Disease resistance in small grain cereals: The South African approach

W.H.P. Boshoff

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Small grain cereals

Wheat

Barley

Oat

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Small grain cereals - improvement

- First wheat planted 1652
- Wheat breeding initiated in 1902
- Barley breeding initiated in 1978
- Oat improvement mainly through introductions

- Improvement Sector
  - ARC-SG founded 1976
  - Sensako (Syngenta Seeds) established 1958
  - PANNAR SEED wheat breeding since 1987 (CORTEVA agriscience)
  - SABBI (AB InBev) - local barley improvement since 1978

- Rust resistance is a long-standing priority of local breeders

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Rust diseases of wheat

P. graminis f. sp. *tritici* (*Pgt*)

Stem rust

Puccinia triticina (*Pt*)

Leaf rust

P. striiformis f. sp. *tritici* (*Pst*)

Stripe rust

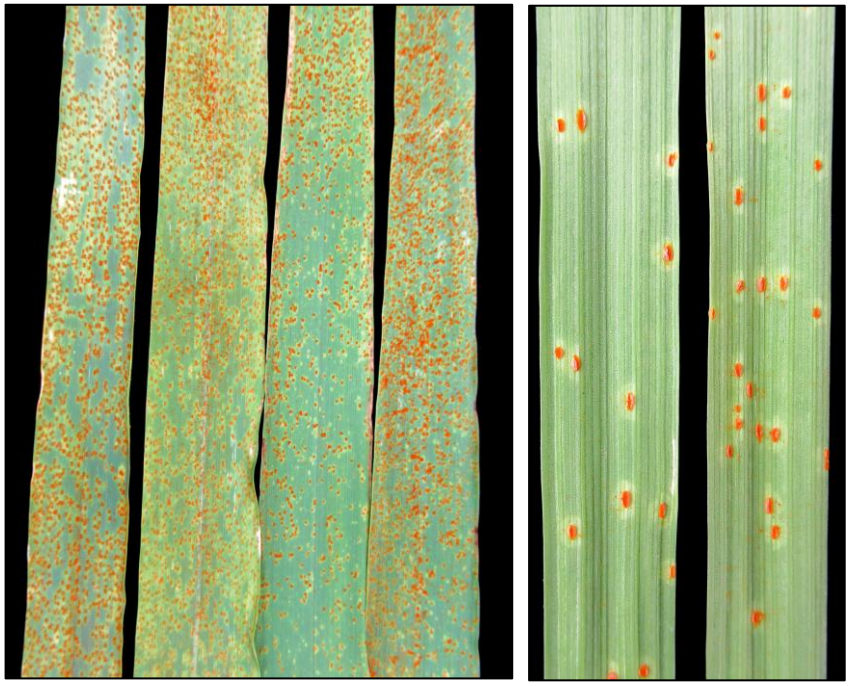
Rust diseases of barley

P. graminis f. sp. *secalis*

P. graminis f. sp. *tritici*

Stem rust

P. hordei



Leaf rust

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Rust diseases of oat

P. graminis f. sp. *avenae*

Stem rust

P. coronata var. *avenae* f. sp. avenae

Crown rust

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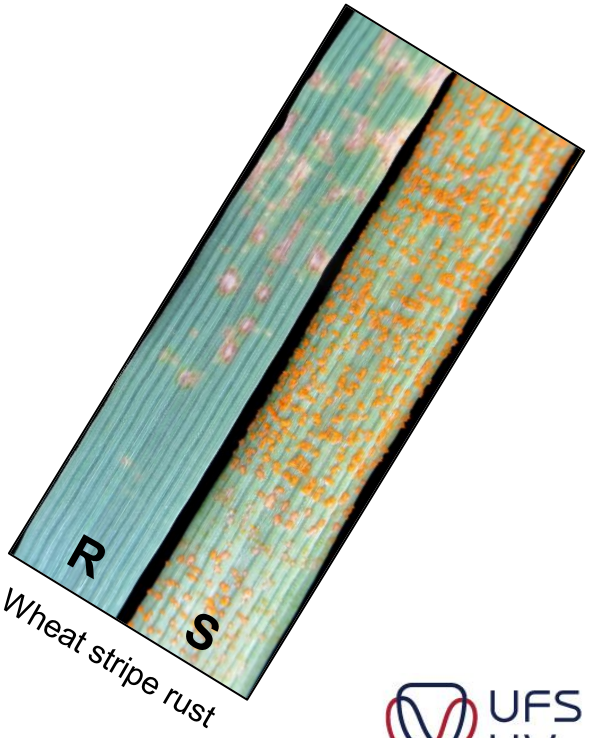
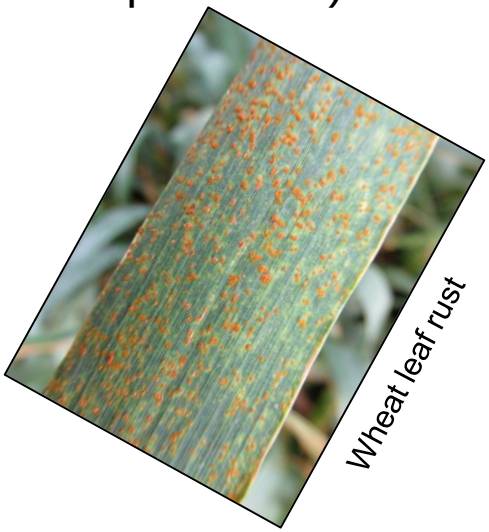
Breeding for rust resistance

- Host-Pathogen interactions
  - Gene-for-gene hypothesis
- Pathogen variation
  - Surveillance studies - determine phenotypic and genotypic variability
- Characterisation of host plants
  - Sourcing and phenotyping of germplasm
- Application in breeding
  - Pathologists and breeders
  - MAS to allow gene stacking
- Resources
  - Human expertise, laboratories, funding etc.



Challenges in rust control

- Genetic and hence pathogenic variability
  - Virulence and aggressiveness (adaption to higher temperatures)
    - Sexual recombination
    - Mutation
    - Somatic exchange
    - Exotic incursions
    - Migration within epidemiological zones



- Cropping systems
  - Monoculture - uniformity of germplasm
  - Ancillary and/or bridging hosts
  - Breeding approach (monogenic vs polygenic resistance)
  - Selective force of varieties with same resistance gene
  - Uniformity of global wheat germplasm
- Ease of dispersal
  - Long-distance

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Variability in cereal rusts in SA

Races detected

- Stem rust wheat (*Pgt*); (5 new races since 2007; last new race 2020)
- Leaf rust wheat (*Pt*); (9 new races since 2009; last new race 2020)
- Stripe rust wheat (*Pst*); (4 races since 1996; last new race 2005)
- Leaf rust barley (*Ph*); (3 races since 1994; last new race 2015)
- Crown rust oat (*Pca*); (10 races since 1998; last new race 2019)
- Stem rust oat (*Pga*); (8 races since 1998; last new race 2017)

Incursions

- *Pst* race 6E16A- (1996); followed by 3 race variants
- *Pgt* race TTKSF (2000); followed by 4 race variants
- *Pt* race CCPS (2009); followed by 4 race variants

