Wheat Nurseries grown at Kalingree
- Confirmed to be a unique race in 1999 (hence called Ug99) by Pretorius et al.
- Remained at non-significant levels until 2002 when found in Kenya and 2003 in Ethiopia

# Ug99: migration and evolution: *current status*




- 1988: Uganda
- 2002: Kenya
- 2003: Ethiopia
- 2006: Yemen and Sudan
- 2006: *Sr24* virulent mutant-Kenya
- 2007: Iran
- 2007: *Sr36* virulent mutant-Kenya
- 2007: *Sr24* virulent mutant-caused epidemic in Kenya
- 2009: Pakistan??

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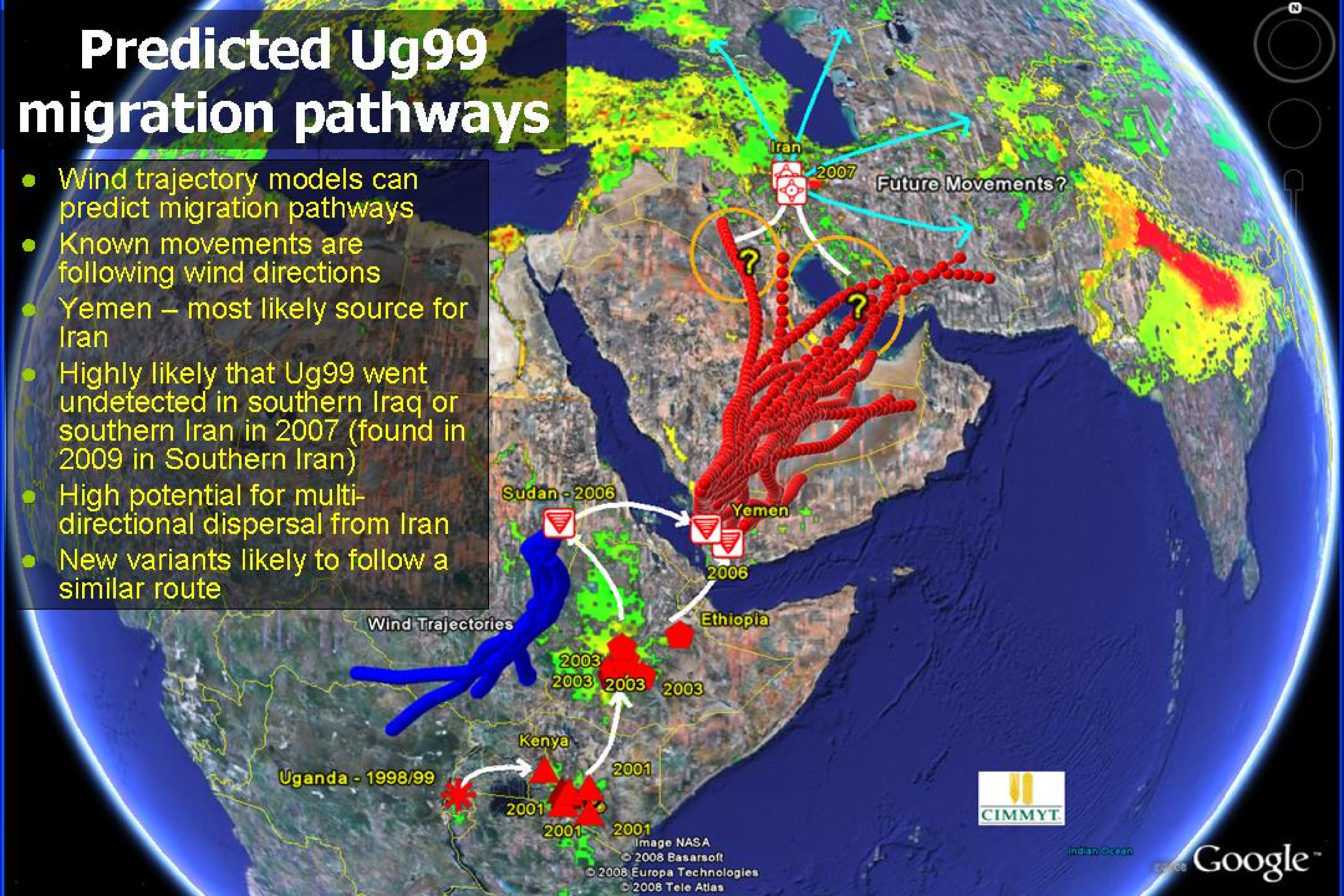
# Predicted Ug99 migration pathways

