



Perspectives on the cereal stem rust pathogen
Thomas Fetch Jr.

Cereal stem rust

Caused by a fungus, *Puccinia graminis*; different f. sp.

Stem rust is the most damaging of all rusts; Can cause complete crop loss in healthy crop (2-3 wk)

Spores are wind-dispersed, rapid-cycle (8-10d), huge spore production (1 Trillion/acre).



Stem rust of barley; NDSU

Stem rust of wheat and barley (Pgt) caused many epidemics in early 1900's, with a major one in 1935. Farmer Sam Lykken saw one green plant in field of Wisc. 37 barley, and increased seed. Ultimately this became 'Kindred barley, source of Rpg1 durable stem rust resistance.



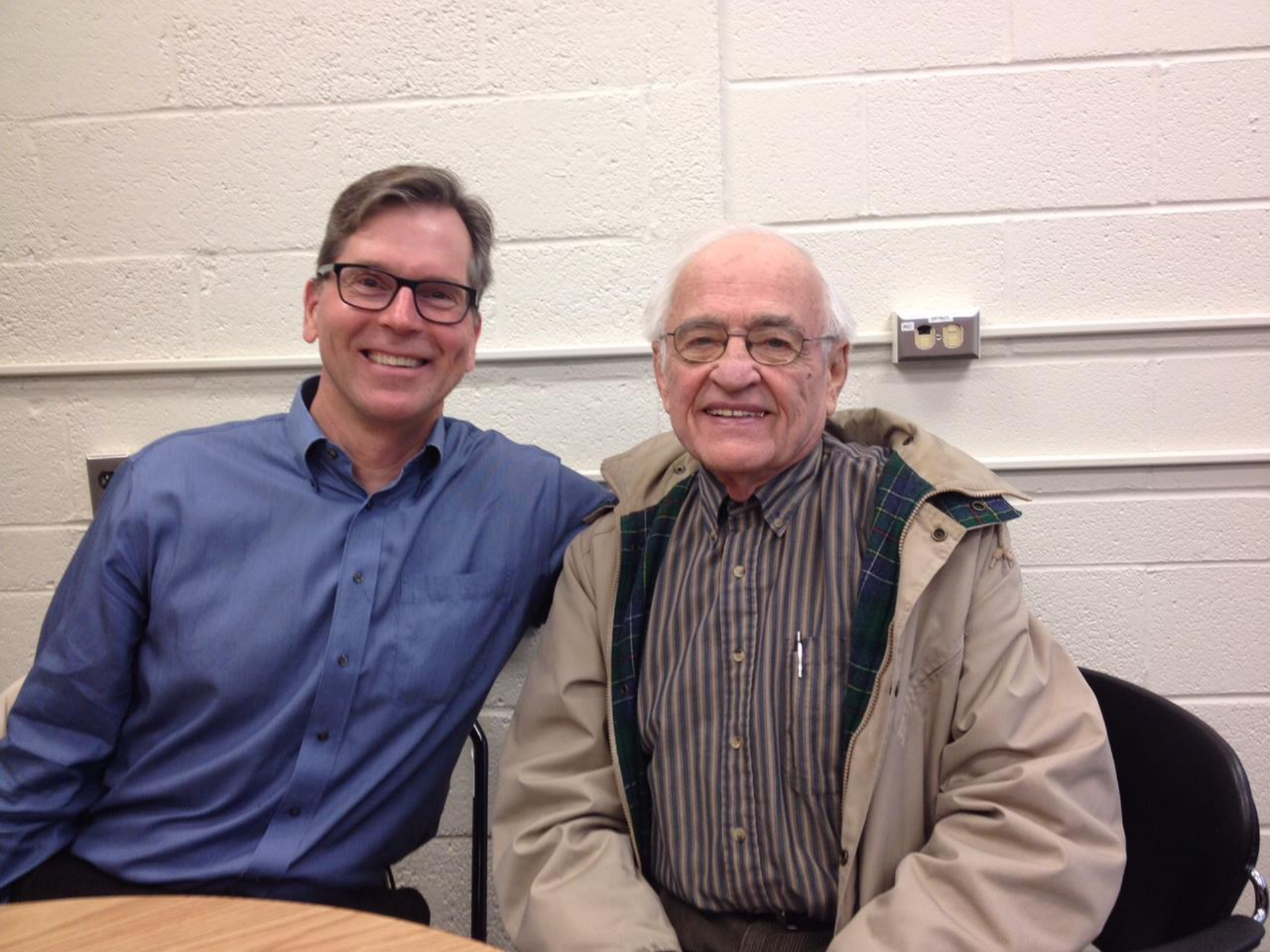
Stem rust of barley; NDSU

Rpg1 was effective against the races found in USA and Canada until 1989, when QCCJ appeared.