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DISEASE NOTES

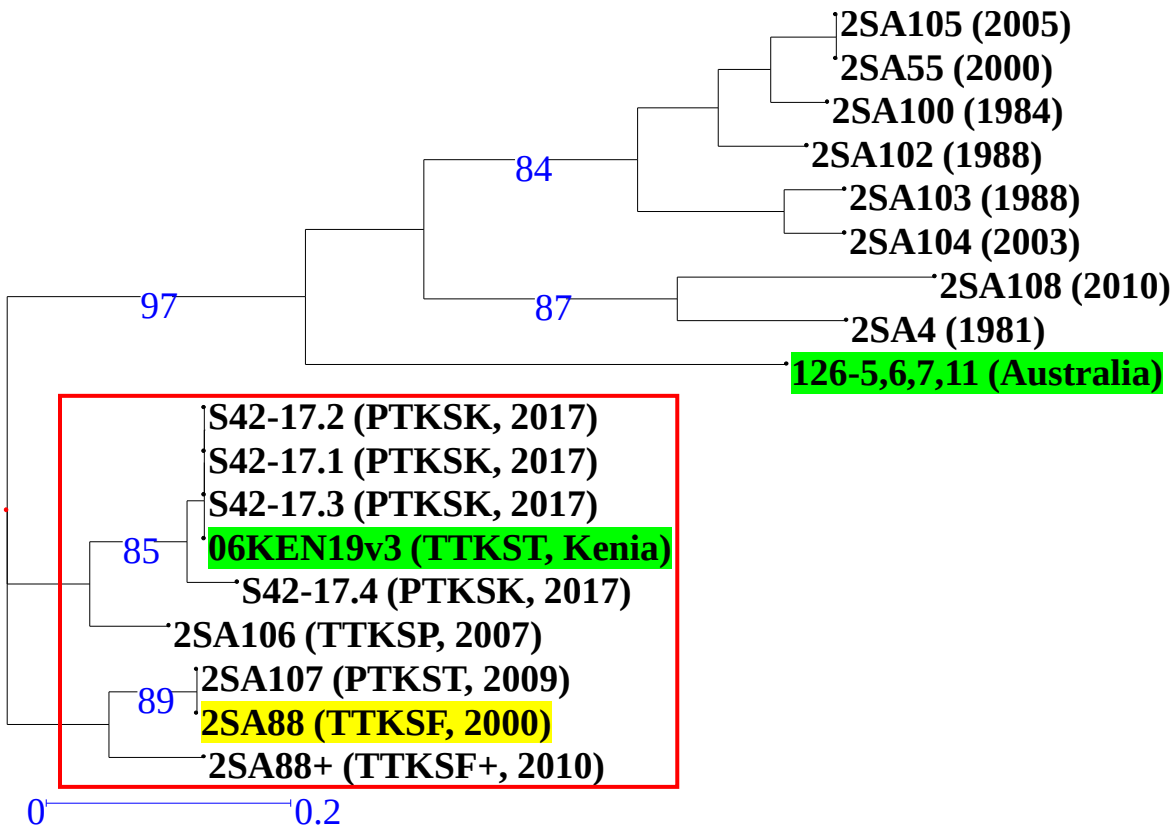
OPEN

First Report of *Puccinia graminis* f. sp. *tritici* Race PTKSK, a Variant of Wheat Stem Rust Race Ug99, in South Africa

T. Terefe, Z. A. Pretorius, B. Visser, and W. H. P. Boshoff

Affiliations

Published Online: 25 Mar 2019 | https://doi.org/10.1094/PDIS-11-18-1911-PDN



Phenogram, based on 10 microsatellite markers, displaying the genetic comparison of 13 South African stem rust races

Importance of disease resistance

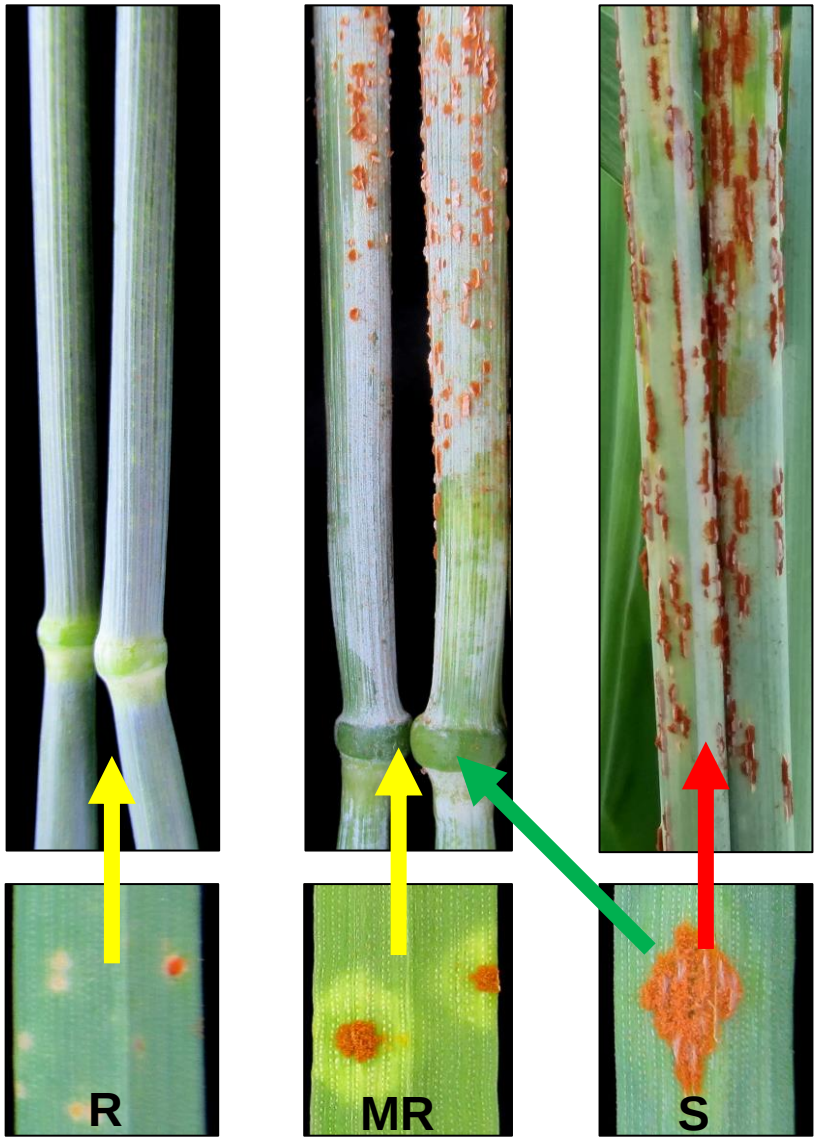
- Add value to seed - the most important input
- Form part of an integrated control strategy
- Lower the risk of epidemic outbreaks
- Contribute to a smaller pathogen population
  - Lower mutation risk
- Prevent repetitive application of chemicals

- Chemical control concerns
  - Affordability - when lower yield potential
  - Contribute to higher input cost
  - Miss-timing of applications
  - Less effective against late season stem rust infections
  - Environmental impact – chemical residues
  - Risk of fungicide intolerance or resistance

Barley leaf rust

Types of rust resistance

Wheat stem rust



Adult plant stage

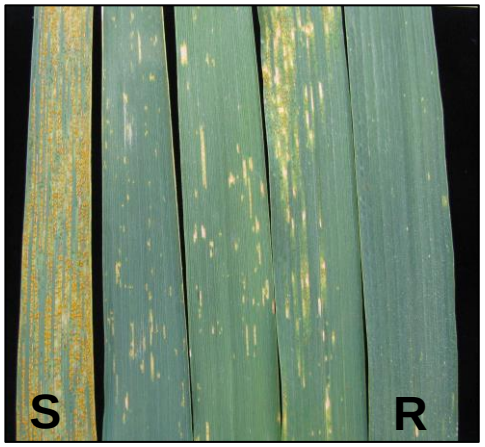
- All-stage resistance (ASR)
- Adult plant resistance (APR)
- Susceptible