- Wind trajectory models can predict migration pathways
- Known movements are following wind directions
- Yemen – most likely source for Iran
- Highly likely that Ug99 went undetected in southern Iraq or southern Iran in 2007 (found in 2009 in Southern Iran)
- High potential for multi-directional dispersal from Iran
- New variants likely to follow a similar route



# Why Ug99 is a threat to wheat producing countries?

- Historical importance of stem rust
- Span of susceptible wheat varieties on >80% area
- Favorable environment (dew/rain and temperatures) for disease build up
- Mountains and other areas where Ug99 can survive during off-season
- Ug99 already in Iran and possibly in Pakistan
- Predicted migration to other regions including South Asia
- Continued evolution giving rise to new biotypes that overcome additional resistance genes
- Early epidemics can cause >70% losses
- If measures not taken, estimated 10% losses in production in South Asian countries alone can be worth approx. US$1.5 billion and will provoke sharp increases in wheat prices

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# Borlaug Global Rust Initiative

## *A multi-institutional partnership for systematically reducing vulnerability of global wheat crop*

- ✓ **Provide farmers with high yielding, rust resistant varieties**
- ✓ Rust surveillance for an early warning system
- ✓ Short term chemical control intervention strategies
- ✓ Diverse genetic resistance in global wheat germplasm
- ✓ New breeding strategies to develop Ug99 resistant varieties
- ✓ Seed multiplication and diffusion of resistant varieties
- ✓ Human capacity and infra-structure building
- ✓ Research advocacy

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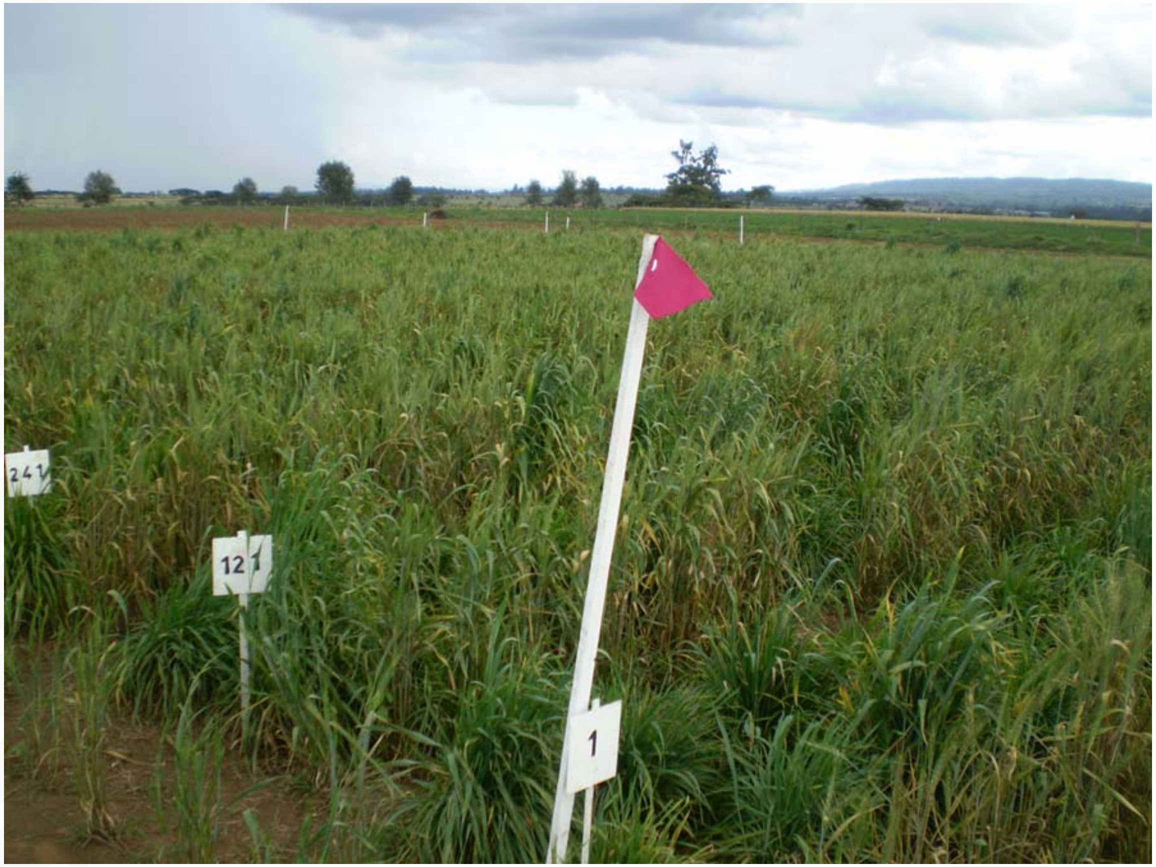
# Ug99 screening facilities for global wheat materials in East Africa

