UKCPVS Stakeholder meeting

Challenges of breeding for yellow rust resistance, post-Warrior

Rachel Goddard, Limagrain

Yellow rust timeline: pre-Warrior

The pathogen population acquires new virulences

Resistance breakdown:

Solstice: 9 rating in 2008

-5

4 rating in 2009

1966 & 1971/72
Rothwell Perdix 1966

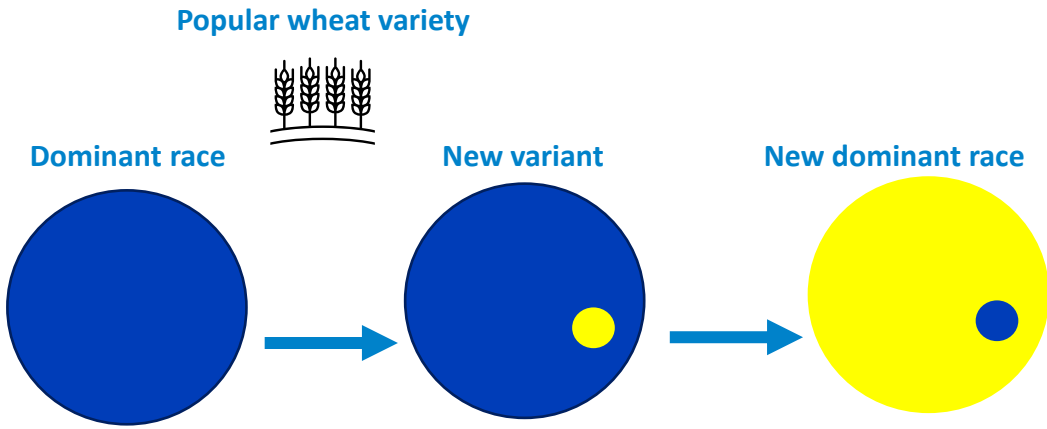
1967: Formation of virulence survey

1985
Slejpner

2000
Robigus

1995
Brigadier

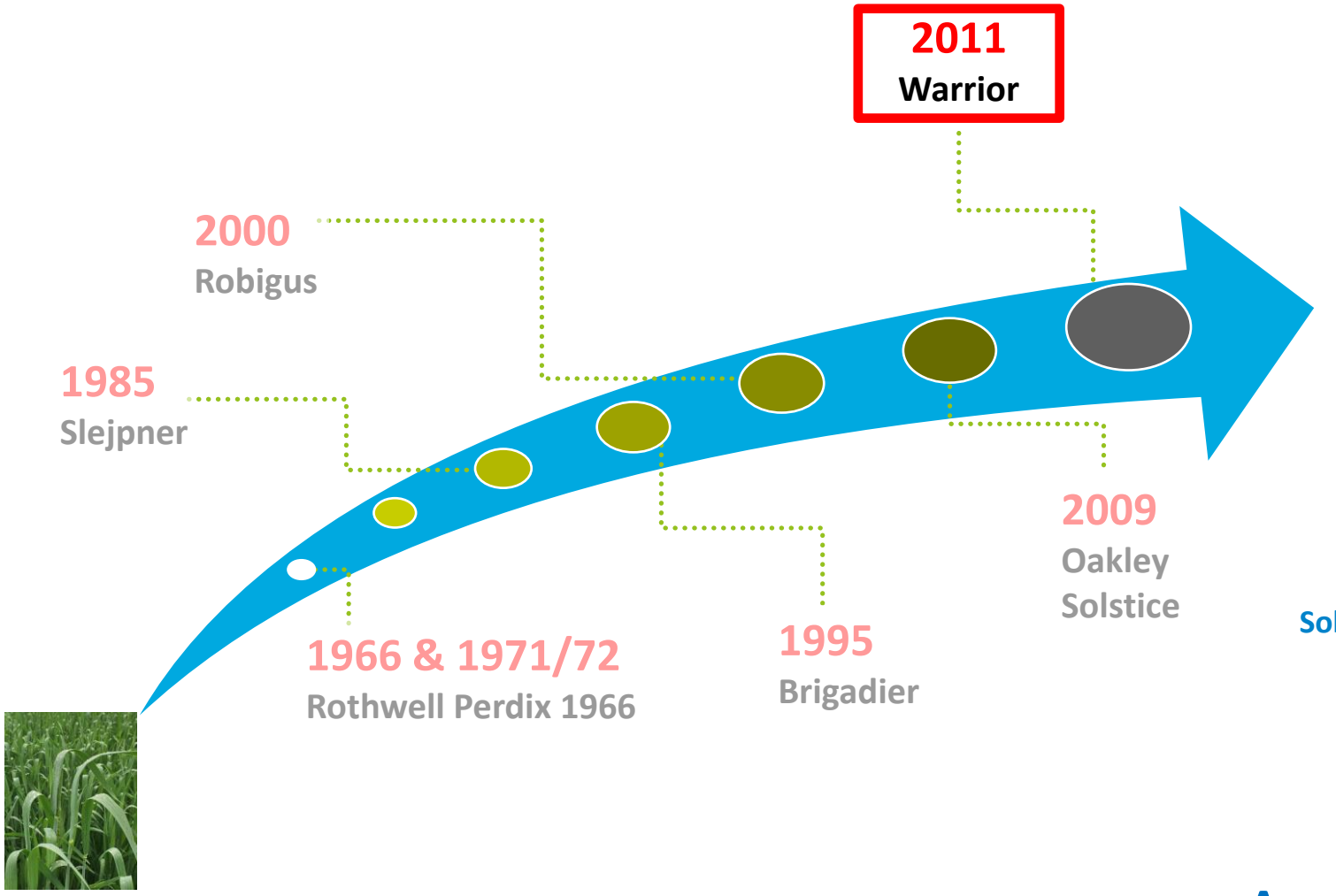
2009
Oakley
Solstice

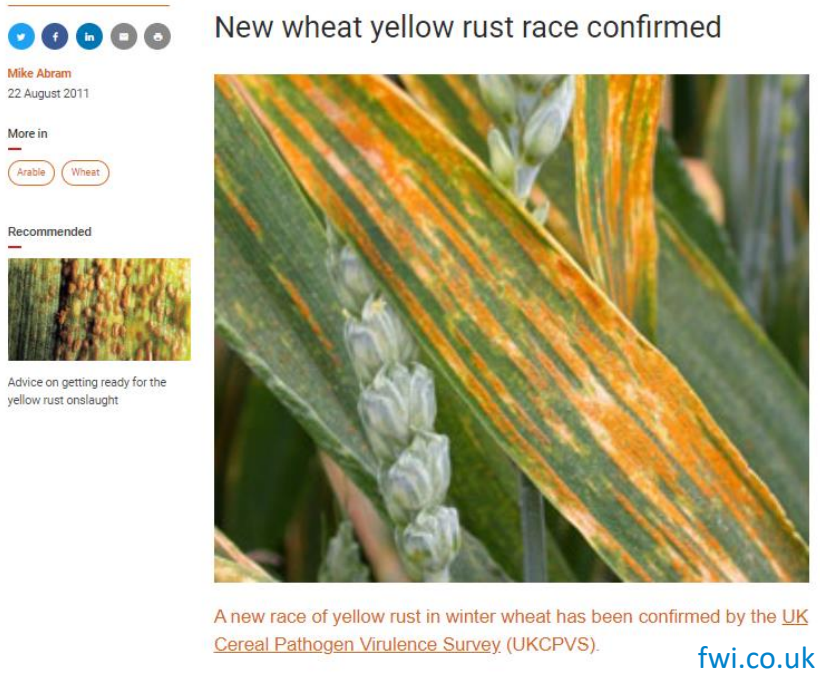


Rare variant every few years = new race

Warrior race: complete population change

Exotic incursion from outside Europe




Mike Abram
22 August 2011
More in
Arable
Wheat
Recommended
Advice on getting ready for the yellow rust onslaught