QCCJ first described by Martens In 1988, widely found in barley fields in 1989, 1990 and 1991.

QCCJ virulent on USA WW in the Midwest, once removed then it declined in Pgt population.





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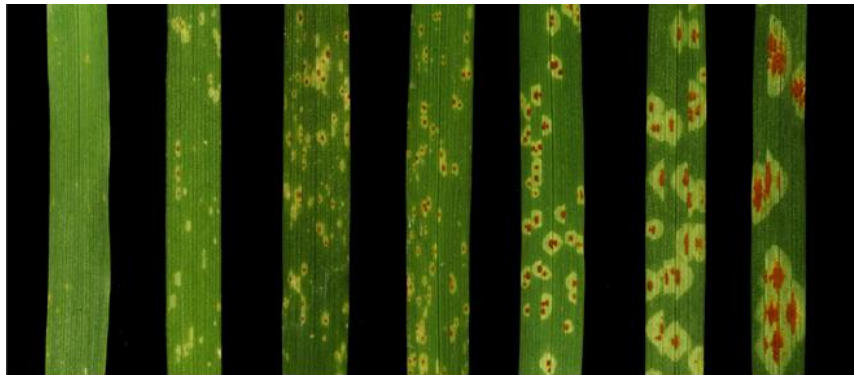


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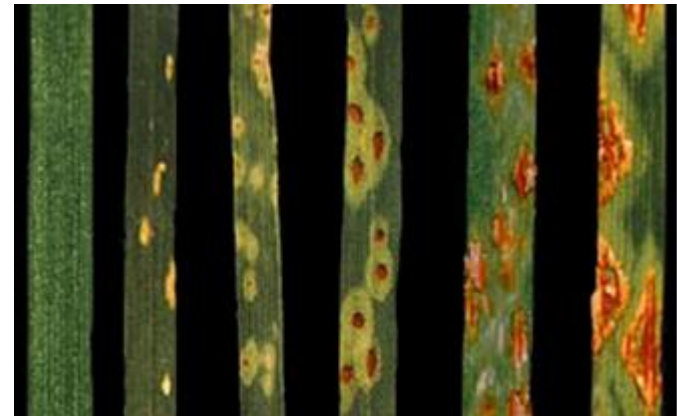
Screened >18,000 barley lines with QCCJ (1994)

Found Q21861 best, rpg4 and rpg5, temperature sensitive

Barley seedlings hard to score, crop resistant until flowering



0; 0;1 10; 12 3-2 3 3+



0 ; 1 2 3 4



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Cereal stem rust

In 2000, hired as AAFC stem rust pathologist at Cereal Research Centre in Winnipeg

Historically, stem rust was most damaging disease of cereal crops in Canada

Remains a Priority 1 disease for breeding wheat, oats, and barley for crop registration



Cereal stem rust

**Initial work was on oat stem rust
due to virulent race NA67**

**Only 17 described oat stem rust
resistance genes (Pg)**

Evaluated 9978 lines from 22

Avena species from 2001-2003

No hexaploid lines were resistant

**Found *A. strigosa* best, hard to
introgress into hexaploid**





Oat Stem rust in farm field near Foam Lake, 2009

2009 9 14

Stem rust of wheat

Caused many minor epidemics in Canada and USA in the early 1900's, with major epidemics in 1916, 1923, 1935. This prompted a meeting in 1924 to resolve the continued and substantial problem of stem rust on wheat, Resulting in construction of Dominion Rust Lab in 1925.



1916 Epidemic Rust Year

5 bu/Ac (12 normal), \$100M CAD, \$200M USD



Dominion Rust Laboratory, built 1925-1926



Rust Lab construction





DOMINION
RUST
RESEARCH
LABORATORY



Carton from Free Press,
April, 1929.