- Screening initiated in 2005
- Njoro Wheat Research Station, KARI, Kenya (bread wheat)
- Debre Zeit Research Station, EIAR, Ethiopia (durum wheat)
- Two crop seasons per year
- Upgrading of greenhouse/lab. facilities at Njoro (Kenya) and Ambo (Ethiopia) underway for race-analysis, inoculum multiplication, resistance characterization, etc.
- CIMMYT scientist posted in Kenya for facilitation
- *>28,000 wheat introductions evaluated in Kenya during 2009*

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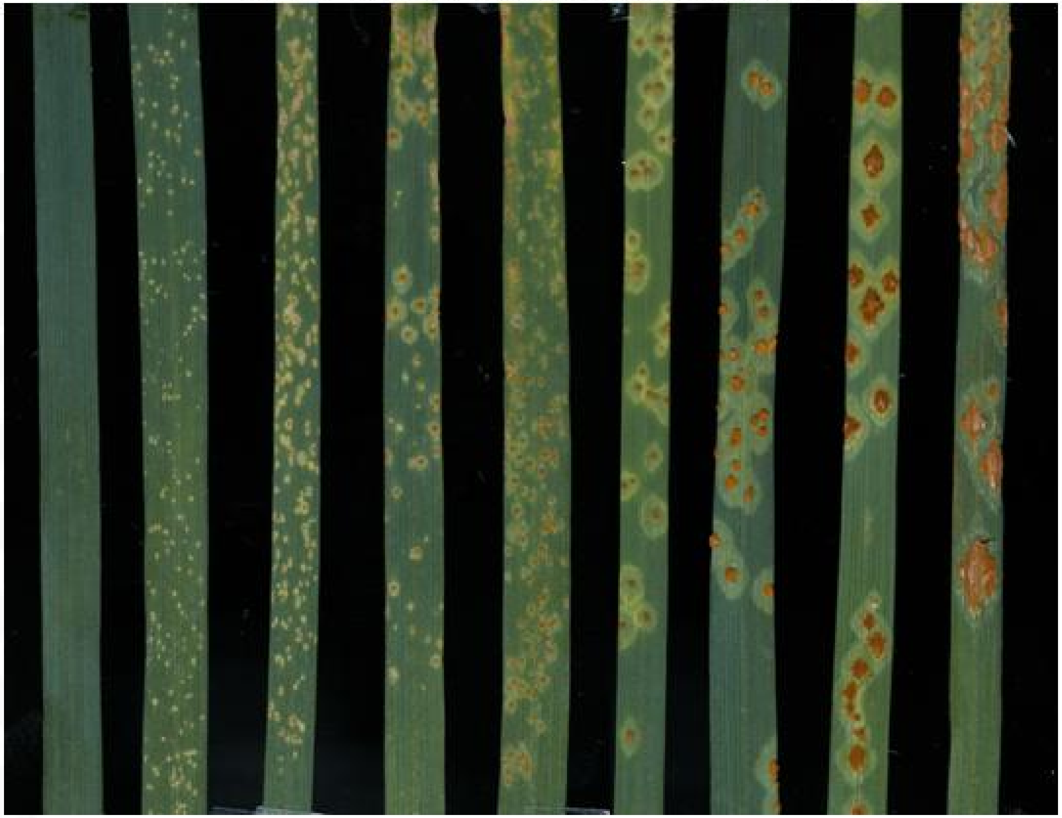
# Diversity for race-specific genes effective to Ug99 group of races