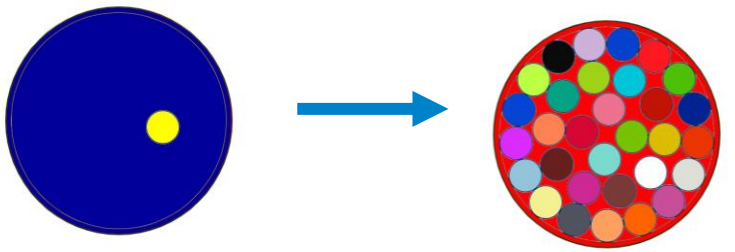
New wheat yellow rust race confirmed

A new race of yellow rust in winter wheat has been confirmed by the UK Cereal Pathogen Virulence Survey (UKCPVS).

fwi.co.uk

Solstice/Oakley – Navy Group

'Warrior'– Red Group



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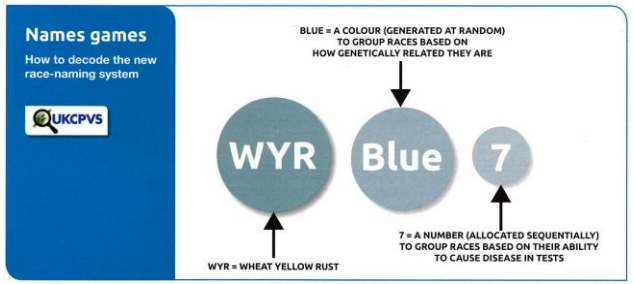
A population of variants that can readily adapt

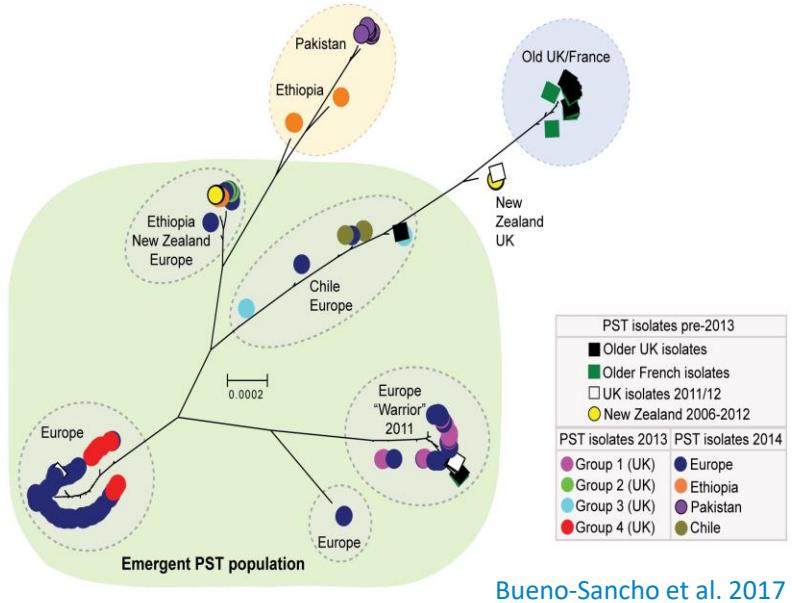
Yellow rust since 2011

A complex pathogen population

- New naming system to reflect complexity
- Several genetic groups
  - Red
  - Pink
  - Purple
  - Blue
- Within each genetic group there are multiple pathotypes (virulence profiles):
  - 50+ Red pathotypes
  - Most common in the UK in 2020 (UKCPVS):
    - Red 37
    - Red 28
    - Red 27