Research Laboratories Raise Rust-Resistant Wheat



'Renown' wheat - 1936

Encouraging results are being obtained by the Dominion Rust Research bureau in the effort to secure a rust-resistant wheat for Western Canada. One variety, originated by C. H. Golden, in charge of the breeding work at the laboratory, gave considerable promise this year. The picture

shows a plot of it growing at one of the test patches of the bureau on the grounds of Manitoba University, Fort Garry. In the centre of the picture is a susceptible variety, wilting and partially lodged. It is flanked on both sides by the rust-resistant variety, well headed out and standing straight.

Stem rust of wheat

Dominion Rust Lab develops and releases several wheat cultivars with resistance to stem rust in 1930s/40s (Renown, Regent, Redman) and provides a “period of immunity”. This ends in early 1950s with new race (strain) 15B, which caused major epidemics from 1953-1955.



Dr. Hanna Warns New Rust Threatens Canadian Wheat

A new type of rust may attack the common hard wheat of western Canada next year, Dr. W. F. Hanna, in charge of the dominion laboratory at the University of Manitoba, said Friday prior to leaving for Grand Forks, N.D.

At Grand Forks he will attend a meeting to discuss the disease.

First discovered in the U.S. about 1936, it did not become widely distributed until quite recently, he said.

Dr. Hanna said the rust was a very virulent type, which affected a wide variety of wheats, even the rust-resisting varieties.

Dr. Hanna said the new rust was not unexpected and the dominion laboratory was prepared for investigations.

"It may be," Dr. Hanna stated, "that 15b rust will be very scarce in Canada next year, but we have got to be prepared for the worst."

Enter, the hero



'Selkirk'

NEWS ITEM: THE DOMINION RUST LABORATORY IS DEVELOPING CT 186 A NEW WHEAT VARIETY, TO RESIST THE MENACE OF STEM RUST.

Stem rust of wheat

‘Selkirk’ had new resistance gene Sr6 that conferred resistance to Race 15B. Origin of Sr6 has similar story as Rpg1: a farmer Joseph McMurachy saw 3 plump wheat heads on table of grain binder from a field of heavily stem-rust infected wheat in McConnell, MB in 1930. He multiplied seed and gave to Winnipeg wheat breeders in 1935, who developed Mida-McMurachy-Exchange and ultimately led to Selkirk and subsequent wheat varieties that have Sr6.



1954 Epidemic Rust Year

Stem rust in Canada

Race 15B was virulent on most cvs

Losses: 45M bu in 1953 (\$60M), 150M bu in 1954 (\$183M), 9M bu in 1955 (\$12M)

Spores: wind-dispersed, rapid-cycle (8d), huge spore production (1 Trillion/ac), Travel long (>100-1000km) distance

Severe epidemics can cause complete loss, FAST (2 wk)

No losses in Canada since '50s epidemics



Stem rust of wheat in Canada

Barberry eradication (1919) eliminated sexual cycle, no new virulent races

Developed highly resistant wheat cvs. with a stack (3-5) of Sr resistance genes

No losses in spring wheat in North America since 1953-1955 epidemic

Do we still need rust pathology?

Arrival of Ug99 (and others)





Stem Rust Never Sleeps

By NORMAN E. BORLAUG APRIL 26, 2008

“During the 1950s, I and other scientists, first in North America and later throughout the world, developed high-yielding wheat varieties that were resistant to stem rust and other diseases.”

“new strains of stem rust, called Ug99 because they were discovered in Uganda in 1999, are much more dangerous than those that, 50 years ago, destroyed as much as 20 percent of the American wheat crop.

