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GRRC report of yellow and stem rust genotyping and race analyses 2021.

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Key highlights stem rust

- Three genetic groups of stem rust were prevalent in Europe. Additional spread was observed in France in particular, but also in other countries in Central/West Europe.
- Clade III-B (race TTRTF) was widespread in southern part of Europe, and in 2021 also detected in Tunisia and Switzerland. Since first detection in Sicily in 2016, we have confirmed TTRTF in 9 countries in Europe, and 4 countries in Africa/Asia.
- Clade IV-F (race TKKTF) was detected in 4 African and 13 European countries in 2021. Previously, we have also detected TKKTF in Azerbaijan, Egypt, Iran, Iraq and Tajikistan.
- Clade IV-B (races TKTTF, TKRTF and TTTTF) was observed in Tanzania and Tunisia and in 8 European countries in 2021. TKRTF was observed in a single isolate from Spain; TTTTF was observed in East Africa but not in Europe.
- Clade I (Ug99) was not observed outside East Africa.

Key highlights yellow rust

- A new incursion of a highly virulent race in East Africa represented a new genetic group, termed PstS16. It was detected in December 2020 in Ethiopia and became widespread in farmer's fields and experimental plots in 2021, but not detected in neighboring countries. PstS16 was also widespread in Afghanistan in 2021.
- Genetic group PstS13 spreads to new areas in South America, including Paraguay, where yellow rust was detected for the first time. A single race/genotype is still prevalent although local variants have been observed. PstS13 has mainly affected triticale and durum wheat in Europe and bread wheat in South America and Australia.
- PstS14 was widespread in Iraq, which represents first detection of this genetic group in Asia. Present in Europe and northern Africa since 2016.
- PstS10 was the most prevalent genetic group in Europe. At least 4 races were detected, each adapted to local, widely grown wheat varieties.
- PstS11 and PstS1/PstS2 were confirmed in multiple countries in East Africa.
- PstS7 (Warrior race) was less prevalent than in previous years, however, up to now detected in Europe, northern Africa and South America.
- Additional genetic groups, including groups which have not yet been named (collectively termed 'Other'), were either absent or detected in low frequencies.
- Samples from Nepal were genetically different from all named groups and revealed high pathogen diversity in this area.

Summary of SSR genotyping and race phenotyping results from GRRC (2008-present) is available online (http://www.wheatrust.org/), including an updated table showing the relationship between races and genetic groups.

This report presents molecular genotyping and race typing results with a focus on samples of rust infected wheat, barley and triticale collected in 2021 across four continents, i.e., Europe, Asia, Africa and South America. The report comprises results for the wheat yellow/stripe rust (*Puccinia striiformis*) as well as the wheat stem rust, *P. graminis* f.sp. *tritici*. The testing of additional samples from 2021 and beginning of 2022 is ongoing with emphasis on alignment of results from different rust diagnostic laboratories and genotyping approaches with the aim of presenting the global landscape for yellow and stem rust infecting wheat.

In 2021, a total of 889 samples/derived isolates from 27 countries were handled (Table 1, Table 2). Each sample generally consisted of multiple rust infected leaves or stems. Incoming samples entered a recovery procedure in parallel to Simple Sequence Repeat (SSR) genotyping based on the incoming samples of rust infected plant material. More than 400 of samples were successfully recovered. In case of the presence of more than a single genotype within a sample, additional genotyping was based on purified samples. Subsets of recovered isolates were race phenotyped using bioassays consisting of differential wheat lines inoculated with live spore samples multiplied under strict experimental conditions (Hovmøller et al. 2017; Patpour et al., 2022).

Nomenclature of races and genetic groups

Genetic groups of yellow rust were named Pst followed by a digit. Race variants were indicated by the additional virulence observed compared to the virulence profile of the core genetic group. For detailed rationale and naming of significant *P. striiformis* races and genetic groups, see Ali et al. (2017) with an updated summary on the GRRC website. The genetic grouping of stem rust is based on Szabo et al. (2022), and detailed alignment of the SSR and SNP genotyping results between the Cereal Disease Lab (USA) and GRRC; the race phenotyping was based on 20 internationally agreed wheat lines differentiating virulence in stem rust (Jin et al., 2008; Patpour et al., 2022).

In yellow rust, a strong correlation between genetic group and race phenotype has been observed for clonal populations, and similarly, most races of wheat stem rust were associated with specific genetic groups ('clades'). A comprehensive documentation of the nomenclature of stem rust races and genotypes, and the underlying experimental procedures are available on the GRRC website, where new mapping tools were implemented. However, in sexual populations unique and diverse genotypes and races are often observed. These and other infrequent groups are termed "Other" in tables in this report and in online maps and charts (www.wheatrust.org).