- About 20 resistance genes have potential (*Sr13, 14, 21, 22, 25, 26, 27, 28, 29, 33, 35, 39, 40, 43, 44*, *45, Tmp, 1A.1R, Sha7* and a few more)
- Most effective genes transferred to wheat from alien species and genera
- Virulence known in other races for nine genes (*Sr13, 14, 21, 25, 27, 28, 45, Tmp, 1A.1R*)
- Immediate value: *Sr22, 26,* 35 and *Sha7;* and to a lesser extent *Sr13, 14, 25, 45, 1A.1R* and *Tmp* for use in combinations
- *Translocations being shortened to reduce the negative effects and new genes being searched*

Drawback: resistance is overcome by new virulent races if not deployed properly

Seeding infection types



-----------------Resistant-------------- Susceptible

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# Durable adult-plant resistance (APR) to stem rust

## *Sr2*-Complex
## (*Sr2* and other minor genes)

- *Sr2* transferred to wheat from ‘Yaroslav’ emmer in 1920s by McFadden
- *Sr2* is linked to pseudo-black chaff
- *Sr2* confers only moderate levels of resistance (about 30% reduction in disease severity)
- Adequate resistance achieved when *Sr2* combined with other unknown genes
- Essential to reduce/curtail the evolution of Ug99 in East Africa and other high risk areas

***Pseudo black-chaff***

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# Identification of durable adult plant resistance to Ug99

- Field evaluation of advanced breeding lines in Kenya/Ethiopia
- Greenhouse seedling tests for susceptibility to Ug99 at USDA-ARS Lab. in St. Paul, Minnesota, US
- Characterization of pseudo-black chaff phenotype and application of *Sr2* molecular marker
- *Identified APR Sources:*

  **Semidwarf:** Kingbird, Kiritati, Juchi, Pavon, Parula, Picaflor, Danphe, Chonte

  **Tall:** Chris, RL6058 (Thatcher+Lr34), Kenya Plume, Kenya Fahari, Kenya Swara

Kingbird-the best source of APR

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# International distribution of diverse sources of resistance to Ug99 in improved backgrounds

- CIMMYT initiated distributing Ug99 resistant materials and relevant data on resistance genes or type of resistance through Stem Rust Resistance Screening Nursery (SRRSN)
  - 2006- 120 sets of 1st SRRSN distributed
  - 2007- 130 sets of 2nd SRRSN distributed
  - 2008- 130 sets of 3rd SRRSN distributed
  - 2009- 130 sets of 4th SRRSN under distribution
  - Data and information on resistance gene/type available on BGRI web: www.Globalrust.org

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# Field performance testing of Ug99 resistant materials for potential variety releases

- Initiated from 2006-2007 crop season through Elite Bread Wheat Yield Trials (EBWYT)
- Targeted to countries growing spring bread wheats considered under high risk
- Goal: to identify new resistant varieties with >5% higher yields than current varieties