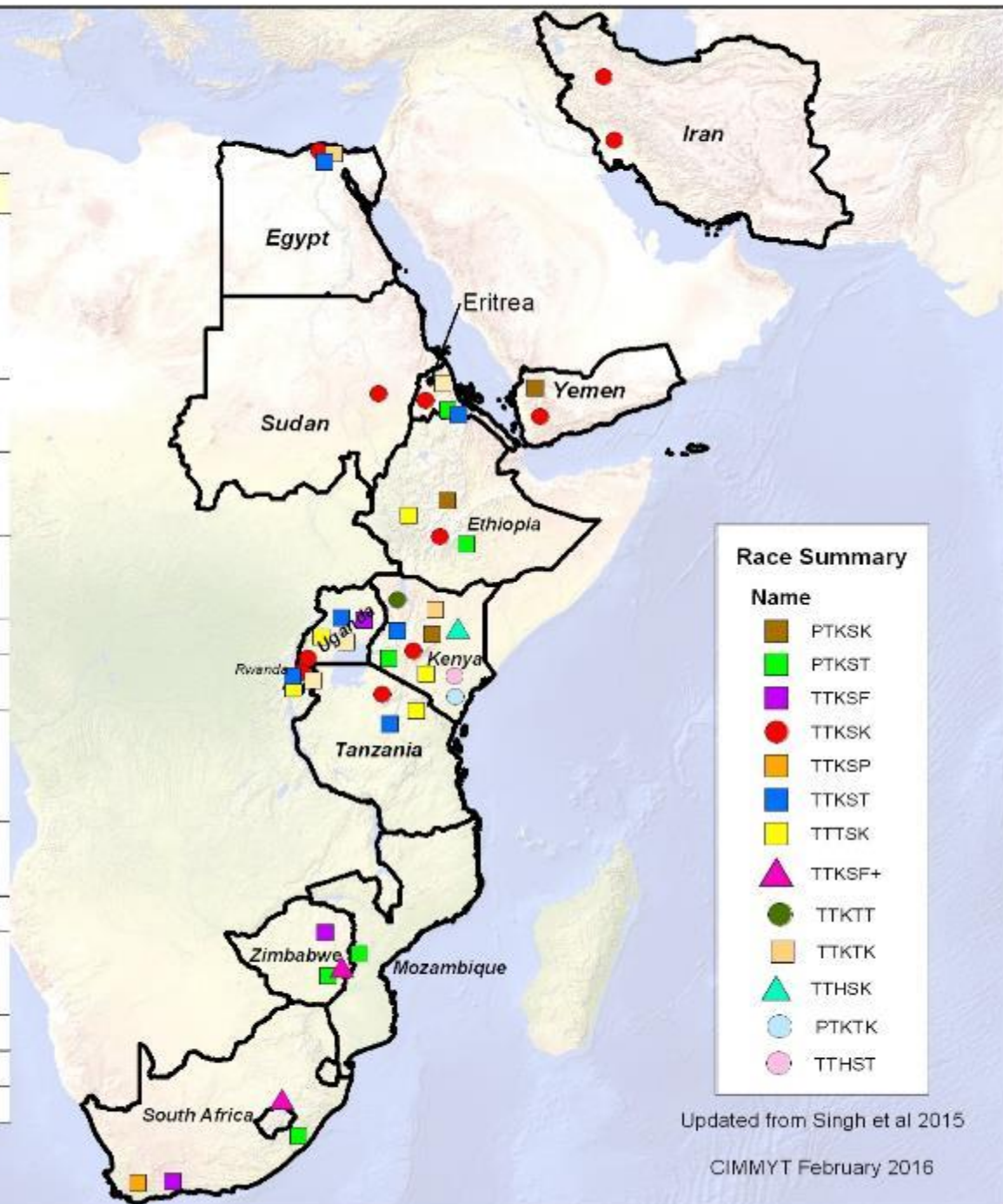
Origin and Spread of Ug99

1998- stem rust found in Uganda (Sr31), samples taken

1999- identified as Pgt-Ug99 (race TTKSK) with virulence on *Sr31*, which is used in developing countries (not Canada). Ug99 is virulent to most wheat cultivars worldwide, and on about 80% of Canadian red spring wheat.

Currently, Ug99 has mutated to 13 additional variants and spread to 13 countries along the east African coast and into Iran and Yemen. When genes *Sr24* and *SrTmp* were deployed into new cultivars and released, these were overcome within 2 years.