Seedling stage

(R = resistant; M = Moderately; S = susceptible)

Resistance breeding perspectives

- Level of protection required
  - Early season infection require ASR sources
  - Risk of disease in a particular production area
  - Long-term commitment required
- Specialised research inputs
  - Surveillance studies - early detection
  - Access to culture collections
  - Disease screening nurseries
  - Accurate phenotyping and selection
  - Germplasm accessibility
  - Breeding approach - conventional vs molecular
- Breeding objectives
  - Yield and quality requirements
  - Several biotic and abiotic breeding goals – need to prioritise
  - Market size, income, cost of breeding



Wheat stripe rust responses

Producer perspectives

- Yield potential
  - Often the most important criteria in cultivar choice
  - Pesticides mostly applied at fixed growth stages
    - This require less monitoring, control of multiple pests through spray mixtures, safe on application cost and time
- Risk of disease outbreaks
  - High with susceptible cultivars and cultivars with race-specific resistance sources
- Need for reliable cultivar response data
  - Revised timeously to reflect virulence changes
  - Easy to interpret
  - Allow for comparison between cultivars from different companies

Photo: D. de Klerk

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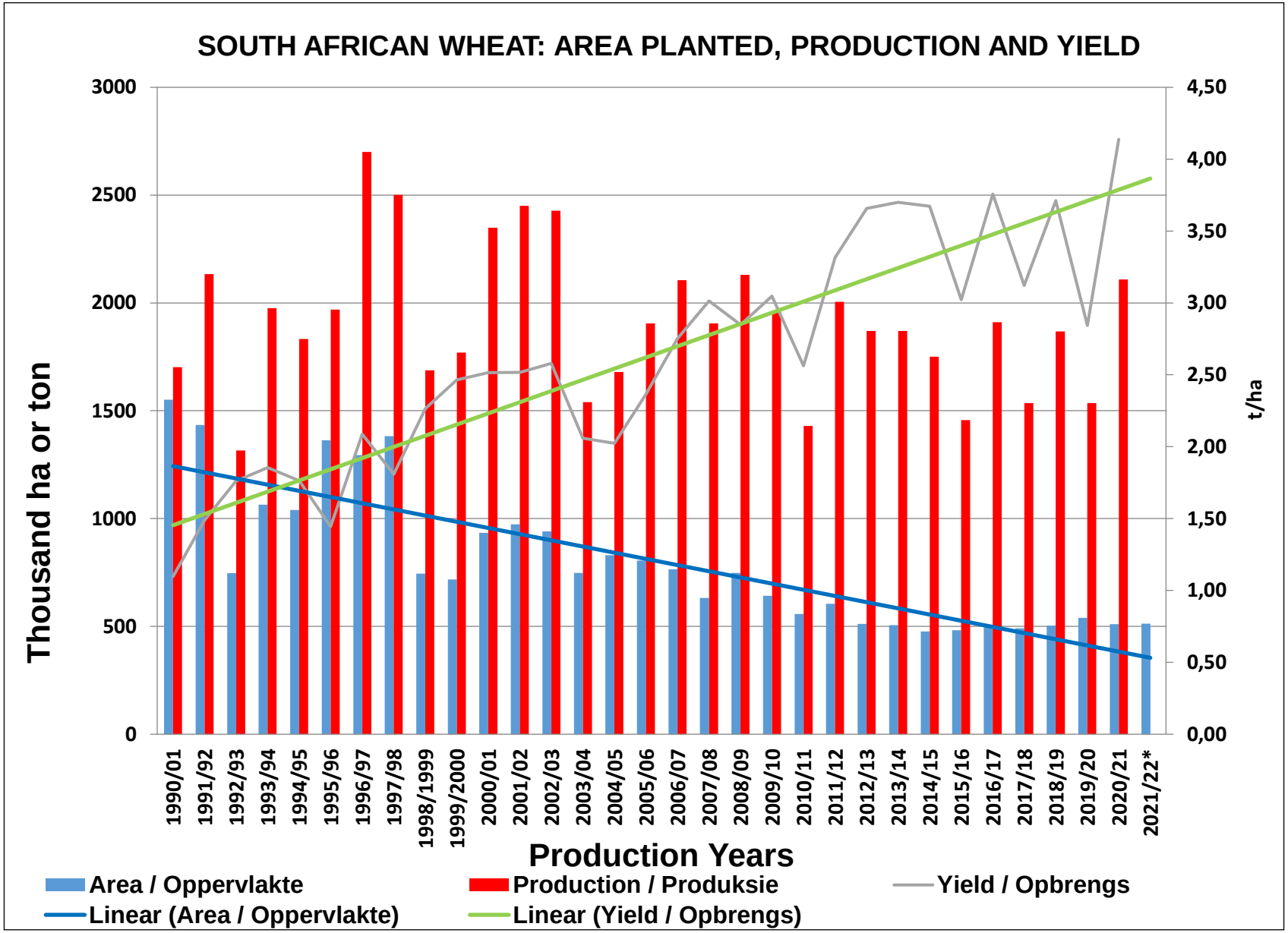
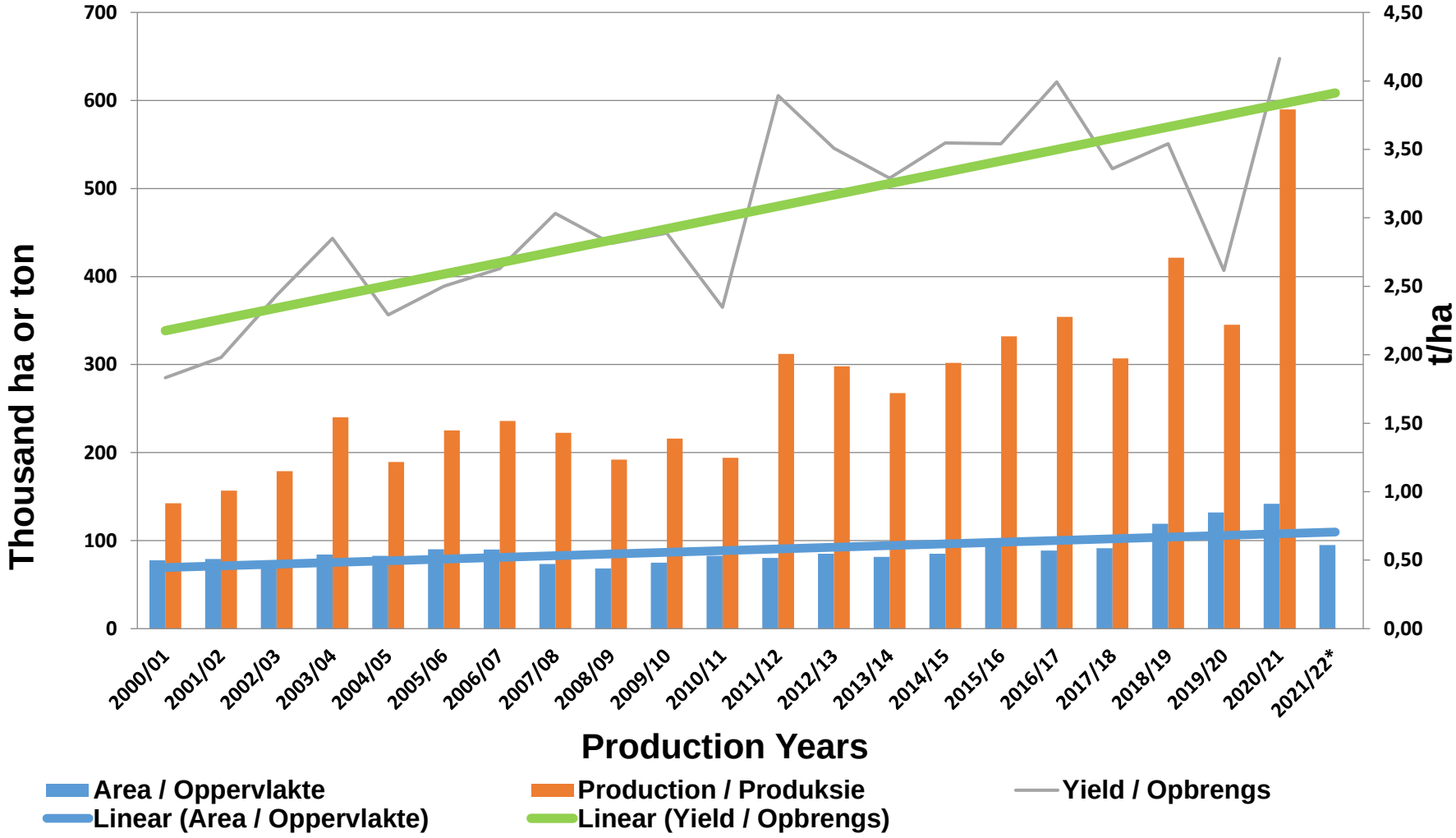


