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RUSTWATCH
WHEAT RUST EARLY WARNING

Virulence assessment of local stem rust isolates and integration of resistance genes in the spring wheat breeding program

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

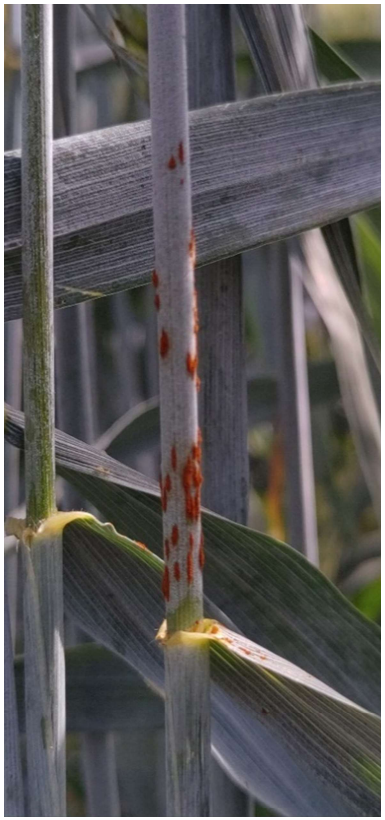
Pathogen causing stem rust disease on wheat

Biotrophic fungal pathogen that requires a living host to grow and reproduce.

Infects leaf sheaths, stems, leaves, glumes and awns

Favoures high temperatures (18-30°C) compared to 15-20°C and 15-25°C for yellow rust and leaf rust respectively (1)

Observed in June and July in Switzerland



Nyon, 15.6.2022

(1) Leaf rust atlas from RA McIntosh, CR Wellings and RF Park

Puccinia graminis f. sp. *tritici*

For sexual reproduction the alternate host barberry is required.

Overwintering on barberry.

On wheat, fungus is at a dikaryotic stage and reproduces asexually via urediniospores.