Race	Country (Year of 1 st detection)
TTKSK	Uganda (1998), Kenya (2001), Ethiopia (2003), Sudan (2006), Yemen (2006), Iran (2007), Tanzania (2009), Eritrea (2012), Rwanda (2014), Egypt (2014)
TTKSF	South Africa (2000), Zimbabwe (2009), Uganda (2012)
TTKST	Kenya (2006), Tanzania (2009), Eritrea (2010), Uganda (2012), Egypt (2014), Rwanda (2014)
TTTSK	Kenya (2007), Tanzania (2009), Ethiopia (2010), Uganda (2012), Rwanda (2014)
TTKSP	South Africa (2007)
PTKSK	Ethiopia (2007), Kenya (2009), Yemen (2009)
PTKST	Ethiopia (2007), Kenya (2008), South Africa (2009), Eritrea (2010), Mozambique (2010), Zimbabwe (2010)
TTKSF+	South Africa (2010), Zimbabwe (2010)
TTKTT	Kenya (2014)
TTKTK	Kenya (2014), Rwanda (2014), Uganda (2014), Eritrea (2014), Egypt (2014)
TTHSK	Kenya (2014)
PTKTK	Kenya (2014)
TTHST	Kenya (2013)



Updated from Singh et al 2015

CIMMYT February 2016

Canadian response to Ug99

- AAFC (Fetch) starts testing in 2005 of Canadian wheat to Ug99 in field nurseries in Njoro, Kenya
- Majority of Canadian wheat is susceptible to Ug99 races, identified new resistance in AC Cadillac & Peace, Webster, Tr129
- Characterized the 3 new sources of resistance, mapped markers, genes available to breeders and used since 2008 when identified
- Invested \$13M to develop Ug99 resistant wheat, upgrades to Morden biocontainment lab (PPC3)

World response to Ug99

“Sounding the Alarm” meeting held in Kenya on May 29, 2005 to inform world of Ug99 threat

Global Rust Initiative began in 2005, later renamed to Borlaug Global Rust Initiative.

Durable Rust Resistant Wheat program begins in 2008 and continued to 2016 with new Durable Genetic Gain in Wheat.

Discovery of Ug99 led to resurgence of science research work on stem rust worldwide.