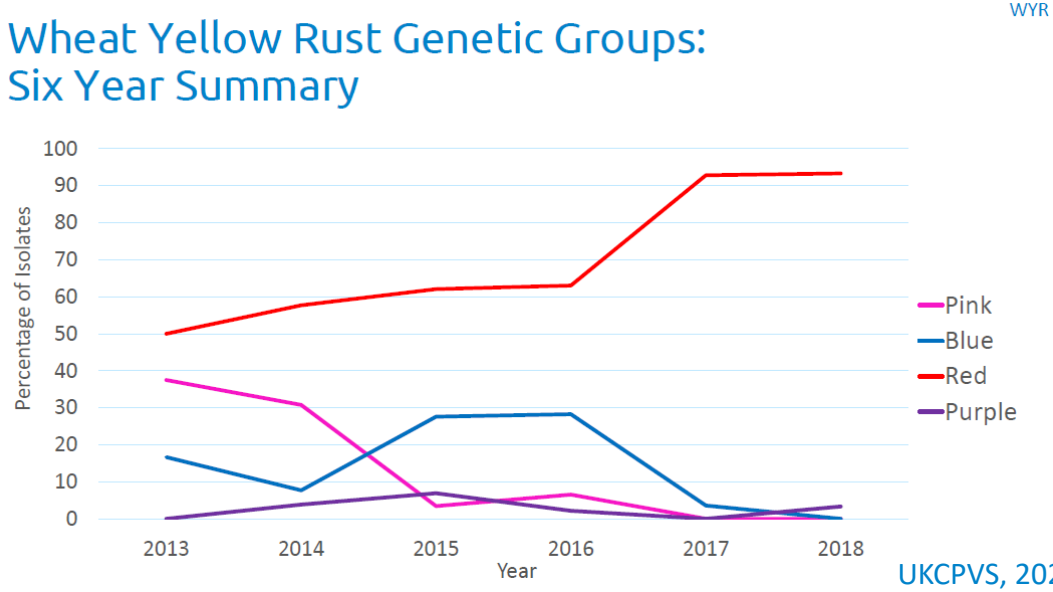


UKCPVS



Bueno-Sancho et al. 2017

WYR



UKCPVS, 2021

Yellow rust Post-Warrior: greater diversity

Pathotypes: changes in space and time

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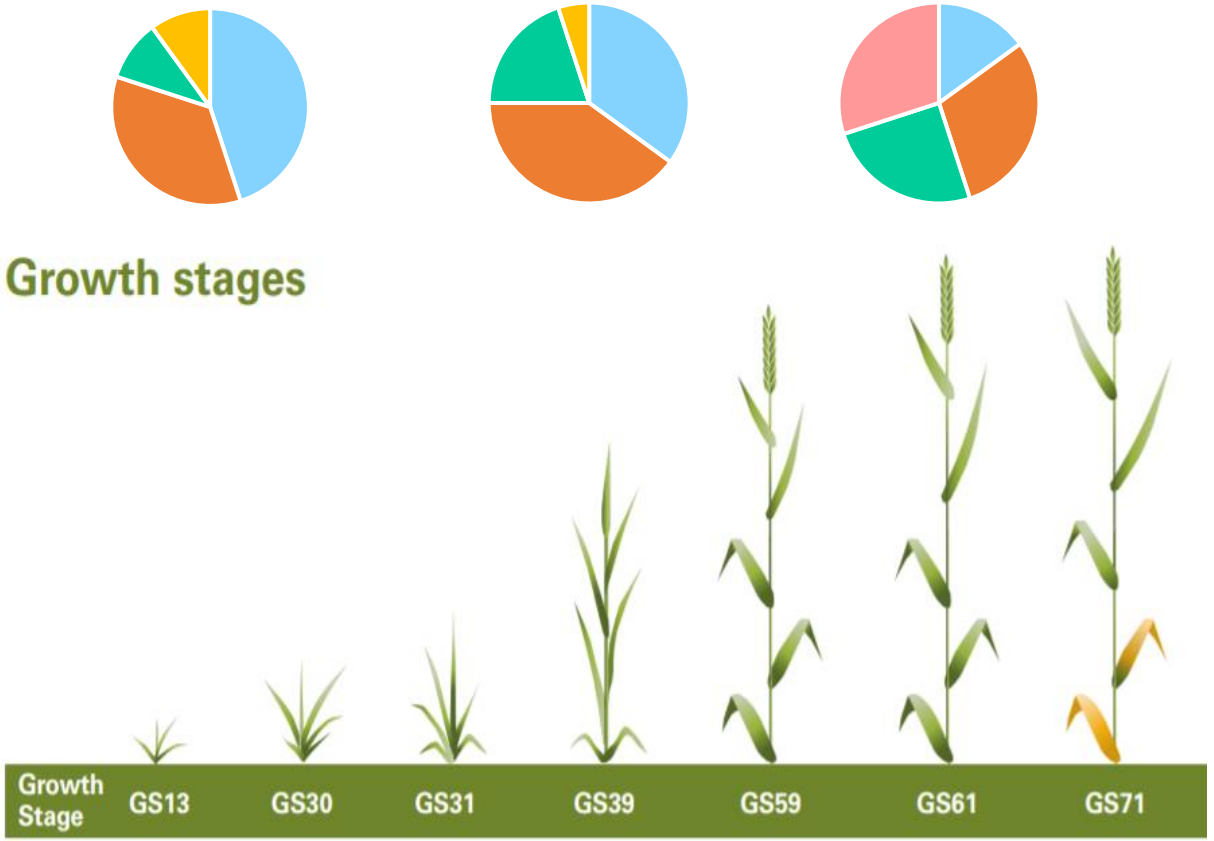
- Different pathotypes can be found within the same field



AHDB

- The frequency of pathotypes in the same field can change throughout the growing season

Research by Dr Chris Judge at NIAB

Optimal yellow rust conditions pre-Warrior:

Warm days, cool nights

- Cool or warm / very warm and sunny days but must have cool, still, dewy nights to develop
- Lush wheat crop growth
- Mild winters and early springs

- Wind
- Warm, dry nights
- Stressed, ‘hard’ wheat leaves
- Development is slowed by cold winters

The Warrior race is more adaptable

Withstands greater changes in the environment

- Cool or warm / very warm and sunny days but must have cool, still, dewy nights to develop
- Lush wheat crop growth
- Mild winters and early springs

- Wind
- Warm, dry nights
- Stressed, ‘hard’ wheat leaves
- Development is slowed by cold winters

- ‘Warrior’ tolerates a greater range of temperatures than the ‘old’ yellow rust
- ‘Warrior’ has a shorter time from infection to sporulation
- ‘Warrior’ produces more spores
- ‘Warrior’ produces black telia later in the season