2021 results – wheat stem rust

In 2021, we received an increasing number of samples compared to previous years (Table 1). Genotyping results of 223 samples from 2021 and 117 samples from 2020, in total representing 21 countries, are presented in Table 2. Race typing was completed for 95 representative isolates from these two years. The races and virulences detected within genetic groups are shown in Table 3 and Table 4. Graphical presentation of results available on www.wheatrust.org. Detailed results for Europe 2016-2021 have been accepted for publication recently, including genetic diversity with respect to race and genotype in local populations in proximity to alternate hosts of Berberis spp. (Patpour et al., 2022).

Table 1. Number of stem rust samples and derived isolates in 2021. (D: dead, L: live/recovered).

Count of Running_numbers		**Testing year**	**Sample_Type**	
		2021		**Grand Total**
Geographic group	**Country**	**D**	**L**	
Africa, CW Asia	Ethiopia		5	5
	Kenya	10	53	63
	Tanzania	35		35
	Tunisia	27	3	30
Africa, CW Asia Total		**72**	**61**	**133**
Europe	Austria		3	3
	Belgium	2	1	3
	Czech Republic	4	5	9
	Denmark		5	5
	France	17	26	43
	Germany		1	1
	Ireland		4	4
	Italy	19	36	55
	Norway		6	6
	Slovakia	2	8	10
	Slovenia	5	1	6
	Spain	4	3	7
	Sweden		16	16
	Switzerland		10	10
	United Kingdom		4	4
Europe Total		**53**	**129**	**182**
Grand Total		**125**	**190**	**315**

Table 2. Distribution of isolates of *P. graminis* f.sp. *tritici* from 21 countries in 2020 and 2021 in prevalent genetic groups.

Geographic area	Country	SSR_name	2020	2021	Total
Africa, CW Asia	**Ethiopia**	Clade IV-F		4	4
	Kenya	Clade I	25	57	82
		Clade IV-F		2	2
	Tanzania	Clade I		7	7
		Clade III-B		1	1
		Clade IV-B		3	3
		Clade IV-F		1	1
	Tunisia	Clade III-B		22	22
		Clade IV-B		1	1
		Clade IV-F		2	2
Africa, CW Asia Total			**25**	**100**	**125**
Europe	**Austria**	Clade III-B	2	2	4
		Clade IV-F	1	1	2
	Belgium	Clade IV-B		3	3
	Czech Republic	Clade III-B	2	2	4
		Clade IV-F		2	2
		Clade VIII	4	1	5
	Denmark	Clade IV-B		3	3
		Clade IV-F		1	1
		Other	2		2
	France	Clade IV-B	6	21	27
		Clade IV-F		16	16
	Germany	Clade IV-B		3	3
		Clade IV-F		1	1
		Clade VIII	1		1
	Hungary	Clade III-B	1		1
		Clade VIII	1		1
	Ireland	Clade IV-B	4		4
	Italy	Clade III-B	13	21	34
		Clade IV-F	11	10	21
	Norway	Clade IV-B		1	1
		Clade IV-F	1	1	2
		Other	1	3	4
	Poland	Clade IV-F		5	5
	Slovakia	Clade III-B	6	3	9
		Clade IV-F	1	1	2
		Clade VIII	3		3
	Slovenia	Clade III-B	16		16
		Clade IV-F	2	1	3
	Spain	Clade IV-B	14	1	15
		Clade IV-F		4	4
	Sweden	Clade IV-B		1	1
		Clade IV-F		2	2
		Other		1	1
	Switzerland	Clade III-B		4	4
		Clade IV-F		6	6
	United Kingdom	Clade IV-B		2	2
Europe Total			**92**	**123**	**215**
Grand Total			**117**	**223**	**340**

Table 3. Relationship between genetic groups and prevalent races detected within these in 2020 and 2021. (cf. Table 2); n.a.: not tested.

SSR_name	Race_name	Total
Clade I	PTKTK	5
	PTKTT	9
	TTKSK	2
	TTKST	3
	TTKTK	1
	TTKTT	13
	n.a.	56
Clade I Total		**89**
Clade III-B	TTRTF	18
	n.a.	77
Clade III-B Total		**95**
Clade IV-B	TKRTF	1
	TKTTF	24
	n.a.	38
Clade IV-B Total		**63**
Clade IV-F	TKKTF	19
	n.a.	57
Clade IV-F Total		**76**
Clade VIII	HFCNC	2
	RFCNC	7
	n.a.	1
Clade VIII Total		**10**
Other	multiple races	4
	n.a.	3
Other		**7**
Grand Total		**340**

Table 4. Correspondence between race name and virulence on common stem rust differential lines.