Borlaug visit to Ottawa in 2006





Minnesota Rust Workshop 2011

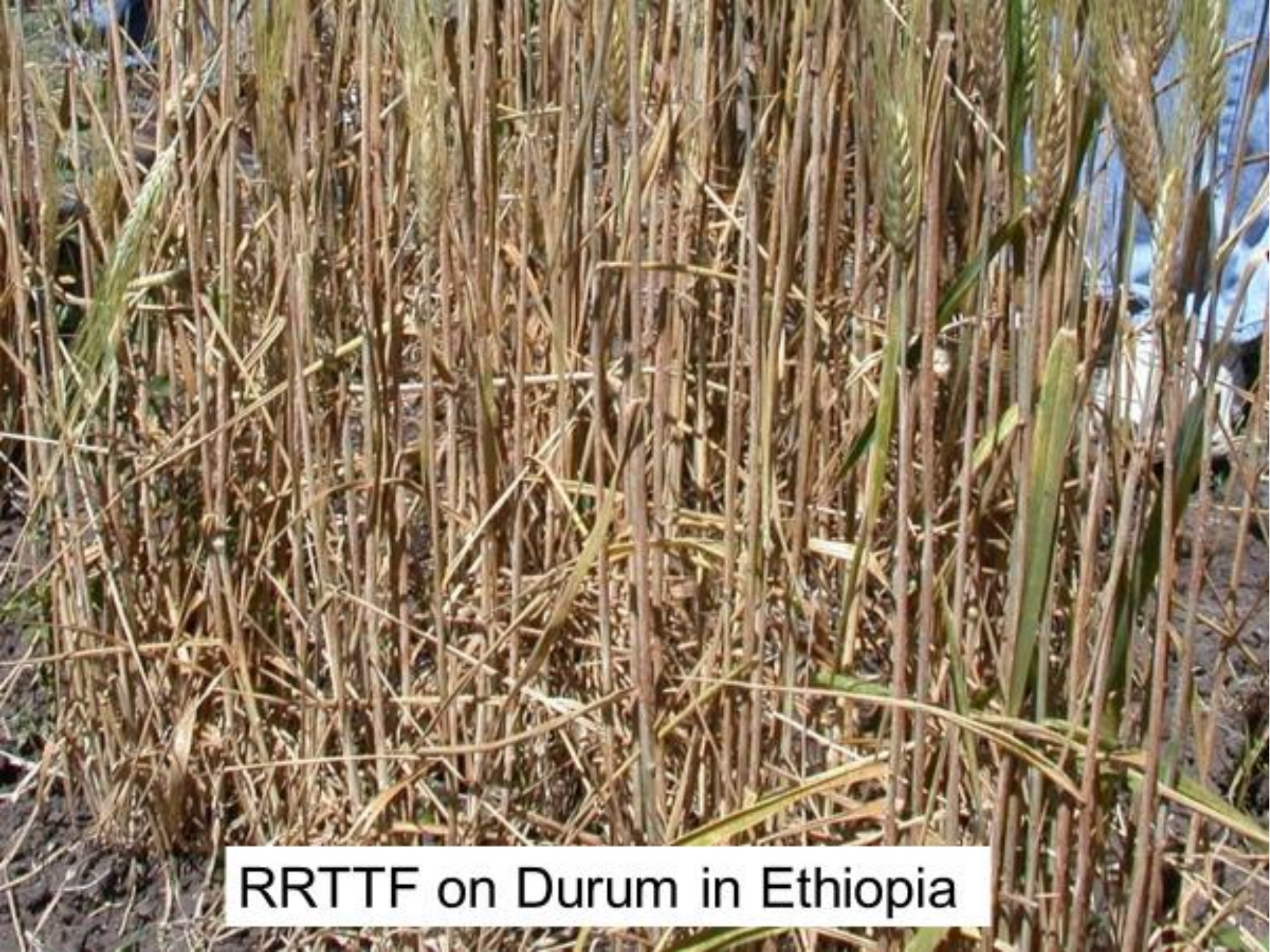
Detection of new stem rust races

RRTTF: identified from Ethiopia and Yemen (07),
Pakistan (09), **Ecuador (16)**

TKTTF: 'Digalu' race caused epidemic losses in
Ethiopia in 2013 with 100% losses on 10K ha

TTRTF, TKKTF, TTTTF: new races in Europe,
east Africa, Middle East. Stem rust epidemic in
Sicily in 2016 & 2017 after 60 yr with no rust