# Grain yield performance of eight new Ug99 resistant entries in 4thEBWYT at ten sites in India, 2008-2009

| Entry | Cross Name | Grain yield kg/ha | Grain yield % Check |
|---|---|---|---|
| 501 | LOCAL CHECKS | 3460 | 100 |
| 529 | WHEAR/SOKOLL | 3959 | 114 |
| 527 | WAXWING*2//PBW343*2/KUKUNA | 3937 | 114 |
| 516 | BECARD | 3857 | 111 |
| 502 | MUNAL #1 | 3828 | 111 |
| 510 | PBW343*2/KUKUNA//PBW343*2/KUKUNA | 3823 | 110 |
| 526 | PRL/2*PASTOR//PBW343*2/KUKUNA/3/TACUPETO F2001*2/KUKUNA | 3808 | 110 |
| 525 | PFAU/SERI.1B//AMAD*2/3/PBW343*2/KUKUNA | 3758 | 109 |
| 509 | PBW343*2/KUKUNA//PBW343*2/KUKUNA | 3705 | 107 |
| | l.s.d. (P = 0.05) | 199 | |
| | CV (%) | 8.8 | |

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# Grain yield performance of seven new Ug99 resistant entries in 4thEBWYT at 5 sites in Pakistan, 2008-2009

| | | Grain yield | |
|---|---|---|---|
| Entry | Cross Name | Kg/ha | % Check |
| 501 | LOCAL CHECKS | 3193 | 100 |
| 508 | WHEAR//INQALAB 91*2/TUKURU | 3615 | 113 |
| 530 | WHEAR//2*PRL/2*PASTOR | 3535 | 111 |
| 515 | WBLL1*2/BRAMBLING | 3447 | 108 |
| 519 | PRL/2*PASTOR//PBW343*2/KUKUNA | 3431 | 107 |
| 529 | WHEAR/SOKOLL | 3370 | 106 |
| 507 | PBW343*2/KUKUNA/3/PASTOR//CHIL/PRL/4/PBW343*2/KUKUNA | 3334 | 104 |
| 518 | BECARD | 3319 | 104 |
| | l.s.d. (P = 0.05) | 299 | |
| | CV ( %) | 4.77 | |

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# Molecular marker development

*Necessary for stacking multiple race-specific resistance genes to enhance their durability*

- Existing information on markers for race-specific genes compiled; markers verified and optimized
- Marker development for additional race-specific genes- a shared responsibility between various research groups to avoid duplications
- Initial mapping identified 3-4 new race-specific genes
- >15 mapping populations developed and phenotyped to map minor resistance genes involved in adult plant resistance

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# Breeding Ug99 resistant wheats for different environments

- Spring bread and durum wheat for irrigated and rainfed areas of South Asia, West Asia, Central Asia, Middle East and Africa **(Primary risk area)**
- Photosensitive Spring wheat for high-latitude areas of Central Asia and China
- Winter, facultative and spring wheat for China
- Winter and facultative wheat for West and Central Asia

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# Breeding approaches

## *Goal: Develop new resistant varieties with 5-10% higher yields and other desirable traits for faster adoption*

### *Near-term*

- **Race-specific, major resistance genes in combinations using molecular markers (fewer options at present- *Sr22, 25, 26, 45, 1A.1R*)**
- **Race-nonspecific, minor resistance genes for adult plant resistance**

### *Long-term*

- **Exploration of genetic mechanism of rust immunity in rice**
- **Development of cassettes carrying multiple resistance genes**