	Virulence corresponding to NA differentials 1-20 (main R-gene indicated)																			
Race_name	***Sr5***	***Sr21***	***Sr9e***	***Sr7b***	***Sr11***	***Sr6***	***Sr8a***	***Sr9g***	***Sr36***	***Sr9b***	***Sr30***	***Sr17***	***Sr9a***	***Sr9d***	***Sr10***	***SrTmp***	***Sr24***	***Sr31***	***Sr38***	***SrMcN***
RFCNC	*5*	*21*	-	*7b*	-	-	*8a*	*9g*	-	-	-	*17*	*9a*	-	*10*	-	-	-	-	*McN*
TKKTF	*5*	*21*	*9e*	*7b*	-	*6*	*8a*	*9g*	-	*9b*	*30*	*17*	*9a*	*9d*	*10*	*Tmp*	-	-	*38*	*McN*
TKTTF	*5*	*21*	*9e*	*7b*	-	*6*	*8a*	*9g*	*36*	*9b*	*30*	*17*	*9a*	*9d*	*10*	*Tmp*	-	-	*38*	*McN*
TTKSK	*5*	*21*	*9e*	*7b*	*11*	*6*	*8a*	*9g*	-	*9b*	*30*	*17*	*9a*	*9d*	*10*	-	-	*31*	*38*	*McN*
TTKST	*5*	*21*	*9e*	*7b*	*11*	*6*	*8a*	*9g*	-	*9b*	*30*	*17*	*9a*	*9d*	*10*	-	*24*	*31*	*38*	*McN*
TTKTK	*5*	*21*	*9e*	*7b*	*11*	*6*	*8a*	*9g*	-	*9b*	*30*	*17*	*9a*	*9d*	*10*	*Tmp*	-	*31*	*38*	*McN*
TTKTT	*5*	*21*	*9e*	*7b*	*11*	*6*	*8a*	*9g*	-	*9b*	*30*	*17*	*9a*	*9d*	*10*	*Tmp*	*24*	*31*	*38*	*McN*
PTKTK	*5*	-	*9e*	*7b*	*11*	*6*	*8a*	*9g*	-	*9b*	*30*	*17*	*9a*	*9d*	*10*	*Tmp*	-	*31*	*38*	*McN*
TTRTF	*5*	*21*	*9e*	*7b*	*11*	*6*	*8a*	*9g*	*36*	*9b*	-	*17*	*9a*	*9d*	*10*	*Tmp*	-	-	*38*	*McN*
TTTTF	*5*	*21*	*9e*	*7b*	*11*	*6*	*8a*	*9g*	*36*	*9b*	*30*	*17*	*9a*	*9d*	*10*	*Tmp*	-	-	*38*	*McN*

Clade III-B (TTRTF), also termed the ‘Sicily race’, was in 2021 detected in two African countries, Tanzania and Tunisia, and in five European countries, Austria, Czech Republic, Italy, Slovakia, and Switzerland. Since our first detection of TTRTF in Sicily in 2016, it has been confirmed 9 countries in Europe, and 4 countries in Africa/Asia.

Clade IV-F, containing race TKKTF (Fig. 1), was detected in four African countries, Ethiopia, Kenya, Tanzania and Tunisia, and 13 European countries in 2021. These includes Austria, Czech Republic, Denmark, France, Germany, Italy, Norway, Poland, Slovakia, Slovenia, Spain, Sweden and Switzerland. Previously, Clade IV-F has also been detected in Azerbaijan, Egypt, Iran, Iraq and Tadjikistan in our studies.

Clade IV-B, generally containing two closely related races, TKTTF and TTTTF, was observed in Tanzania and Tunisia and in eight European countries in 2021, including Belgium, Denmark, France, Germany, Norway, Spain, Sweden and the United Kingdom. In clade IV-F in Europe, we observed race TKTTF in all isolates, except one from Spain showing TKRTF. In East Africa, both TKTTF and TTTTF were present.

Clade I (Ug99 group) was only observed in Kenya and Tanzania in 2020 and 2021. So far, this group has not been detected in Europe. Six different races were detected in this clade, of which race TTKTT was the most prevalent (38%) and then PTKTT (29%), the latter being avirulent to Sr21 (Table 3).