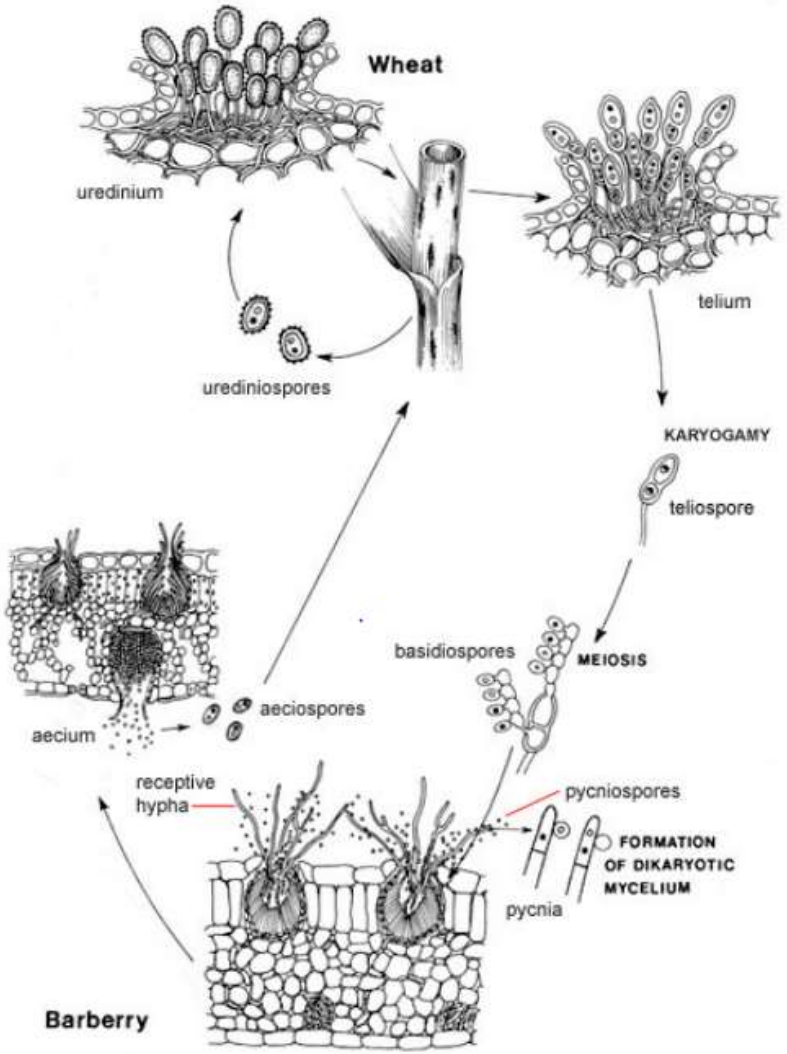
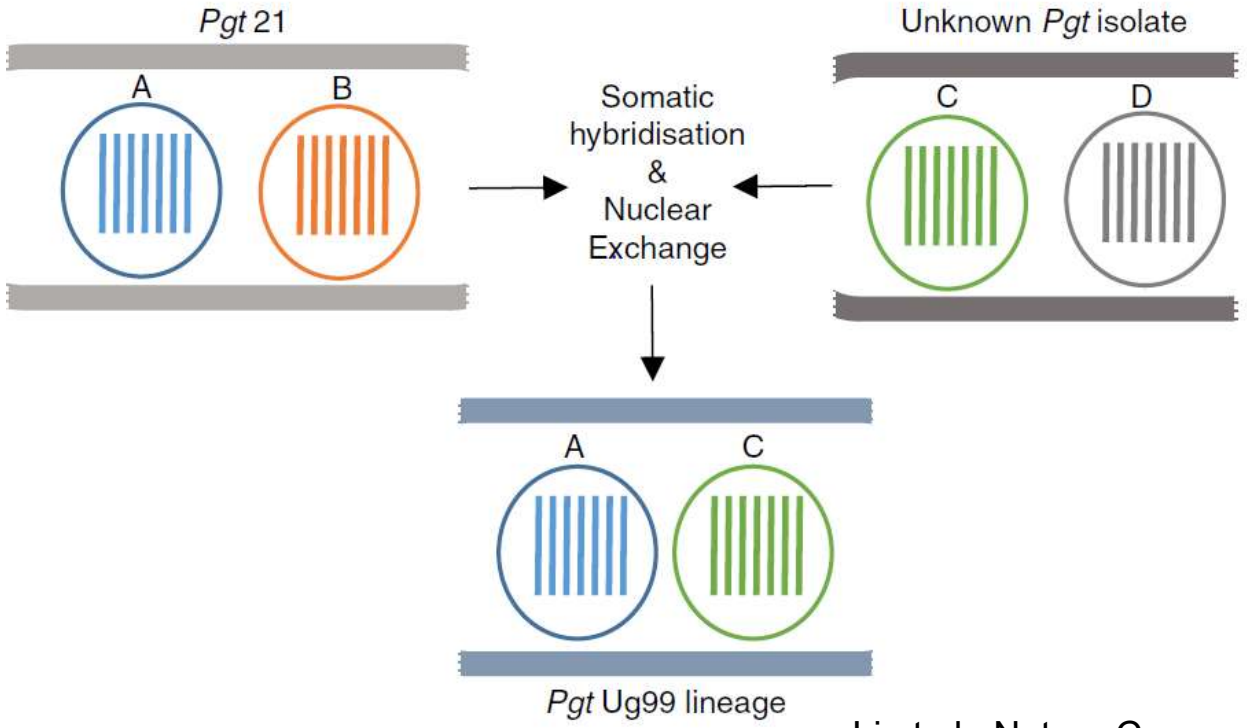