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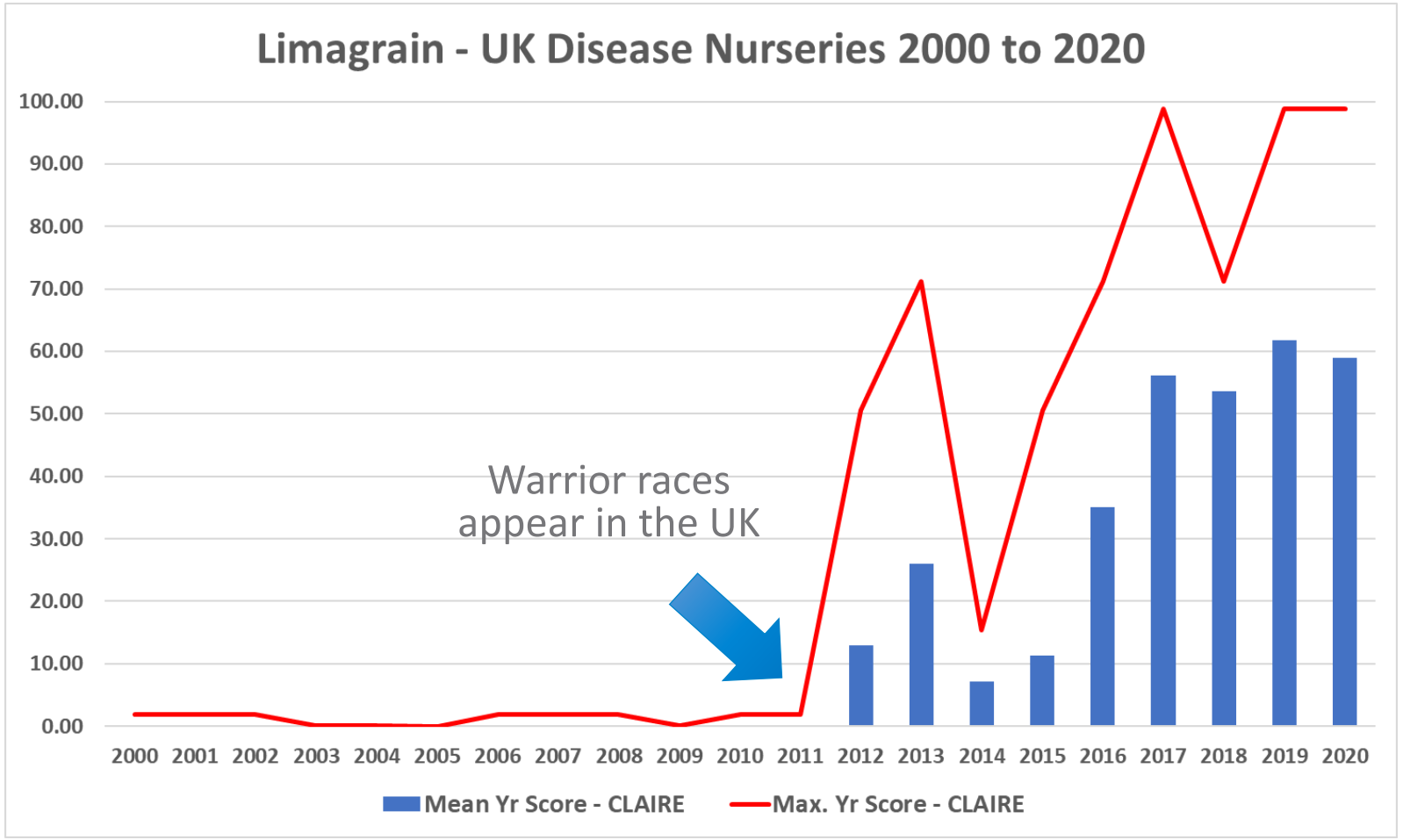
- ‘Warrior’ breaks a range of formerly effective resistance genes and gene combinations

Yellow rust post-Warrior is like a new disease

How did Warrior change resistance breeding?

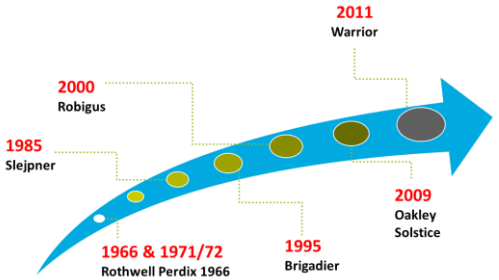
Claire APR: a single gene that was defeated by Warrior