Clade VIII, containing two closely related races, HFCNC and RFCNC (predominant), was only observed in Eastern Europe. In contrast to prevalent races, these two races were avirulent to Sr6, Sr9b, Sr9d, Sr9e and Sr38 (Table 4).

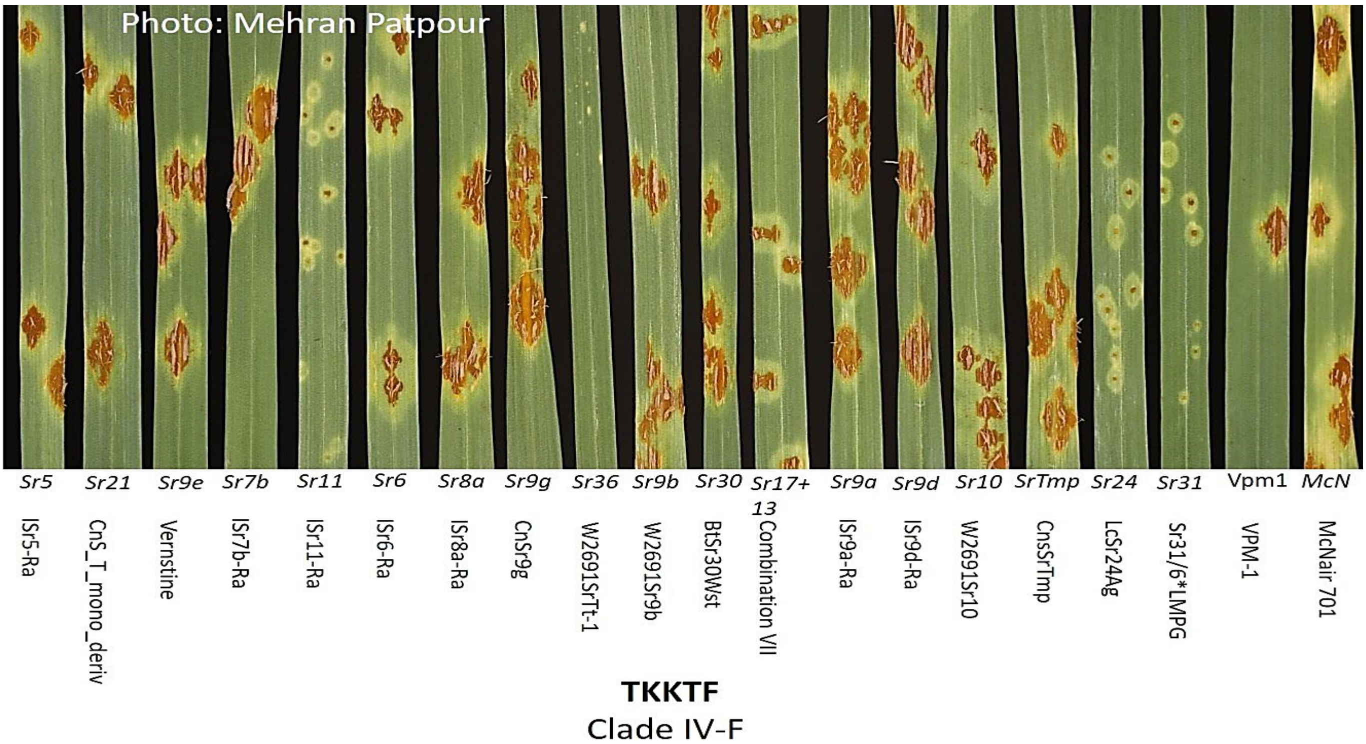

Figure 1. Infection type responses on wheat differential lines of a stem rust race (Clade IV-F), which was widespread in Europe 2021.

2021 results – wheat yellow rust

A total of 574 samples from 24 countries and four continents were handled in 2021, of which 243 were successfully recovered (D: Dead, L: live).

Table 5. Number of yellow rust (P. striiformis) samples and derived isolates in 2021.