Figure: APS-Webpage

Recombination by somatic hybridisation

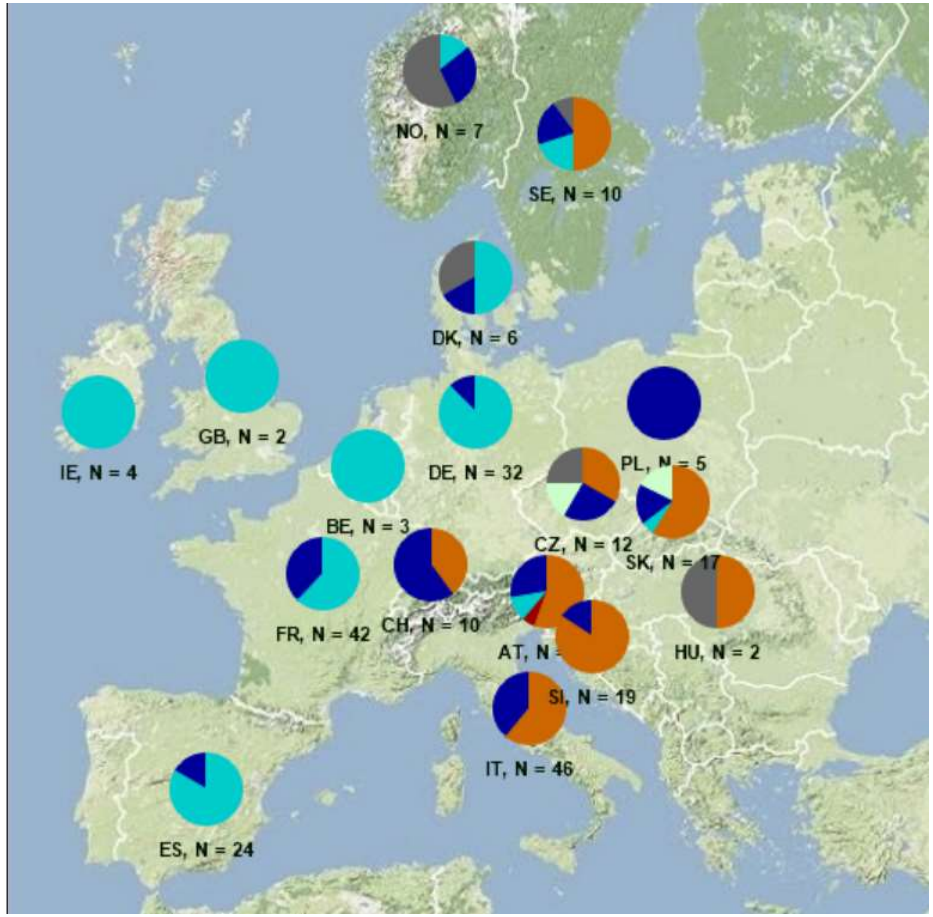
High resolution sequence of Ug99 and Pgt21

Ug99 arose from a nuclear exchange between Pgt21 and another unknown isolate.



Li et al., Nature Communications, 2019

Stem rust clades 2020 and 2021



Clade III-B	TTRTF
Clade IV-A.1	TKTTF & TTTTF
Clade IV-B	TKTTF
Clade IV-F	TKKTF
Clade VIII	RFCNC
Other	

Highly virulent strains are present in Europe.

Separation East and West

Data and illustrations from the GRRC, Aarhus University and JKI, Germany, 1.3.2023

Stem rust in Europe 2020 and 2021

	Four gene differential sets			
	Sr5	*Sr21*	*Sr9e*	*Sr7b*
	Sr11	*Sr6*	*Sr8a*	*Sr9g*
	Sr36	*Sr9b*	*Sr30*	*Sr17*
	Sr9a	*Sr9d*	*Sr10*	*SrTmp*
Pgt letter	*Sr24*	*Sr31*	*Sr38*	*SrMcN*
B	L	L	L	L
C	L	L	L	H
D	L	L	H	L
F	L	L	H	H
G	L	H	L	L
H	L	H	L	H
J	L	H	H	L
K	L	H	H	H
L	H	L	L	L
M	H	L	L	H
N	H	L	H	L
P	H	L	H	H
Q	H	H	L	L
R	H	H	L	H
S	H	H	H	L
T	H	H	H	H