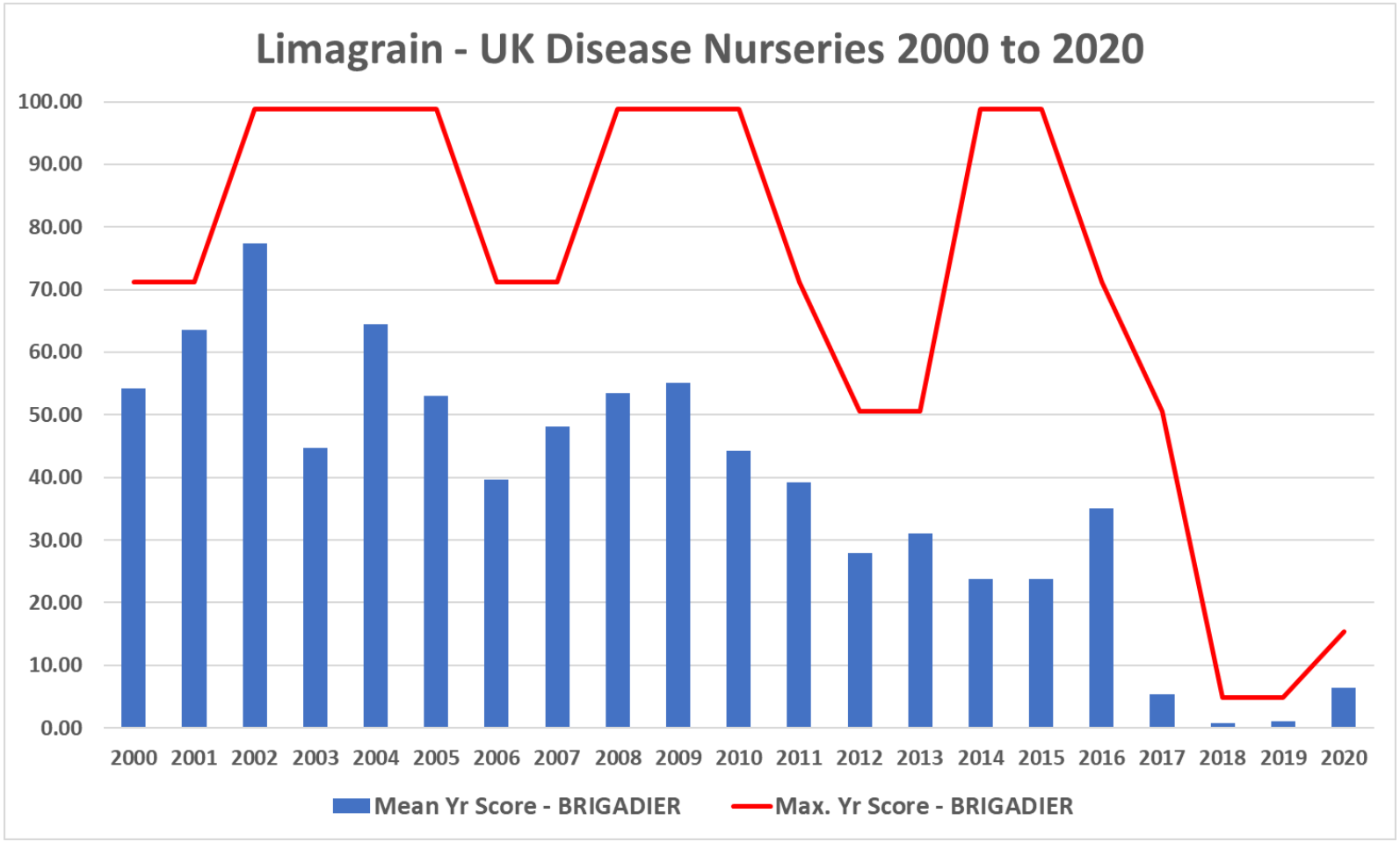


- Following the breakdown of Brigadier in 1997, *YrClaire* was used extensively in breeding
- A single adult plant resistance (APR) gene providing significant resistance
- *YrClaire* broke down following the Warrior incursion
- *YrClaire* is now thought to be a susceptibility factor

How did Warrior change resistance breeding?

Brigadier: defeated by old clonal Yr races, but not Warrior!





- Resistance broke down pre-Warrior

  1995: rating of 9

  ↓ -7

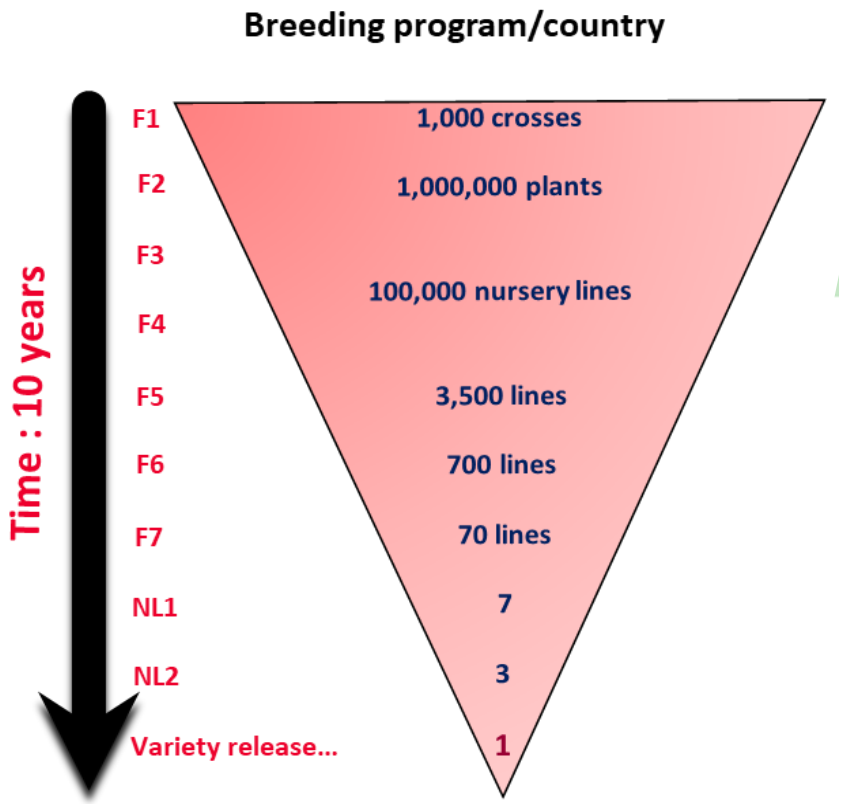
  1997: rating of 2

- Post 2011, Brigadier has *Yr* genes that now provide resistance against the Warrior population of races

Resistance breeding post-Warrior

Informed choices using all the data available

- We can't predict how the UK rust population will change
  - New exotic incursions
  - Climate change
- It's difficult to predict which host resistances are durable
  - "Resistance … remains effective during its **prolonged** and **widespread** use in an environment favourable to the disease." Johnson, 1981
- A traditional wheat breeding cycle takes ~10 years
  - Crosses made 4-5 years ago may not be resistant when they reach RL trials



A greater understanding of the pathogen population

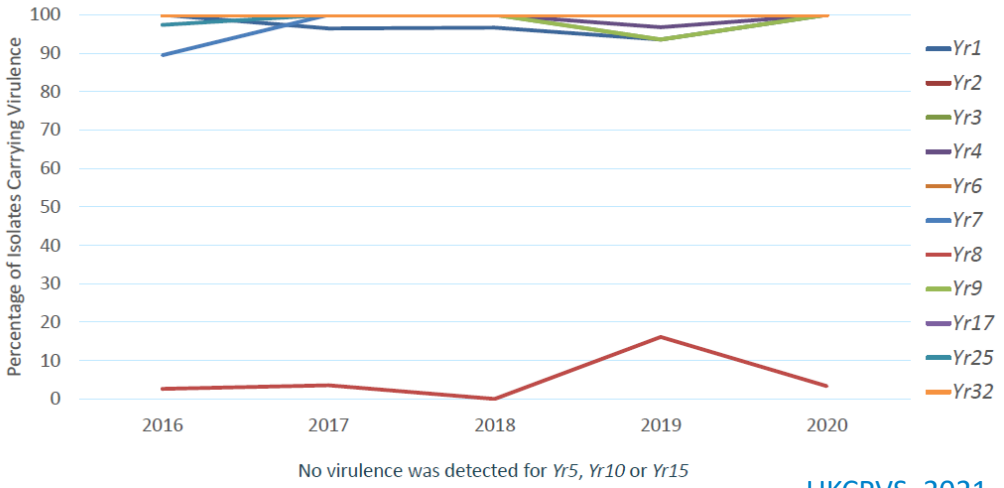
UKCPVS data is essential

- As breeders, we work on host genetics and not the pathogen itself
- The work of the UKCPVS is important to help us understand the diversity in the UK population
  - Early warning system of any race changes
  - Validation of new races
  - Which virulences are present?
- We routinely inoculate our disease nurseries with the official rust races supplied by NIAB
  - This ensures we don't select breeding lines that may be susceptible to new races