		Testing year	Sample_type	
		2021		Total
Geographic group	Country	D	L	
Africa, C&W Asia	Afghanistan	66	22	88
	Ethiopia	74	13	87
	Iraq	33		33
	Kenya	17	36	53
	Tanzania	1	4	5
Africa, C&W Asia Total		**191**	**75**	**266**
Europe	Czech Republic	11	3	14
	Denmark	10	21	31
	Estonia	1	2	3
	France	3	8	11
	Germany	8	10	18
	Hungary		2	2
	Italy	6	10	16
	Latvia		6	6
	Netherlands		5	5
	Norway	10	27	37
	Poland	10	6	16
	Portugal	1	1	2
	Slovakia	3		3
	Spain	8		8
	Sweden	18	18	36
	United Kingdom	11	24	35
Europe Total		**100**	**143**	**243**
South America	Paraguay	4	5	9
	Uruguay	7	17	24
South America Total		**11**	**22**	**33**
South Asia	Nepal	29	3	32
South Asia Total		**29**	**3**	**32**
Grand Total		**331**	**243**	**574**

A total of 259 isolates from Africa, Asia, and South America, and 176 from Europe were successfully genotyped in 2021(Table 6). Race typing was done for 65 isolates for alignment and confirmation of genetic grouping and emergence of new races within these. Common races and virulence phenotypes within groups are shown in Table 7. Graphical presentation of results available on www.wheatrust.org.

First indication of a new incursion of a highly virulent genotype/race (termed PstS16) into East Africa by the end of 2020 was confirmed. In 2021, PstS16 was widespread in farmer's fields and experimental plots in Ethiopia, but not yet detected in neighboring countries (Table 6). An identical race/genotype was widespread in Afghanistan in 2021. Additional experiments at GRRC of leading Ethiopian wheat varieties showed that PstS16 was virulent on additional varieties compared with previous prevalent races such as PstS6 and PstS11.

PstS13 was prevalent in samples from South America, including Paraguay where yellow rust was detected for the first time. In Europe, PstS13 was mainly detected on triticale, but also durum wheat, rye, spelt and bread wheat were affected, whereas this genetic group has not yet been detected in Africa and Asia. Alignment experiments in collaboration with University of Sydney, Australia, confirmed PstS13 in Australia, where it is now one of the most widespread races (Ding et al., 2021).

PstS10 was the most prevalent genetic group in Europe, but since 2018 it was also confirmed in Australia (Ding et al. 2021). At least four races have been detected in PstS10 in Europe, each adapted to local, widely grown wheat varieties, typically named after the wheat varieties where they first caused significant epidemics. In practice, these races differ by quantitative shifts in rust susceptibility of commercial varieties, e.g., from 'resistant' to 'susceptible' or from 'susceptible' to 'extreme susceptible'. This demonstrated the evolutionary capacity within this widely distributed genetic group, which has been prevalent in Europe since 2013. It has not yet been possible to differentiate the new races within PstS10 by molecular techniques nor by standard wheat differential lines.

PstS14 was completely dominating in samples from Iraq in 2021, which represents the first detection of this group in Asia. It was present in low frequencies in Europe, where it has been present since 2016. PstS11 was still prevalent in East Africa, now confirmed in eight countries in East Africa and in the Middle East.

PstS1 and PstS2, which are not distinguishable by SSR genotyping, share race and epidemiological features such as adaptation to warmer temperatures. In Table 6, these two groups are not separated because they have not yet been tested by SCAR markers developed for this purpose.

Samples from Nepal were different from all previously named genetic groups (termed 'Other'), and revealed high pathogen diversity in this area, which is consistent with previous results from the near-Himalayan region in Asia.

Table 6. Distribution of isolates in *P. striiformis* from 26 countries in prevalent genetic groups. (Continues next page).

			Year		
Geographic area	**Country**	**SSR name**	**2020**	**2021**	**Total**
Africa, C&W Asia	**Afghanistan**	Other		11	11
		PstS16		54	54
	Ethiopia	PstS11	8	34	42
		PstS16	2	33	35
	Iraq	PstS14		32	32
	Kenya	PstS1/2	4	16	20
		PstS11	12	34	46
	Tanzania	PstS1/2		5	5
Africa, C&W Asia Total			**26**	**219**	**245**
South America	**Paraguay**	PstS13		2	2
	Uruguay	PstS13		18	18
		PstS7		1	1
South America Total				**21**	**21**
South Asia	**Nepal**	Other		19	19
South Asia Total				**19**	**19**

Table 6. Distribution of isolates in *P. striiformis* from 26 countries in prevalent genetic groups. (Continued).