Set 1
Set 2
Set 3
Set 4
Set 5

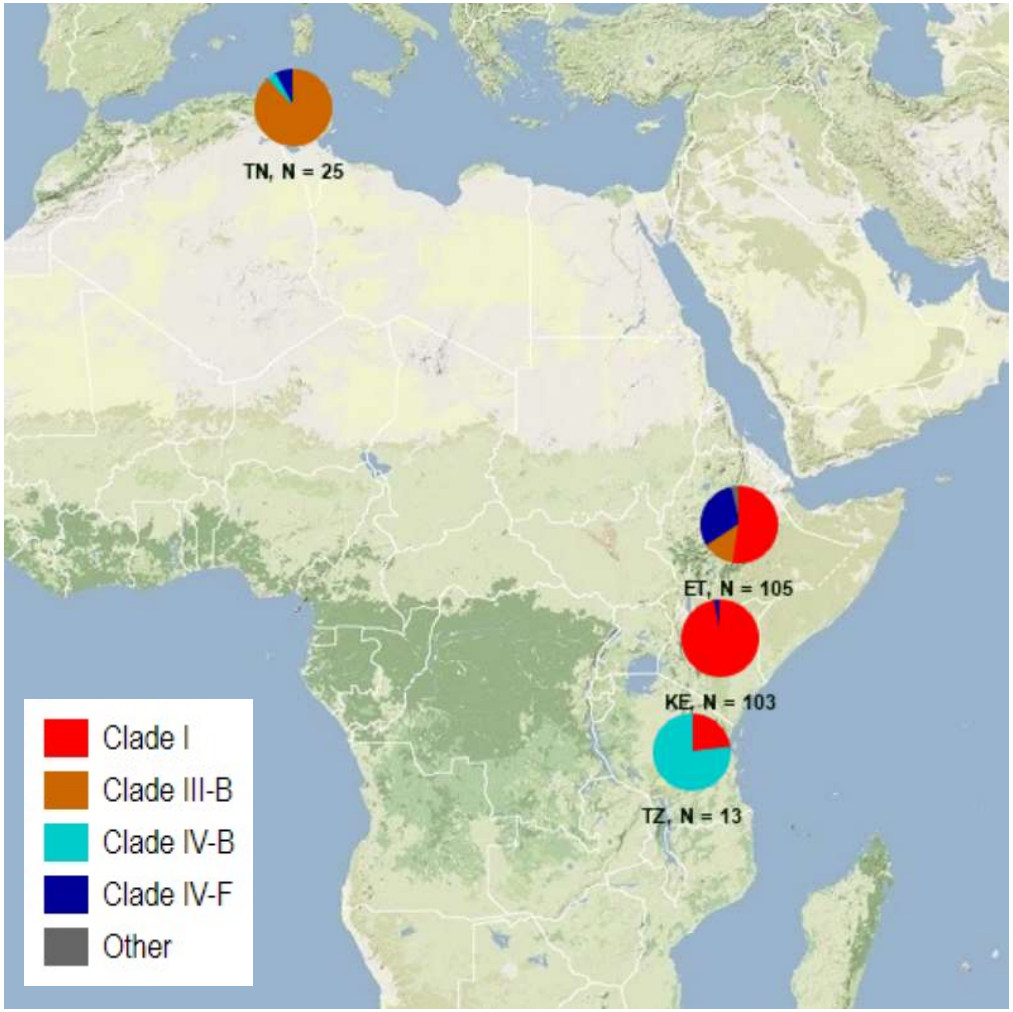
Clade III-B	TTRTF
Clade IV-A.1	TKTTF & TTTTF
Clade IV-B	TKTTF
Clade IV-F	TKKTF
Clade VIII	RFCNC
Other	

	Sr24	*Sr31*	*Sr38*	*SrMcN*
F	L	L	H	H
C	L	L	L	H

No virulence against *Sr24* and *Sr31* in Europe

H = High Infection Type (3-4 on standard evaluation scale)
L = Low Infection Type (0-2 on standard evaluation scale)

Different clade in Africa



Diverse clade I with virulence on *Sr24* and *Sr31* that is not present in Europe

Clade	Race	Pattern
Clade I	TTKSK	[1111|1111|0111|1110|0111]
	TTKSF	[1111|1111|0111|1110|0011]
	TTKST	[1111|1111|0111|1110|1111]
	TTTSK	[1111|1111|1111|1110|0111]
	TTKSP	[1111|1111|0111|1110|1011]
	PTKSK	[1011|1111|0111|1110|0111]
	PTKST	[1011|1111|0111|1110|1111]
	TTKTT	[1111|1111|0111|1111|1111]
	TTKTK	[1111|1111|0111|1111|0111]
	TTHSK	[1111|1111|0101|1110|0111]
Clade III-B	TTRTF	[1111|1111|1101|1111|0011]
Clade IV-B	TKTTF	[1111|0111|1111|1111|0011]
	TTTTF	[1111|1111|1111|1111|0011]
Clade IV-F	TKKTF	[1111|0111|0111|1111|0011]
Other	Other	[9999|9999|9999|9999|9999]

Data and illustrations from the GRRC, Aarhus University and JKI, Germany, 1.3.2023

Sr31-virulence in Europe

Mehran Patpour et al., Frontiers, 2022

Extensive study on almost 500 stem rust isolates from 17 countries in Europe (collected in 2017-2021)
Genotyped with SNP chip and or SSR markers and the race was determined

- *Sr31*-virulence was observed in Spain and Siberia
- *Sr31*-virulence evolved several times independently from Ug99
- Sexual reproduction in areas where barberry is growing

Aim of the study

Increasing temperatures might favour spread of stem rust and lead to earlier establishment of disease in the season

Estimation of the threat for Swiss wheat production

- Virulence of Swiss stem rust isolates
- Resistance/susceptibility of Swiss wheat varieties