https://www.grainsa.co.za/pages/industry-reports/production-reports

SOUTH AFRICAN MALTING BARLEY: AREA PLANTED, PRODUCTION AND YIELD



https://www.grainsa.co.za/pages/industry-reports/production-reports

Rust resistance screening

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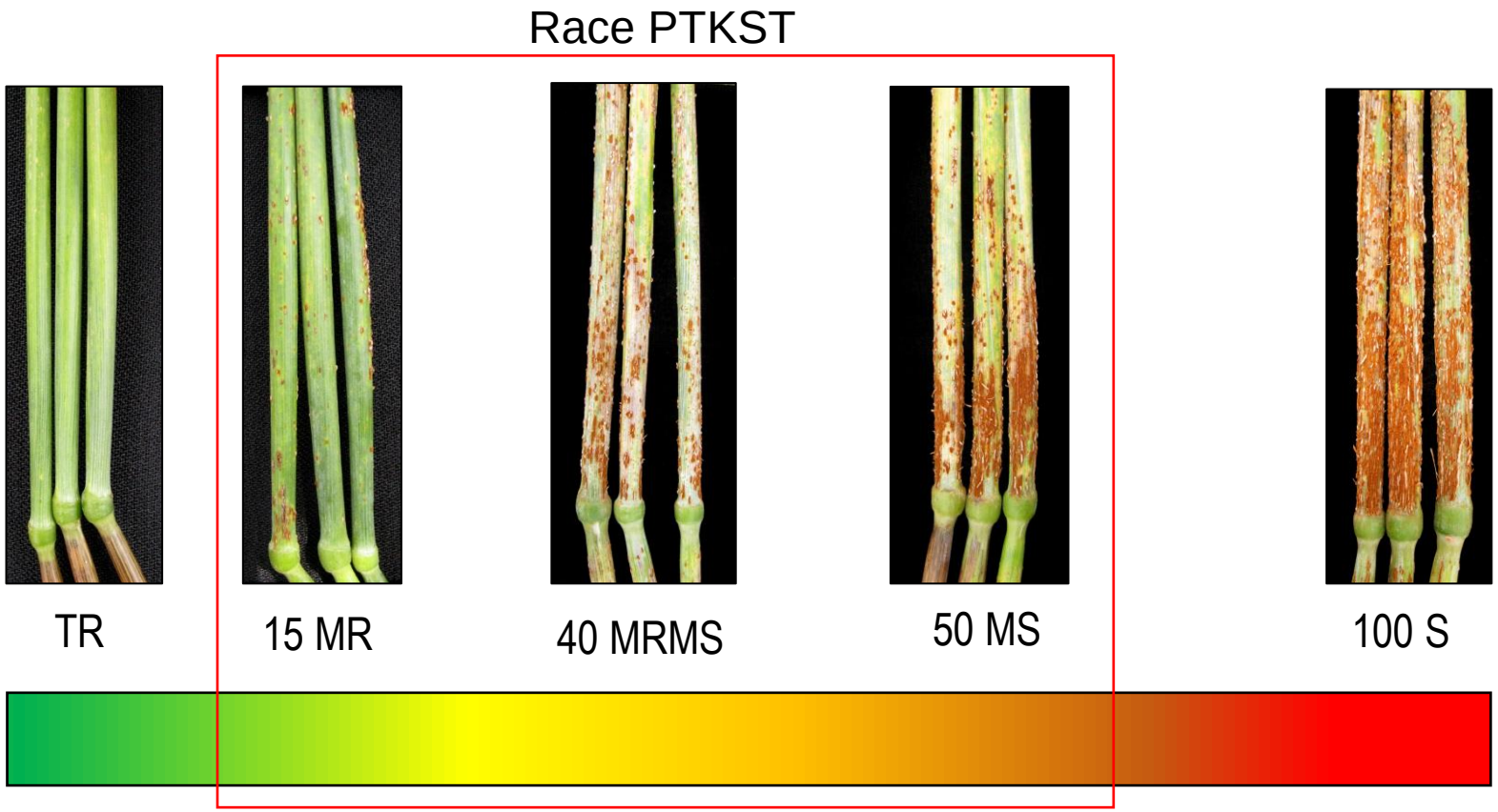
Wheat cultivar response - stem rust