New Pathotypes Found in 2020

Pathotype	% Frequency
1,2,3,4,6,7,9,17,25,32,Re,Sp,Ro,So,St,Ev	3
1,2,3,4,6,7,9,17,25,32,Re,Sp,Ro,So,St,Ap,Ev	3
1,2,3,4,6,7,9,17,25,32,Re,Sp,Ro,So,Ca,St,Kr,Ap	3
1,2,3,4,6,7,9,17,25,32,Re,Sp,Ro,So,Wa,St,Kr,Ap,Ev	3
1,2,3,4,6,7,8,9,17,25,32,Sp,Ro,So,St,Kr,Ap,Ev	3

Wheat Yellow Rust Virulence Frequencies

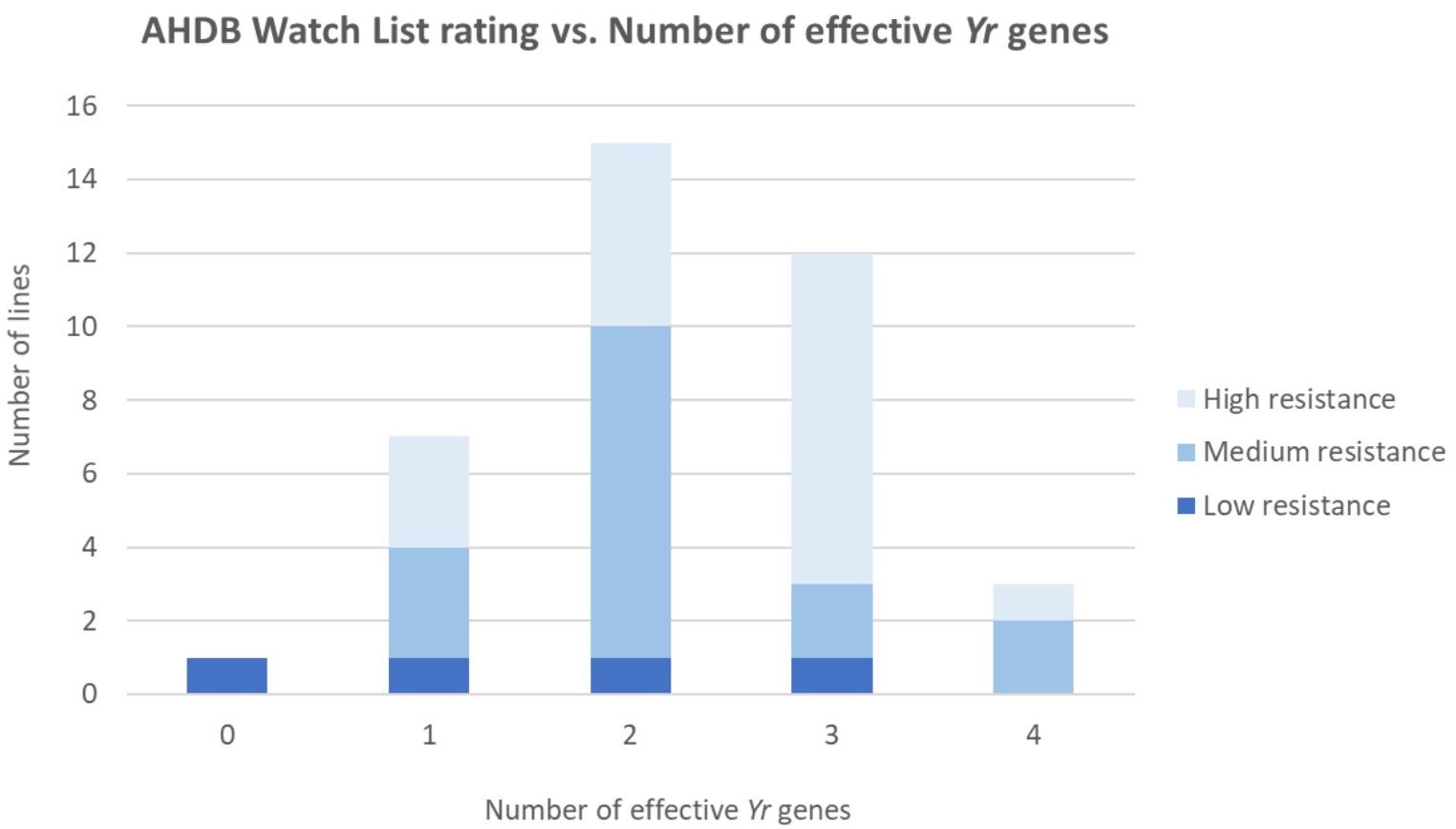


No virulence was detected for *Yr5*, *Yr10* or *Yr15*

UKCPVS, 2021

Understanding the resistance in elite UK wheats

AHDB Yellow rust watch list 2022/23



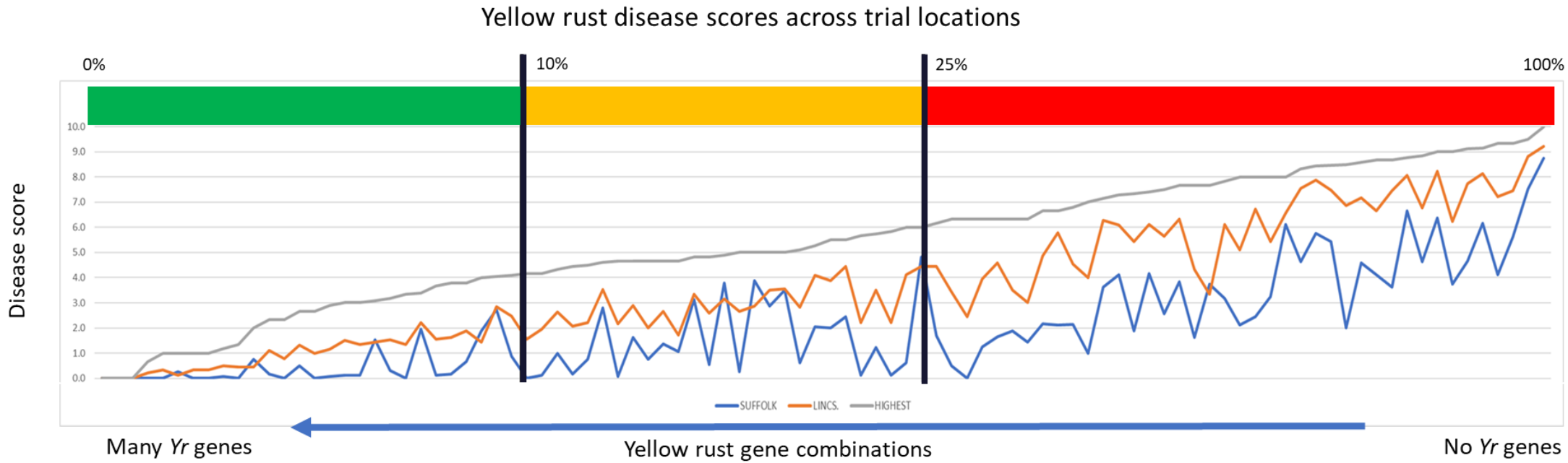
- There are at least 8 different effective *R* genes for yellow rust resistance found in RL varieties
  - These are found at different frequencies
- Not all *R* gene combinations are effective against Warrior
- From crossing to entry into RLT takes 7-10 years

High resistance
Medium resistance
Low resistance