Implications for the wheat breeding program

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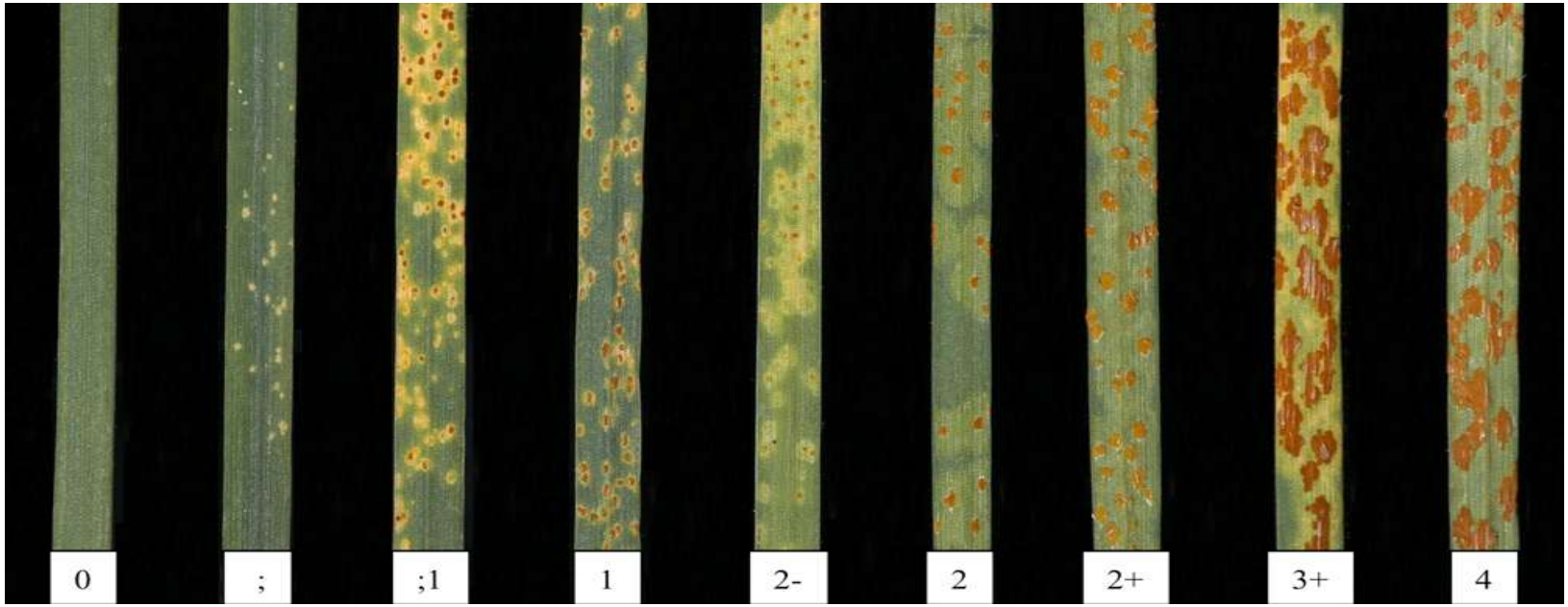
Seedling resistance of Swiss varieties

Infection of seedlings (two-leaves-stage) in growth chambers

Determination of high and low infection type as for differential set



Low infection type

High infection type

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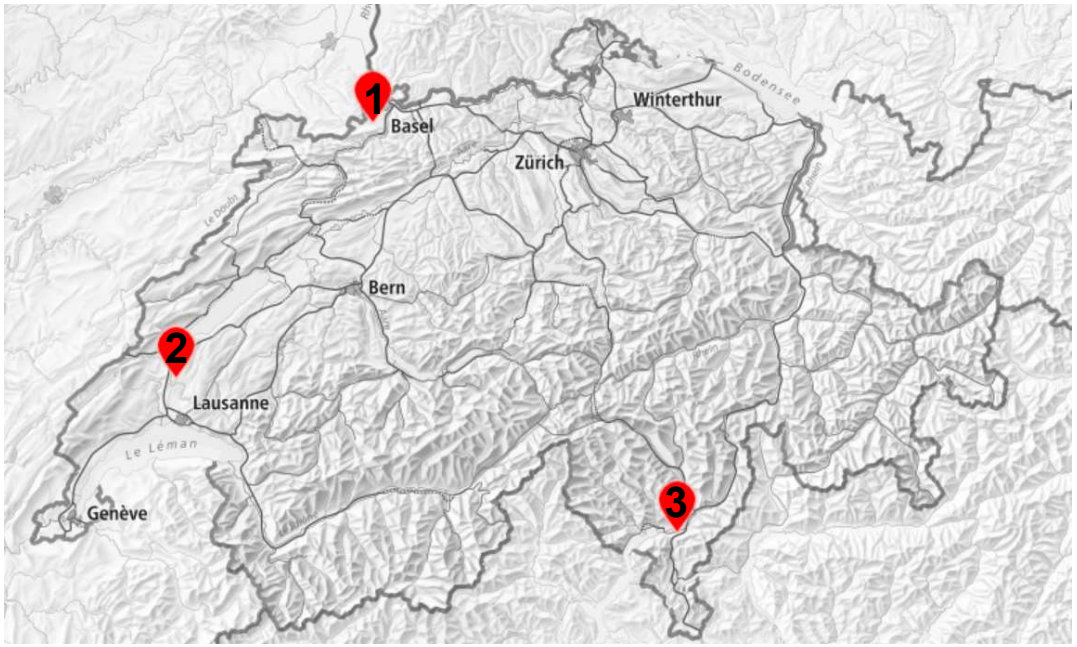
Isolates for resistance screening