Geographic area	Country	SSR name	Year 2020	2021	Total
Europe	**Belgium**	PstS10	10		10
		PstS13	1		1
		PstS7	1		1
	Czech Republic	PstS0	1		1
		PstS10	1	10	11
		PstS13		1	1
		PstS7		1	1
	Denmark	Other		2	2
		PstS10	64	17	81
		PstS13	9	3	12
		PstS15	4		4
		PstS7		1	1
	Estonia	ME2018*		3	3
	France	PstS10	11	6	17
		PstS15	1	1	2
		PstS7	1	1	2
	Germany	PstS10	2	3	5
		PstS13	1	2	3
	Hungary	PstS13	1		1
		PstS7	3	1	4
	Italy	PstS10	8	6	14
		PstS13	2	7	9
		PstS7		1	1
	Latvia	ME2018*	1	1	2
		PstS15		1	1
	Netherlands	PstS10	7	4	11
	Norway	Other	1	1	2
		PstS10	15	25	40
		PstS13	2		2
		PstS7	1	1	2
	Poland	Other		2	2
		PstS10	1	1	2
		PstS13	5	3	8
		PstS7		1	1
	Portugal	PstS10		2	2
	Slovakia	PstS10		1	1
		PstS13		1	1
		PstS14	1	1	2
		PstS7	2		2
	Spain	PstS10	17	5	22
		PstS13	6	1	7
		PstS14		1	1
		PstS7	3		3
	Sweden	PstS10	20	25	45
		PstS13	9	6	15
		PstS7	1		1
		PstS8	1		1
	Switzerland	PstS14	1		1
	United Kingdom	PstS10	9	25	34
		PstS7	1		1
		PstS8	1		1
Europe Total			**226**	**174**	**400**
Grand Total			**252**	**435**	**687**

* Provisional name

Table 7. Correspondence between genetic groups and prevalent races of *P. striiformis* sampled from epidemic sites since 2000, Global Rust Reference Center.

Common names of prevalent races and genetic groups in yellow rust - GRRC, March 2022			
Genetic group	**Race**	**Virulence phenotype[b]**	**Prevalence in geographical region**
PstS0	Brigadier	1,2,3,-,-,-,-,-,9,-,-,17,-,25,-,-,-,AvS,-	Europe
	Brigadier,v4	1,2,3,4,-,-,-,-,9,-,-,17,-,25,-,-,-,AvS,-	Europe
	Madrigal_Lynx	1,2,3,-,-,6,-,-,9,-,-,17,-,25,-,-,-,AvS,-	Europe
	Madrigal_Lynx,v4	1,2,3,4,-,6,-,-,9,-,-,17,-,25,-,-,-,AvS,-	Europe
	Robigus	1,2,3,4,-,-,-,-,9,-,-,17,-,25,-,32,-,AvS,-	Europe
	Solstice_Oakley	1,2,3,4,-,6,-,-,9,-,-,17,-,25,-,32,-,AvS,-	Europe
	Tulsa	-,-,3,4,-,6,-,-,-,-,-,-,-,25,-,32,-,AvS,-	Europe
PstS1	PstS1/2[a]	-,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,-	North America, Australia
	PstS1/2,v1	1,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,-	East Africa
	PstS1/2,v1,v27	1,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,-	East Africa
PstS2	PstS1/2	-,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,-	East Africa, West Asia, South Asia
	PstS1/2,v1	1,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,-	East Africa
	PstS1/2,v3	-,2,3,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,-	East Africa
	PstS1/2,v27	-,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,-	East Africa, West Asia, North Africa
	PstS1/2,v1,v27	1,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,-	East Africa, West Asia
	PstS1/2,v3,v27	-,2,3,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,-	East Africa
	PstS1/2,v10	-,2,-,-,-,6,7,8,9,10,-,-,24,25,-,-,-,AvS,-	East Africa, West Asia
	PstS1/2,v10,v27	-,2,-,-,-,6,7,8,9,10,-,-,24,25,27,-,-,AvS,-	West Asia
	PstS1/2,v3,v10,v27	-,2,3,-,-,6,7,8,9,10,-,-,24,25,27,-,-,AvS,-	East Africa
PstS3	PstS3	-,(2),-,-,-,6,7,8,-,-,-,-,-,25,-,-,-,AvS,-	Europe, Asia
	PstS3,v1	1,(2),-,-,-,6,7,8,-,-,-,-,-,25,-,-,-,AvS,-	Asia
PstS4	Triticale2006	-,2,-,-,-,6,7,8,-,10,-,-,24,-,-,-,-,-,-	Europe
PstS5	PstS5	1,2,3,4,-,6,-,-,9,-,-,-,-,25,-,32,-,AvS,Amb	Central Asia
	PstS5,v17	1,2,3,4,-,6,-,-,9,-,-,17,-,25,-,32,-,AvS,Amb	Central Asia, South Asia
PstS6	PstS6	1,2,-,-,-,6,7,-,9,-,-,17,-,-,27,-,-,AvS,-	East Africa, Central Asia, South Asia
PstS7	Warrior	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb	Europe, North Africa
PstS8	Kranich	1,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,-,AvS,Amb	Europe
PstS9	PstS9	1,2,3,4,-,6,-,-,9,-,-,-,-,25,27,32,-,AvS,Amb	Central Asia, South Asia
	PstS9,v17	1,2,3,4,-,6,-,-,9,-,-,17,-,25,27,32,-,AvS,Amb	Central Asia
PstS10	Warrior(-)	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,-	Europe, North Africa
	Kalmar	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,-	Europe
	Benchmark	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,-	Europe
	Amboise	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,-	Europe
PstS11	PstS11	-,2,-,(4),-,6,7,8,-,-,-,17,-,-,27,32,-,AvS,-	Central and West Asia, East Africa
PstS12	Hereford	-,2,3,-,-,6,7,8,-,-,-,17,-,25,-,32,-,AvS,-	Europe
PstS13	Triticale2015	-,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,AvS,-	Europe, South America, West Asia
	Triticale2015,v10	-,2,-,-,-,6,7,8,9,10,-,-,24,-,-,-,-,AvS,-	Europe
PstS14	PstS14	-,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,(Sp),AvS,-	Europe, North Africa, West Asia
PstS15	PstS15	1,2,3,-,-,6,7,-,9,-,-,17,-,25,-,32,-,AvS,Amb	Europe