Sweden: Stem rust outbreak in 2017, appears to
be coming from Barberry



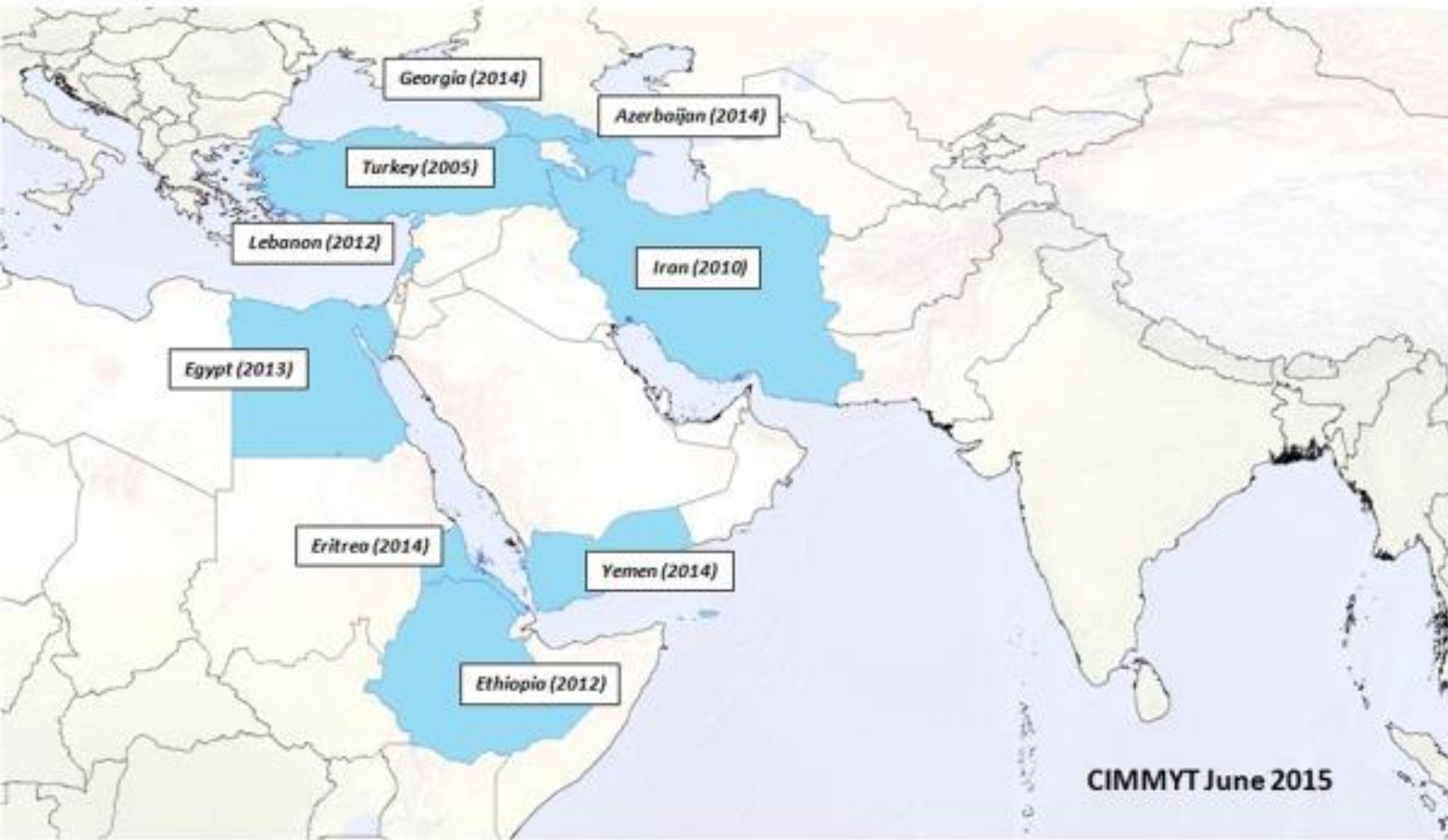
RRTTF on Durum in Ethiopia

'Digalu' race in Ethiopia in 2013

Fungicide treated



Map 1: Race TKTF confirmed countries and year of first detection



Importance of Barberry

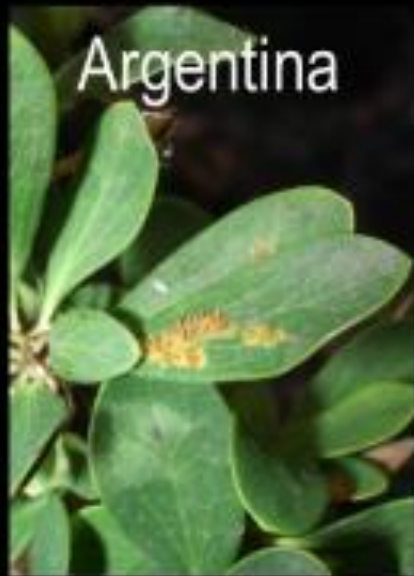
Alternate host for stem rust to complete sexual cycle, primary means of generating new races

Eradicated Barberry in USA/Canada

Barberry still prevalent in mountainous regions in Iran, Georgia, Spain, China and new virulent races of stem rust still getting generated

Since soybean rust migrated from South America to North America, developed project with Brazil to look for Barberry in SA

Barberry in Brazil/South America project



14 Barberry, 22 rust species

Importance of Barberry

Found 14 different species of Barberry, but none were hosts of *Puccinia graminis*

In Ecuador, found telia would develop quickly on wheat stems, indicative that there is a host for *Pgt* and/or *P. striiformis*.

SUMMARY

- Stem rust can devastate cereal crops, but has been controlled in Canada for over 60 years
- New OSR races (TJS) virulent on all deployed Pg genes, need to resume work to look for new genes
- Ug99 and other highly virulent Pgt strains are spreading and mutating. Need continued surveys to know what genes are useful and put into new cultivars
- “Rust never sleeps” and continues to evolve due to sexual cycle (Barberry). Breeding for resistance to rust diseases still remains the most efficient and economical means of controlling these pathogens

“The price of security from rust damage is a continuous vigilance in the form of surveys to detect any pathogenic changes in the economically important rusts and unrelenting efforts to develop cereal varieties resistant to any virulent races that may arise”

Johnson and Newton, 1946