Number	Origin	Year	Race
1	Witterswil (SO)	2020	TKKTF
2	Goumoëns (VD)	2020	TTFTC
3	Cadenazzo (TI)	2021	TTTTF

→ Clade IV-F

→ Clade IV-B

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Seedling resistance of Swiss varieties

Same result for all three isolates

Species (Type)	Susceptible	Resistant	Tested
Wheat (winter)	38	8	46
Wheat (summer)	11	4	15
Spelt	15	2	17
Triticale	0	8	8

Triticale are all resistant.
Only few spelt and wheat varieties are resistant.

Seedling resistance of Swiss varieties

Swiss varieties (buiscuit quality)
German varieties

Resistance due to the known resistance genes *Sr24* and *Sr31*?

Known resistance genes present in resistant varieties

Variety	Origin	Resistance?	*Sr24*	*Sr31*
LG Mondial	Germany	yes	yes	No
LG Gelik	Germany	yes	yes	No
KWS Expectum	Germany	yes	yes	No
KWS Eternel	Germany	yes	yes	No
KWS Sharki	Germany	yes	yes	No
Intelligence	Germany	yes	yes	No
Quintus	Germany	yes	yes	No
Campesino	Germany	yes	yes	No
Sheriff	Germany	yes	yes	No
Bulldoza	Germany	yes	yes	No
Dilago	Switzerland	yes	No	Yes
Tinzen	Switzerland	yes	No	Yes
Toronit	Switzerland	NA	No	Yes

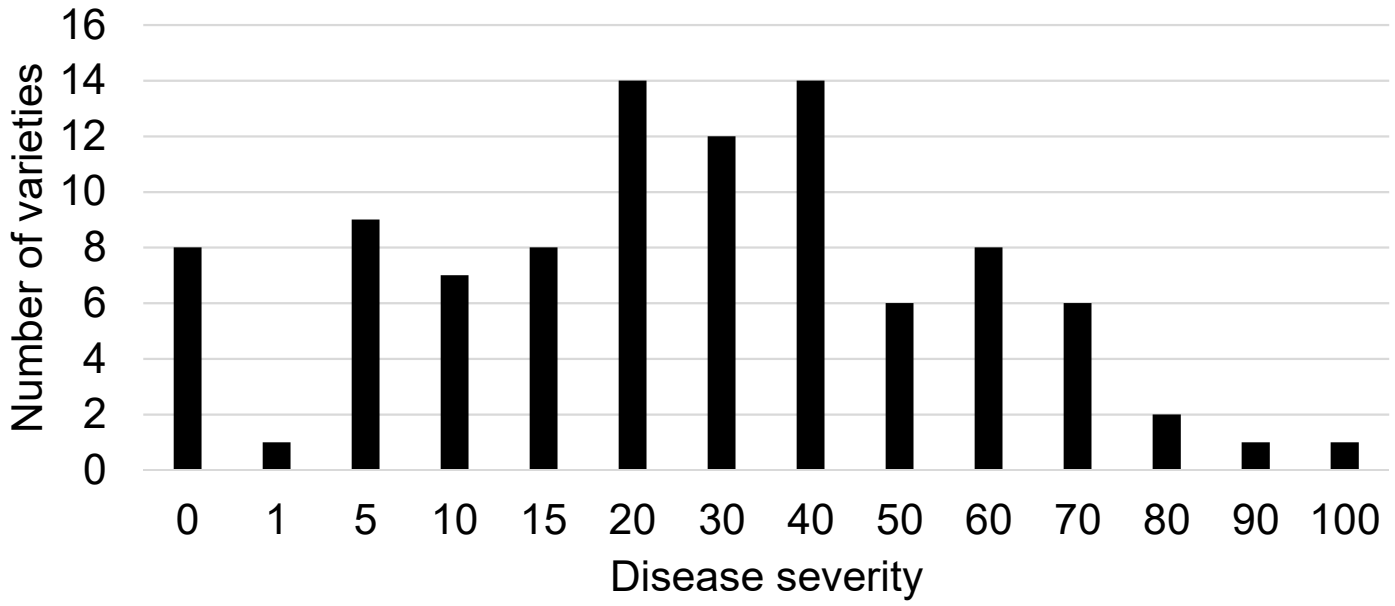
PCR markers:
Sr24#12[(1)] for *Sr24*
SCSS30.2$_{576}$[(2)] for *Sr31*