Yellow rust watch list data from AHDB (AHDB.org.uk)

Monitoring effective resistances

Surveillance and diversity

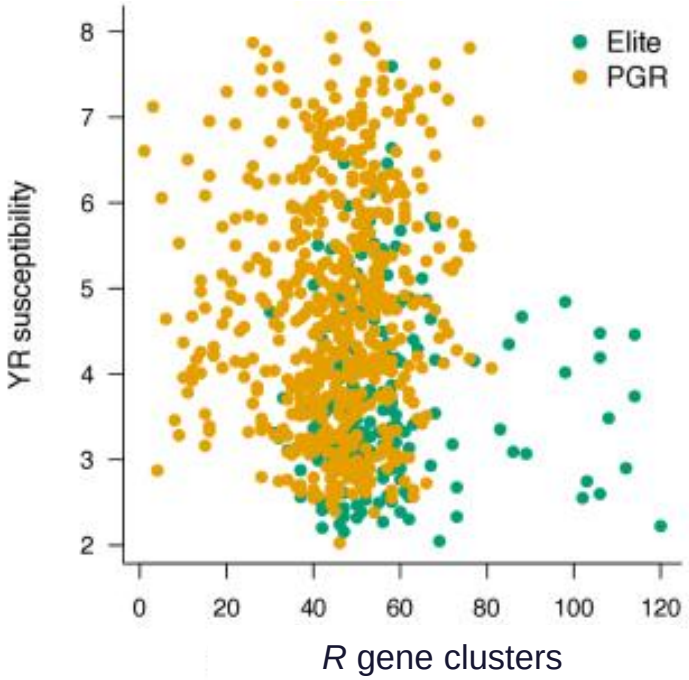


- We monitor different combinations of *Yr* genes in our disease nurseries
  - Which genes are effective across locations?
  - Which genes are losing efficacy?
- The pathogen population is complex and changes yearly
- We can't rely on a single gene or a single combination to provide resistance

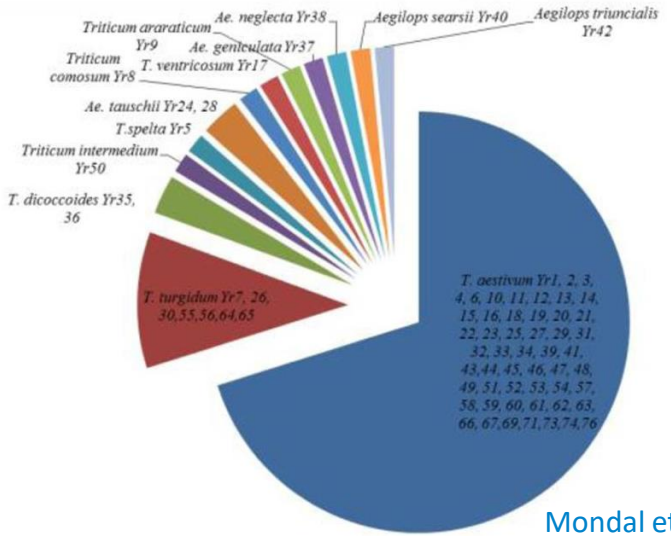
Resistance pre-breeding

Introducing new resistances

- Breeders have been successful at increasing resistance
- However, the elite wheat gene pool is quite narrow
  - elite x elite crosses produce a limited number of *Yr* combinations
- Most yellow rust resistances are native *Triticum aestivum* genes
  - Non-native genes: *Yr5*, *Yr8*, *Yr9*, *Yr17*
  - Contrastingly, most leaf rust resistances are non-native