Slide: Z.A. Pretorius

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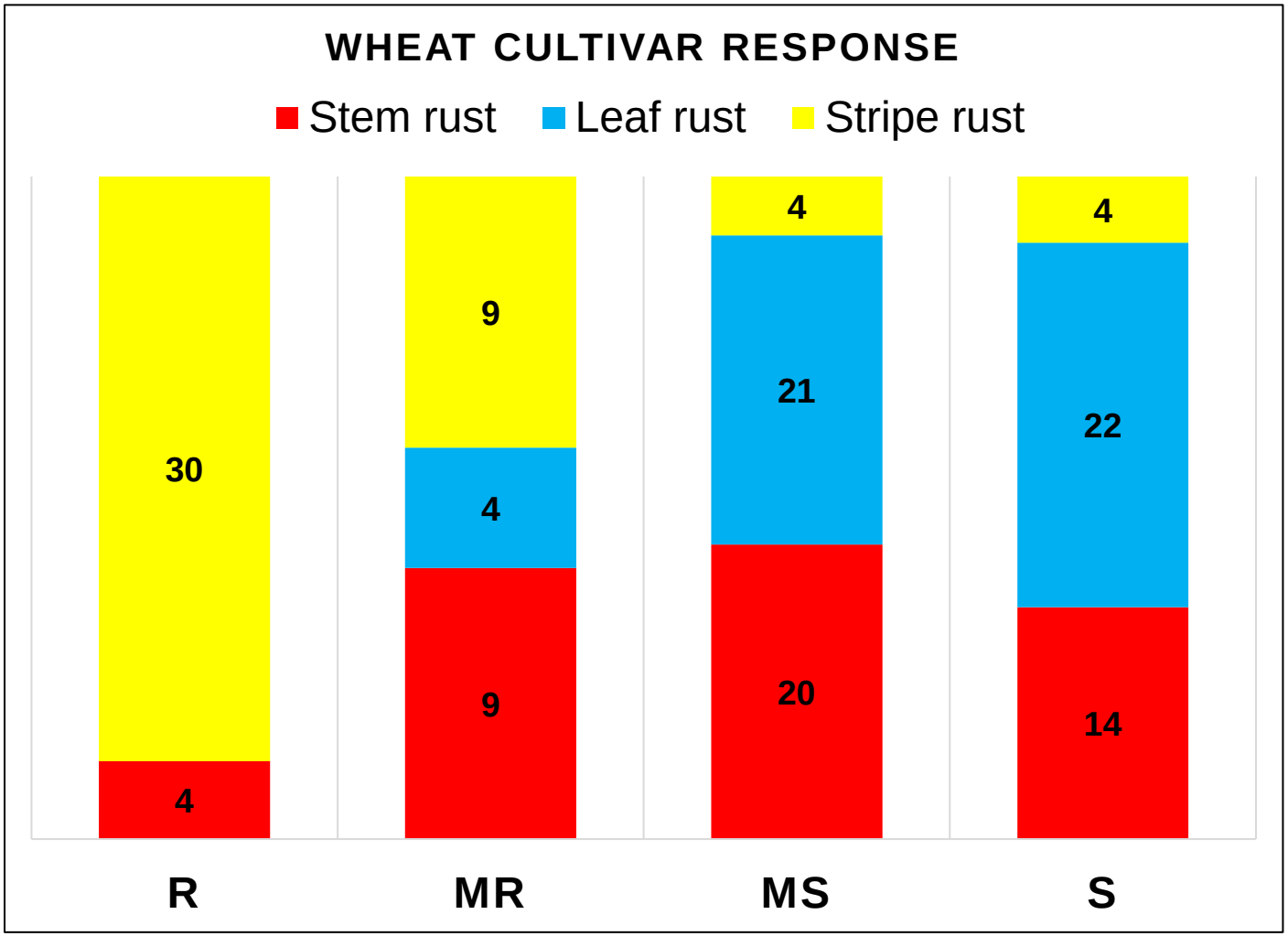
Status of rust resistance - wheat



Results from two years of field screening

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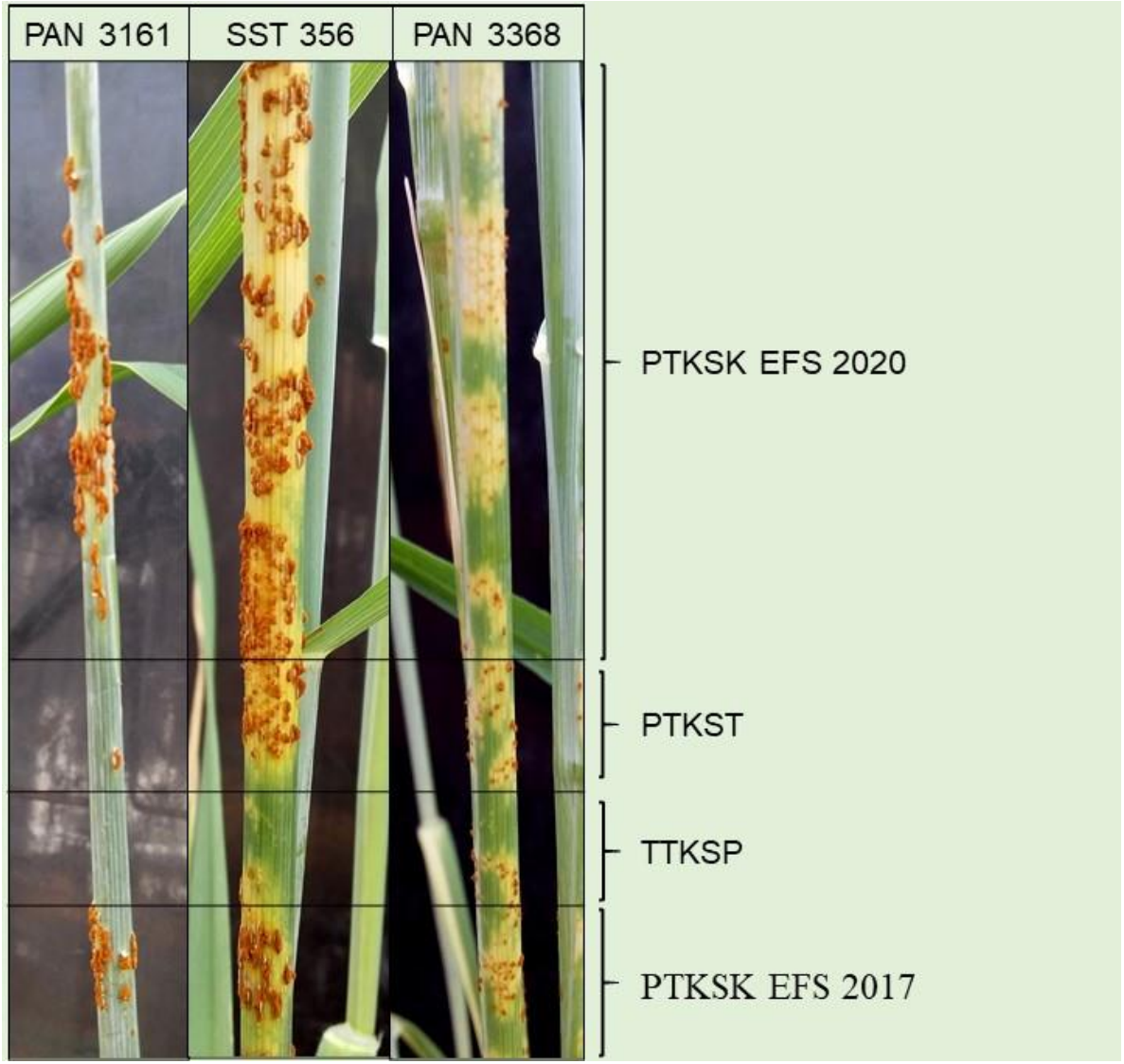
Status of rust resistance - wheat stem rust

Point inoculation



Status of rust resistance - wheat stem rust

Low IT ≤2+

High IT ≥3

	Seedling IT	
Cultivar	BFGSC	PTKST
SST 015	2	3
SST 056	22+	3
SST 087	1	;1
SST 0127	;1	3
SST 0147	0;	2-
SST 0166	;1-	2-
SST 0187	1	22+
PAN 3471	;C	3
PAN 3408	2	3
Ratel	;1C	3
Steenbok	;1-	22+
Tredou	;1-	3
Tankwa	0;	;1+
SST 0117	4	4
SST 88	4	4

Five older *Pgt* races avirulent

- New race BFGSC Western Cape 2020-season
- Virulent to *Sr38* present in SST 88 & SST 0177

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Accomplishments in wheat rust research in South Africa