a) PstS1 and PstS2 not distinguishable by race and SSR (but SCAR). b) Figures and symbols designate virulence and avirulence (-) corresponding to yellow rust resistance genes: Yr1, Yr2, Yr3, Yr4, Yr5, Yr6, Yr7, Yr8, Yr9, Yr10, Yr15, Yr17, Yr24, Yr25, Yr27, Yr32, and the resistance specificity of Spalding Prolific (Sp), Avocet S (AvS) and Ambition (Amb), respectively. Kalmar, Benchmark and Amboise are races in PstS10, which can only be distinguished by these varieties.

Submission and preparation of samples

Samples of rust infected wheat are submitted according to an import permit issued by GRRC valid for one country and one year in compliance with the Nagoya Protocol about control, access and utilization of genetic resources. The details of sampling preparation are available at http://wheatrust.org/submission-of-isolates/; a video demonstrates the ideal sampling procedures. Bilateral agreement with private/public enterprises is also possible. Since 2011, GRRC has accepted samples of both yellow rust, leaf rust and stem rust.

Several cycles of spore multiplication were generally made to obtain sufficient amount of spores for storage and race analyses. In case of signs of multiple genotypes/races within a sample, these were generally sub-cultured for purification according to standard GRRC procedures (Hovmøller et al. 2017), open-access for downloads for non-commercial and educational purposes. The SSR genotyping of isolates based on DNA extraction from infected leaves (single lesions) was highly successful for appropriate discrimination of genetic groups, following the procedures of Thach et al. 2016.

Supporting litterature

Ali et al., 2017. Yellow Rust Epidemics Worldwide Were Caused by Pathogen Races from Divergent Genetic Lineages. *Frontiers in Plant Science*, Vol. 8, 1057, 06.2017.

Ding Y et al. 2021. Incursions of divergent genotypes, evolution of virulence and host jumps shape a continental clonal population of the stripe rust pathogen Puccinia striiformis. Molecular Ecology, 20.09.2021.

Hovmøller et al. 2017: Race Typing of *Puccinia striiformis* on Wheat. In: *Wheat Rust Diseases: Methods and Protocols*, ed. S. Periyannan. Springer, p. 29-40. Downloading accepted for non-commercial and educational purposes.

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Table 8. People submitting samples of rust infected leaves/stems of cereals 2021 (Continues next page).