Kale et al. 2022



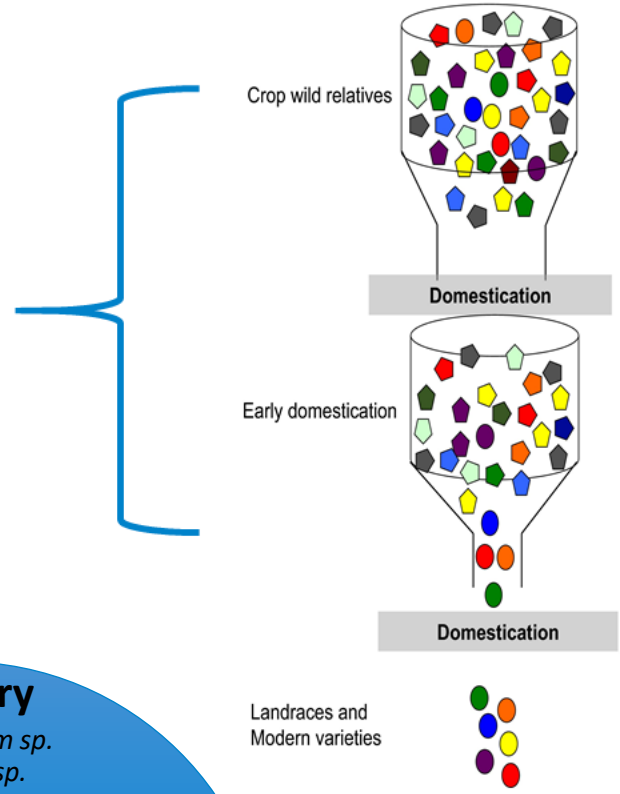
Mondal et al. 2016

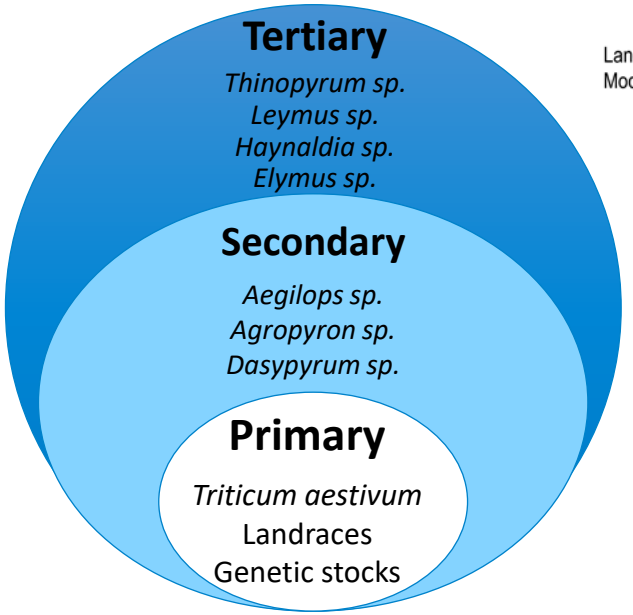
Additional resistance sources

Expanding the gene pool

1. Landraces
2. Wheat progenitors
3. Crop wild relatives

Wulff and Moscou, 2014





Zhang et al. 2016

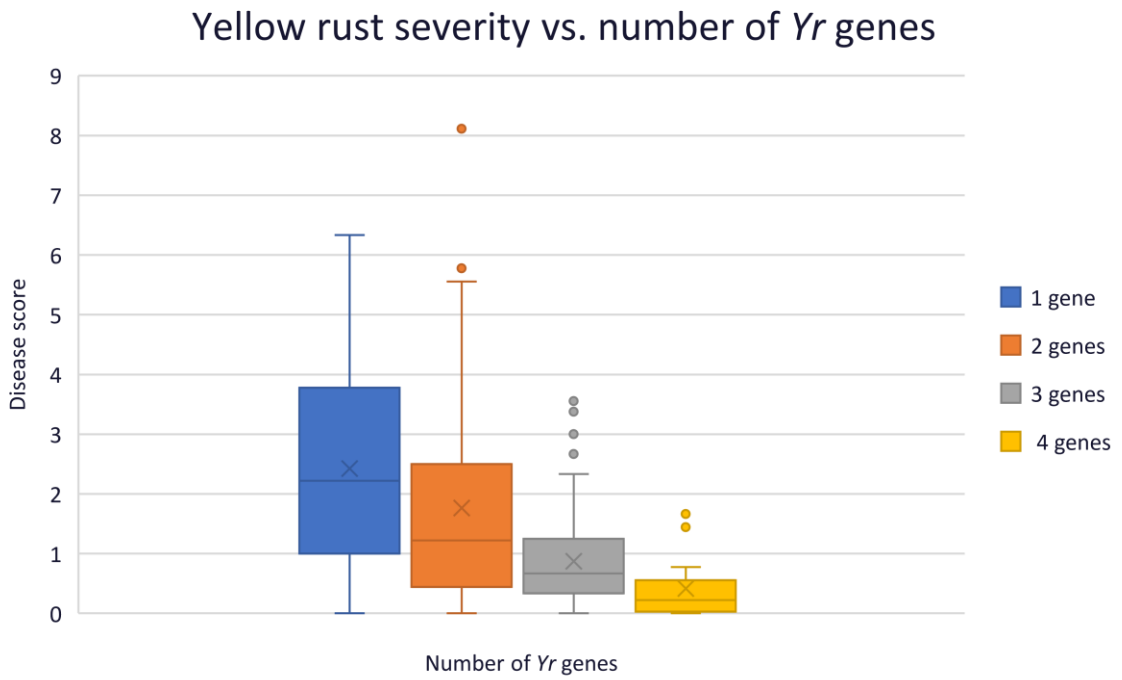
Issues to consider with non-native sources:

- Poor agronomic performance
  - Lodging, low yield, sterility
- Introduction into breeding programs takes 2 – 3x as long as elite sources

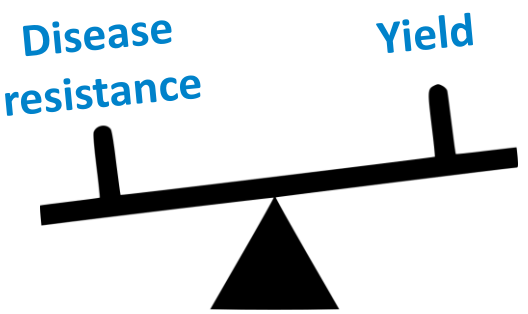
Stacking *Yr* resistance genes

The more, the better?

- Stacking genes provides more durability
  - But this requires 1000s of lines to create effective gene stacks with 4+ genes
- The effect on yield must be considered
  - More genes = lower yielding?
  - Yellow rust resistance is only a single trait
- Genetic markers are needed to produce stacks
  - Phenotypic selection alone doesn't work



1 gene or a gene stack?



Take-home messages

- We are finding new sources of resistance to Warrior
- Crossing them into our elite breeding pool, which takes time
- Developing new markers in order to:
  - Follow their inheritance
  - Increase their frequency
  - Stack them with other resistances to maintain diversity
- Going forward, single genes will not be deployed on their own!

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