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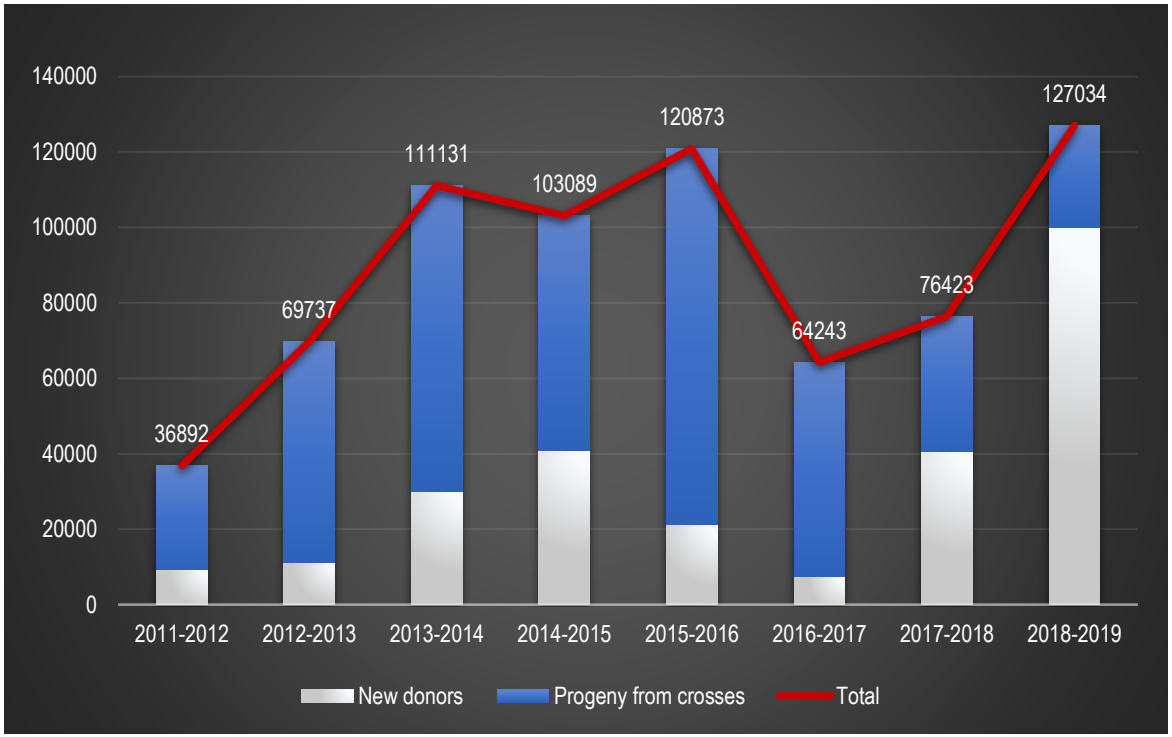
Rust diseases, although seasonal, have been severe constraints in wheat production in South Africa for almost 300 years. Rust research gained momentum with the institution of annual surveys in the 1980s, followed by race identification, an understanding of rust epidemiology, and eventually a focused collaboration amongst pathologists, breeders and geneticists. Diversity in South African populations of *Puccinia triticina*, *P. graminis* f. sp. *tritici* and *P. striiformis* f. sp. *tritici* has been described and isolates are

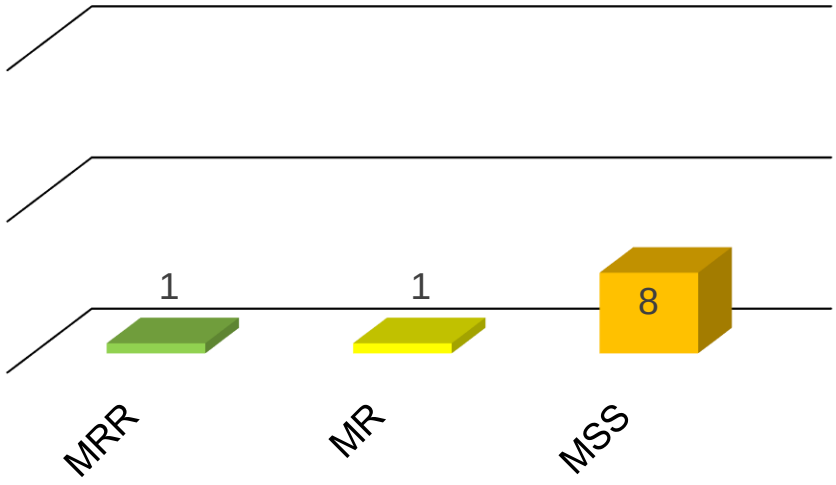


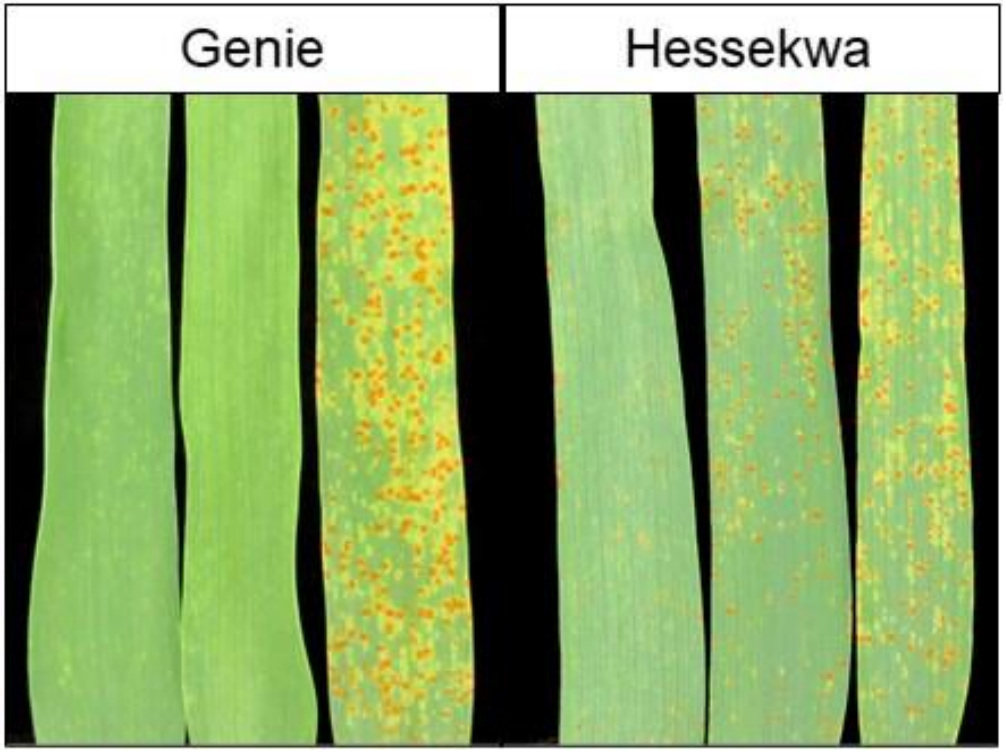
Number of data points generated since MAS inception in 2011

Cultivar response - barley leaf rust

Results from two years of field screening

Ph race UVPh7235





APR genes available:
Rph20, *Rph23 and Rph24*

From left to right on each plate: *P. hordei* races UVPh3231, UVPh7231 & UVPh7235

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Australasian Plant Pathology (2020) 49:679–690
https://doi.org/10.1007/s13313-020-00744-2

ORIGINAL PAPER

Assessments and perspectives on stem rust resistance in South African malting barley