(1) Mago et al., 2005, 10.1007/s00122-005-2039-z,
(2) Das et al., 2006, 10.1111/j.1439-0523.2006.01282.x

Adult plant resistance in Njoro, Kenya

Stem rust phenotyping platform in Njoro:
CIMMYT in collaboration with Cornell University and the Kenya Agricultural and Livestock Research Organization (KALRO)

100 varieties tested, results from 97 varieties



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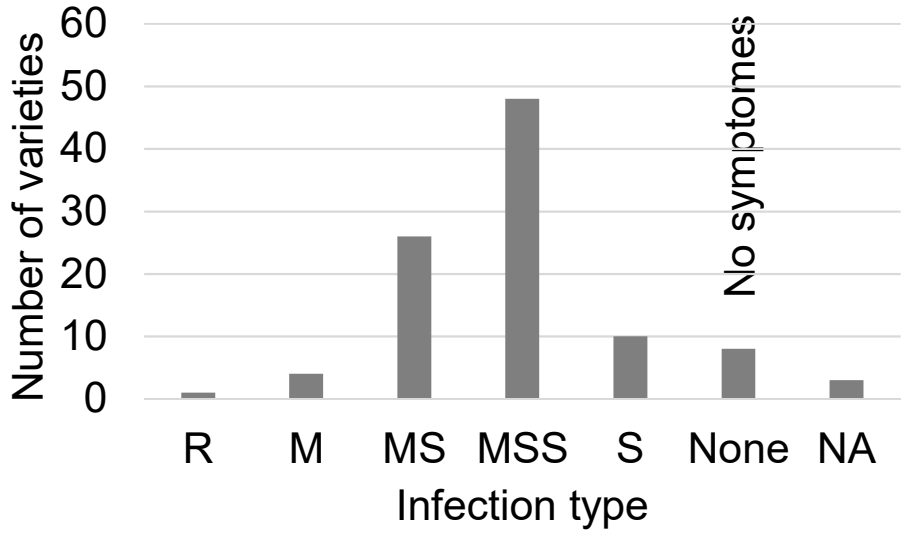
Adult plant resistance in Njoro, Kenya

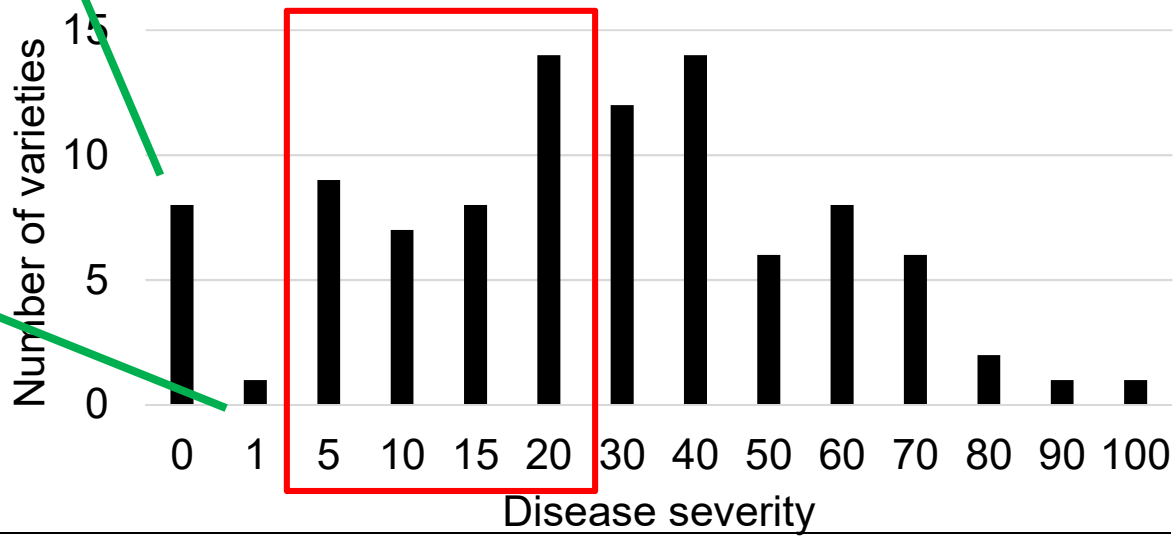
8 varieties without any symptomes:

- CH NARA
- CH CAMEDO
- DOLLY
- PERSEUS
- PIZNAIR
- BALINO
- LERMA
- TRIANGOLI

1 varieties classified as resistant (1% severity):

- PICODÁNETO





Adult plant resistance in Njoro, Kenya

8 varieties without any symptomes:

- CH NARA
- CH CAMEDO
- PIZNAIR
- BALINO
- LERMA
- TRIANGOLI
- PERSEUS
- DOLLY

Susceptible in CH

Triticale were also resistant in CH and have *Sr31*

1 varieties classified as resistant (1% severity):

- PICODÁNETO

DILAGO, TORONIT and TINZEN containing *Sr31* (resistant in CH) are susceptible in Kenya!

CAMPESINO and SHERIFF containing *Sr24* (resistant in CH) are susceptible in Kenya!

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The breeders perspective

Genotyping of advanced breeding lines: *Sr24*

10% of the lines contain *Sr24*

Introgression was unintentionally

Crossings with Quintus
Crossing with Draco (Secobra)
Crossings with a line from Strube

Implications for breeding

Sr31 already in the Swiss gene pool

- Translocation (1BL.1RS) from rye
- Associated with reduced baking quality (Gobaa et al., 2008)
- Resistance broken in Europe (Patpour et al., 2022)

Sr24 is a valuable resistance gene in Europe

- Not in Africa
- Might not be in effective in the future

Alternative resistance gene for breeding?

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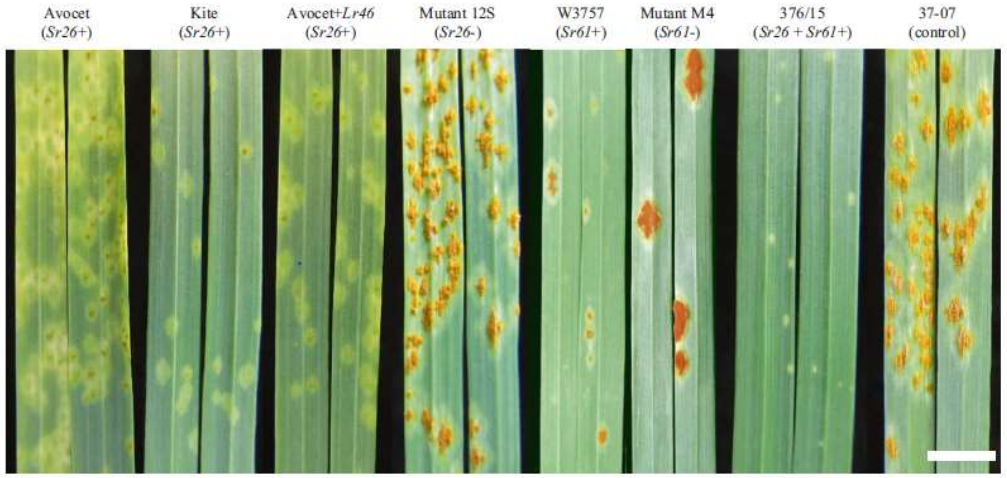
Sr26 and *Sr61* to complement *Sr24*

- *Sr26* and *Sr61* have been independently introduced from *Thinopyrum ponticum*
- Both are NLR genes
- No Pgt isolates known to be virulent on *Sr26* and *Sr61*

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]✉

2021



Summary

- Highly virulent stem rust races are present in Switzerland
- These are the same as elsewhere in Europe and they are avirulent on *Sr24*-carrying lines
- Lack of Swiss spring wheat varieties that are resistant against local stem rust isolates
- *Sr26, Sr61* and *Sr24* for the spring wheat breeding program
- Quantitative resistance genes?

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Thank you for your attention

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