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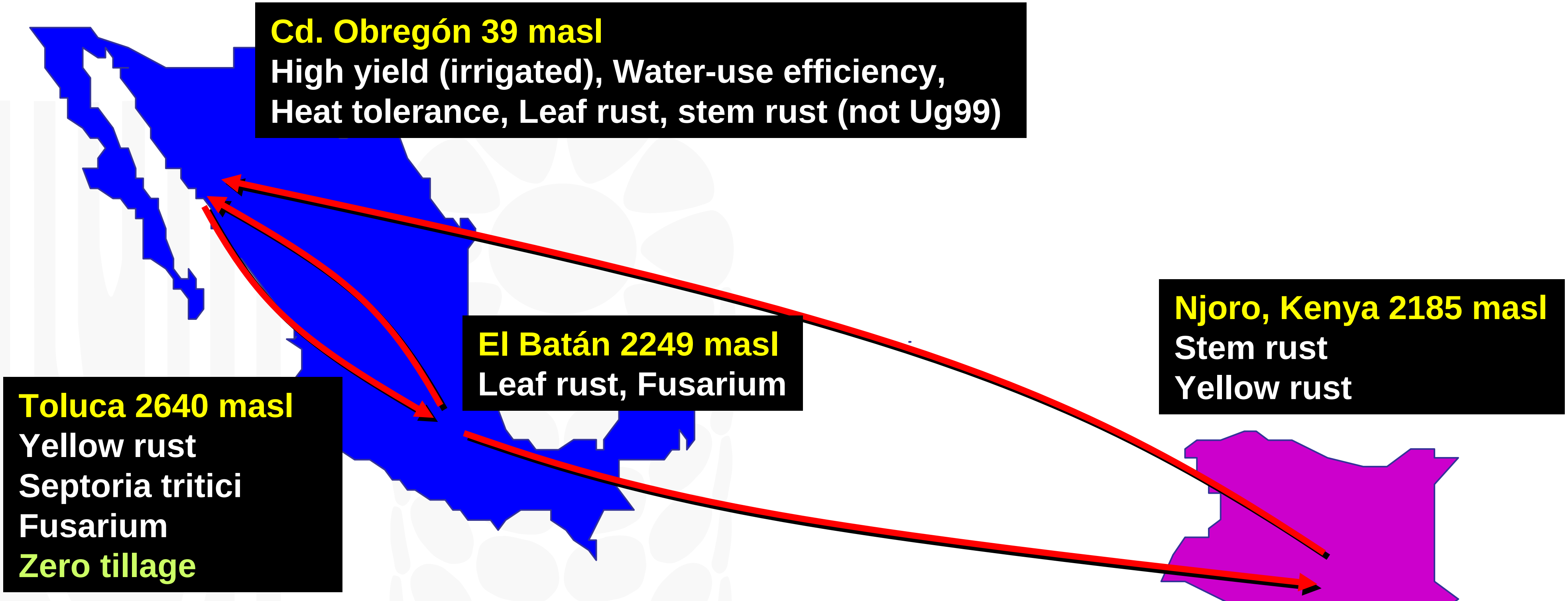
# Breeding for durable, adult-plant resistance at CIMMYT

## *Mexico (Cd. Obregon-Toluca/El Batan)- Kenya International Shuttle Breeding: a five-year breeding cycle)*




- Shuttle breeding between Mexico and Kenya initiated in 2006
- High yielding, resistant lines from 1st cycle of Mexico-Kenya shuttle under seed multiplication for international distribution in 2010
- Breeding initiated by various National Programs. Field based selection at Ug99 sites expected to initiate in coming years.

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# Seed multiplication strategies

- Promote seed multiplication of existing resistant varieties
- Fast-track identification of new resistant varieties with diverse resistance
- Simultaneous seed multiplication and diffusion through ‘Participatory Variety Selection’ and other approaches
- Establish at least 5% wheat area under resistant varieties for seed procurement when necessary

*Ideally identify/breed resistant varieties with superior yields for a faster adoption and to meet future wheat demands*

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# Seed multiplication: *progress*

- Identification of existing resistant varieties in India
- Release of Ug99 resistant varieties: ‘Millennium’ in Ethiopia, ‘Lasani 2008’ in Pakistan and Misr 1 and Misr 2 in Egypt.
- Special funds from USAID to support multiplication and testing of Ug99 resistant varieties in Ethiopia, Egypt, Afghanistan, Pakistan, Nepal and Bangladesh

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# Building Human Capacity

- Workshops

- Hands-on training courses

# Conclusions

- The strong partnership generated by BGRI should mitigate the threat of major Ug99 stem rust epidemics through:
  - Enhanced awareness
  - Pathogen tracking allowing an early warning
  - Development and deployment of varieties with diverse and durable sources of resistance
  - Accelerated seed multiplication and distribution
  - Capacity building
- A well planned research strategy and developmental agenda is necessary for sustainable control of other rusts.

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