R. Prins[1,2] · B. J. Steffenson[3] · A. J. Case[3,4] · W. H. P. Boshoff[5] · G. M. Agenbag[1] · Z. A. Pretorius[5]

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Pgt race PTKST

Pgs isolate UVPgs1

Pgt race PTKST

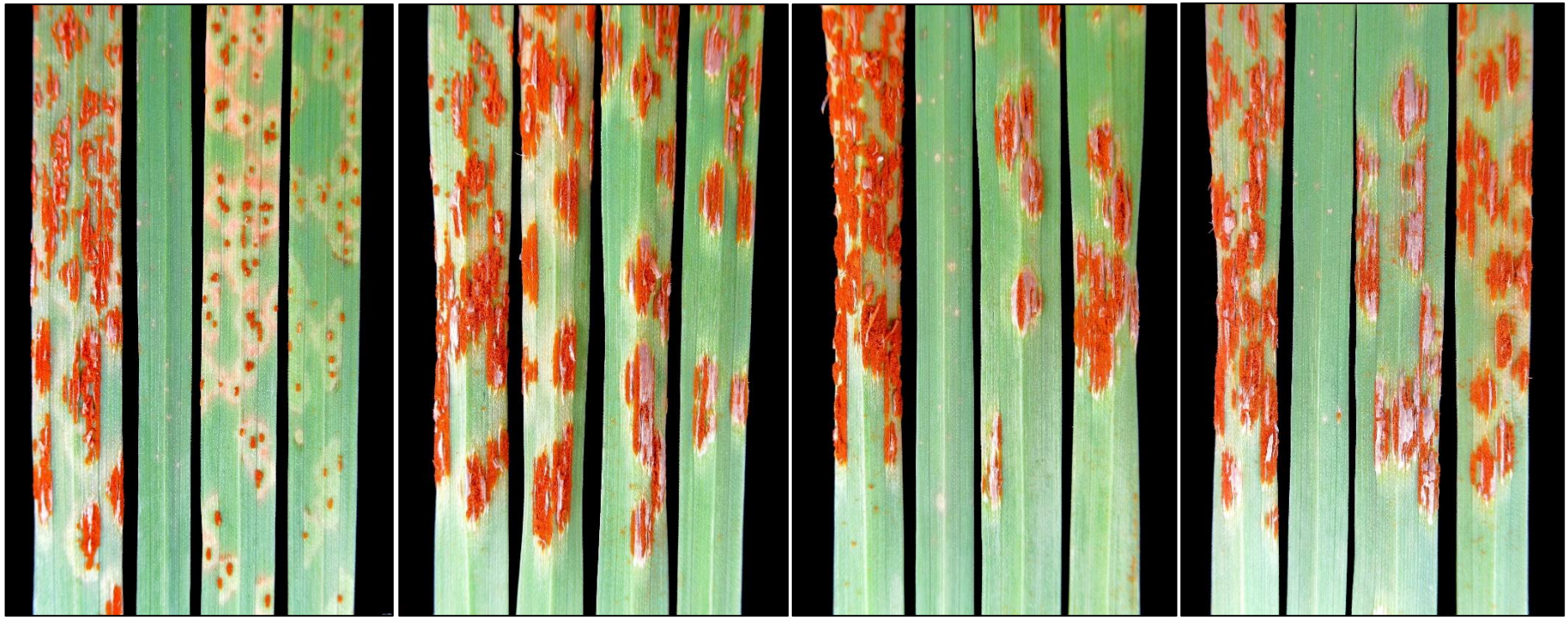
Photos: Z.A. Pretorius

Eur J Plant Pathol (2019) 155:1165–1177
https://doi.org/10.1007/s10658-019-01845-5

Diversity in *Puccinia graminis* f. sp. *avenae* and its impact on oat cultivar response in South Africa

W. H. P. Boshoff · B. Visser · T. Terefe · Z. A. Pretorius

RGN RSJ RJS RJJ

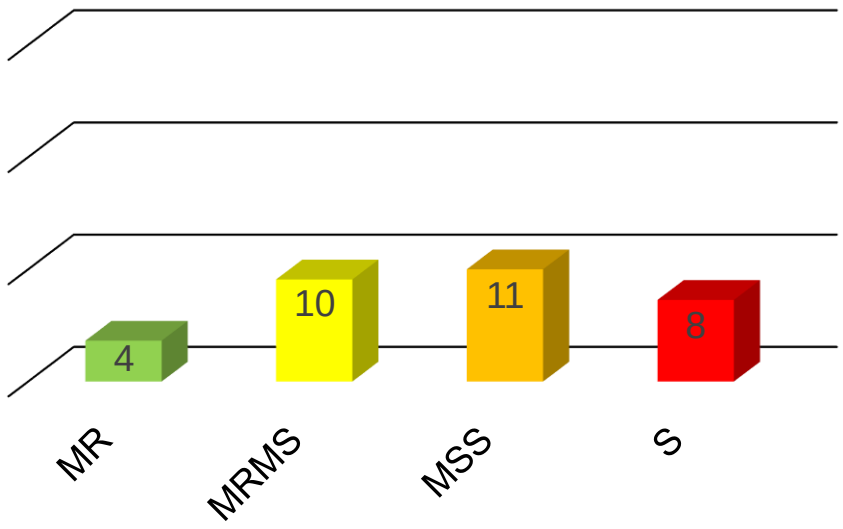


From left to right on each photo: Outback, Saia, Drakensberg and Letucana

Cultivar response - oat stem rust

Results from two years of field screening

Pga races RSJ and RJS



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Occurrence and pathogenicity of *Puccinia coronata* var *avenae* f. sp. *avenae* on oat in South Africa

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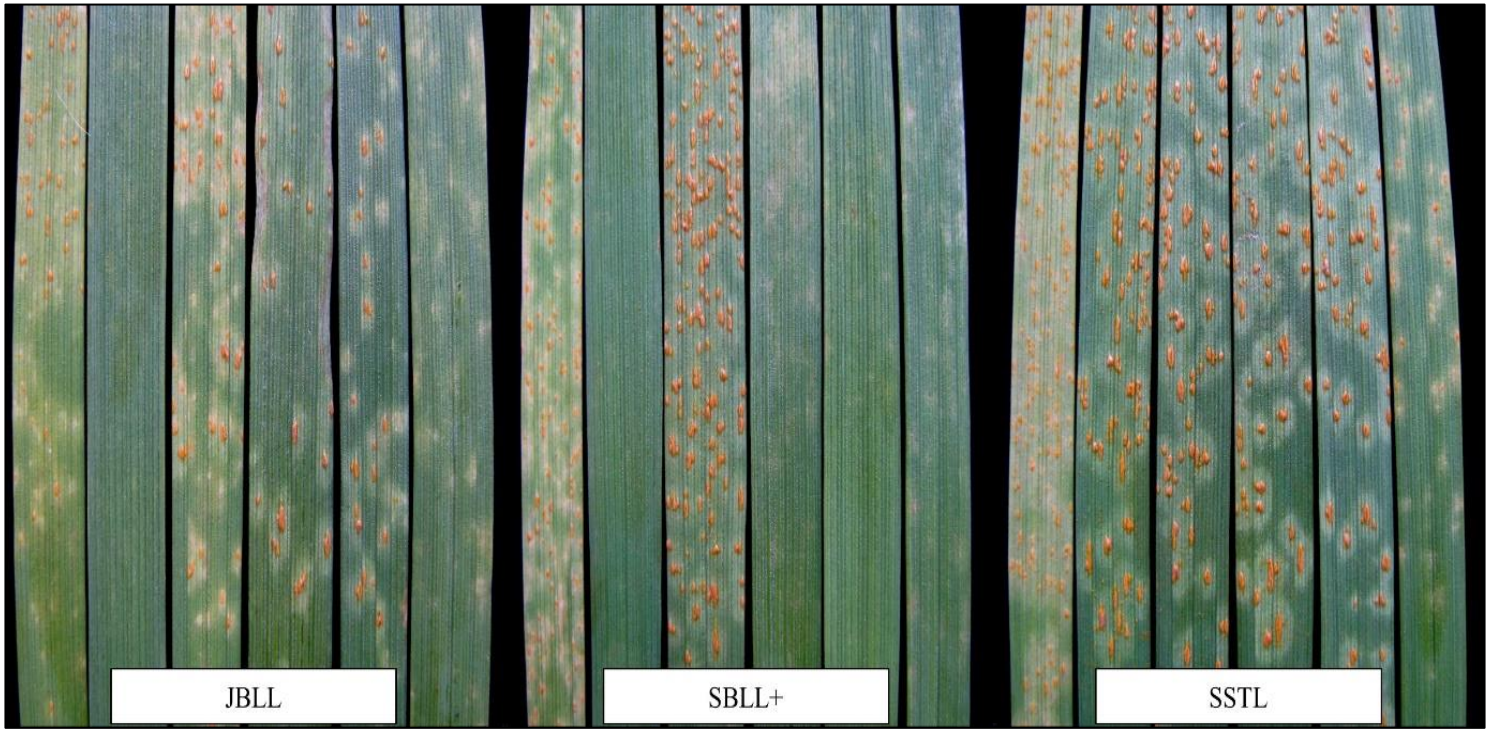
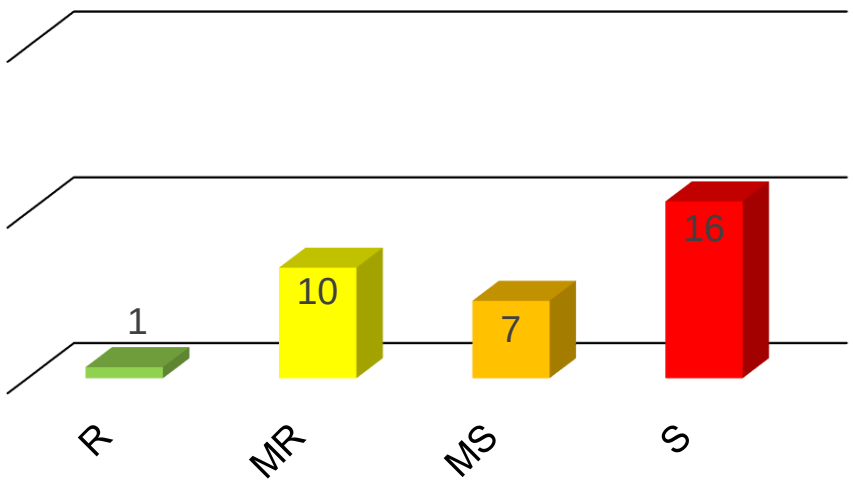
[b] *Agricultural Research Council - Small Grain, Private Bag X29, Bethlehem, 9700, South Africa*

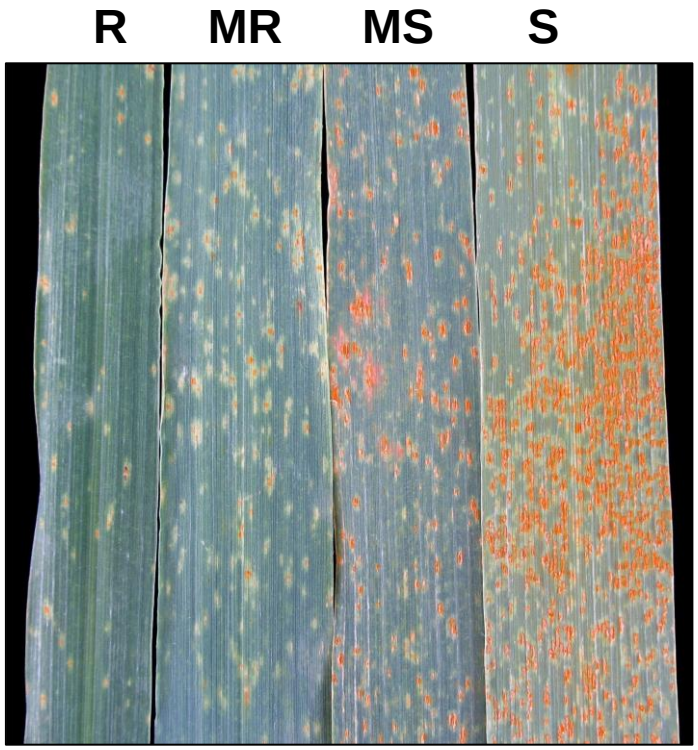


From left to right on each photo: Towerberg, Kompasberg, Overberg, Drakensberg, Le Tucana and Majoris

Cultivar response - oat crown rust

Results from two years of field screening



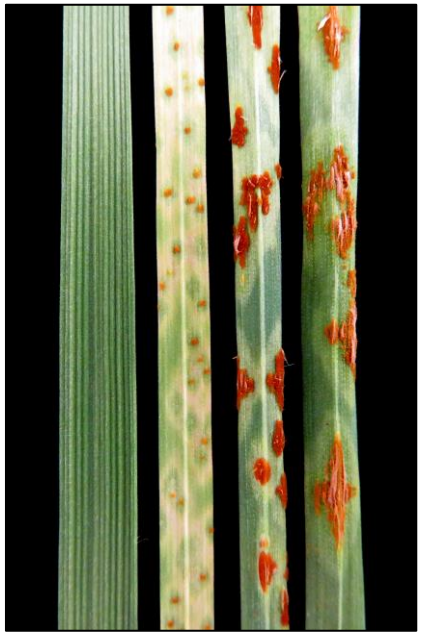


Reaction of South African rye, triticale and barley forage cultivars to stem and leaf rust

Willem HP Boshoff, Cornel M Bender & Zacharias A Pretorius

To cite this article: Willem HP Boshoff, Cornel M Bender & Zacharias A Pretorius (2019) Reaction of South African rye, triticale and barley forage cultivars to stem and leaf rust, South African Journal of Plant and Soil, 36:2, 77-82, DOI: 10.1080/02571862.2018.1522381

To link to this article: https://doi.org/10.1080/02571862.2018.1522381



Stem rust rye

Leaf rust rye

Stem rust barley

Stem rust triticale

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Conclusions

- Application of MAS
  - Future cultivars expected to contain more complex sources of resistance
- Resources and expertise
  - Can only be secured through sustained funding
- Monitoring of rust pathogens - surveillance
  - Maintain living collections of cultures
- Rust research in support of industry needs
  - Breeders - advise on resistance sources and support in rust screening
  - Producers - advise on cultivars response and control strategies

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Conclusions

- Maintain and strengthen international collaboration

ARTICLE

https://doi.org/10.1038/s41467-021-23738-0 OPEN

Check for updates

A recombined *Sr26* and *Sr61* disease resistance gene stack in wheat encodes unrelated *NLR* genes

Jianping Zhang[1,2], Timothy C. Hewitt[1,2], Willem H. P. Boshoff[3], Ian Dundas[4], Narayana Upadhyaya[2], Jianbo Li[1], Mehran Patpour[5], Sutha Chandramohan[2], Zacharias A. Pretorius[3], Mogens Hovmøller[5], Wendelin Schnippenkoetter[2], Robert F. Park[1], Rohit Mago[2], Sambasivam Periyannan[2], Dhara Bhatt[2], Sami Hoxha[1], Soma Chakraborty[2], Ming Luo[2], Peter Dodds[2], Burkhard Steuernagel[6], Brande B. H. Wulff[6], Michael Ayliffe[2], Robert A. McIntosh[1], Peng Zhang[1✉] & Evans S. Lagudah[1,2✉]

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