Region	Country	Collector	Yellow rust	Stem rust
Africa, Asia and South America	**Afghanistan**	Abdul Bari	x	
		Ahmadi Nabizada	x	
		Baryalai Malekzada	x	
		G. Ghanizada	x	
		Saifudin Safi	x	
		Shakib Ataee	x	
		Shamsullhaq	x	
		Mirwais Amirzai	x	
	Ethiopia	Anduamlak A	x	
		Asela Kesho	x	
		Ayele Badebo	x	
		Belachew Bekele	x	
		Dagne Abu	x	
		Dereje Amare	x	
		Getahun T	x	
		Girma Abebe	x	
		Girma Teshome	x	
		Jemal T	x	
		Kabna Asefa	x	
		Kitessa G	x	
		Mequanint Andualem	x	
		Solomon B	x	x
		Tamene	x	
		Tamirat N	x	x
		Tekilu	x	
		Tilahun Bayisa	x	
		Tsegaab Tesfaye	x	
		Yared Tesfaye	x	
		Yitagesu Tadesse	x	
		Yoseph Alemayehu	x	
		Zerihun Eshetu	x	
		Zerihun Tadesse	x	
	Iraq	Dheyaa Mohsin Ali	x	
		Emad Al-Maaroof	x	
		Sarkawt Salih	x	
		Nabaz Rashid	x	
	Kenya	Zennah Kosgey	x	x
	Tanzania	Salome Munissi	x	x
	Tunisia	Amor Yahyaoui		x
		Sarrah Ben M'Barek		x
		Wided Abdedeyam		x
	Paraguay	Marta Fernandez	x	
	Uruguay	R. García	x	
		Venancio Riella	x	
		F. Pereira	x	
	Nepal	Basistha Acharya	x	
		Bhajuman Maharjan	x	
		Dhurba Thapa	x	
		Khem Pant	x	
		Laxman Aryal	x	
		Prem Bahadur Magar	x	
		Sunita Adhikari	x	
		Suraj Baidya	x	

Region	Country	Collector	Yellow rust	Stem rust
Europe	**Austria**	Michael Oberforster		x
		Monika Opalo		x
	Belgium	Pierre Hellin		x
	Czech Republic	Alena Hanzalová		x
	Denmark	Anne Ladegaard	x	
		Ellen Jørgensen	x	
		Finn Borum	x	
		Lise Nistrup Jørgensen	x	x
		Martin Clausen	x	
		Ole Harild	x	
		Peter Spies		x
		Rikke B. Heinfelt	x	
		Susanne Sindberg	x	x
	Estonia	Max Kurg	x	
	France	Alexandre Klein		x
		Anne-Lise Boixel		x
		Auberi Avalle		x
		Audrey Remont-warin		x
		Cédric Picard		x
		Christophe Jeudi		x
		Christophe Michelet		x
		Clément Dusserre		x
		Corentin Picard		x
		Courbet		x
		Damien Coulon		x
		Emmanuel Heumez		x
		Fanny Savaete		x
		Franck Gaudichau		x
		Jean-Charles Talbourdet		x
		Jean-Philippe Maigniel	x	
		Jérôme Enjalbert		x
		Joelle Daucourt		x
		Lefevre		x
		Marine Henry		x
		Pascal Girardeau		x
		Romain Bandini		x
		Romain Valade		x
		Sabine Snyder		x
		Sandrine Longuet		x
		Solène Barrais	x	
		Stéphane Porrez		x
		Sylvain Chombart		x
		Sylvain Gaubrie		x
		Thierry Demarquet		x
		Valerie Dufayet		x
	Germany	Andreas Jacobi		x
		Bärbel Liebherr	x	
		Claudia Meyer		x
		Kathlen Spät		x
		Monika Spiler		x
		S. Hagen	x	
		Thomas Zschaeckel	x	
		Uta Liesenberg	x	x

Table 8. People submitting samples of rust infected leaves/stems of cereals 2021. (Continued).

Region	Country	Collector	Yellow rust	Stem rust
Europe		Victoria Hasler		x
		Volker Heiden	x	
	Hungary	Bernat Poos	x	
	Italy	Alessandro Infantino		x
		Andreina Belocchi		x
		Angela Iori		x
		Anna Maria Mastrangelo		x
		Biagio Randazzo	x	x
		Daniela Marone	x	x
		Eder Groli		x
		Elisabetta Mazzucotelli		x
		Fabrizio Quaranta		x
		Giuseppina Goddi		x
		Lucio Salafia		x
		Marco Martelli		x
		Marco Nocentini	x	x
		Mauro Fornara		x
		Paolo De Franceschi		x
		Stefania Licciardello		x
		Virgilio Balmas		x
	Latvia	Lïga Feodorova-Fedotova		
	Netherlands	L. van den Brink	x	
	Norway	Andrea Ficke	x	
		Chloé Grieu	x	
		Inga Holt	x	
		Ingvild Evju	x	
		Min Lin	x	x
		Morten Lillemo	x	x
		Rune Karlsen	x	
	Poland	Pawel Czembor	x	x
	Portugal	Asmae Jlilat	x	
		Cláudia Rato da Silva	x	
	Slovakia	Svetlana Šliková	x	x
	Slovenia	Ales Kolmanic		x
	Spain	Dolors Villegas	x	
		Fernando Martinez-Moreno	x	x
		Roser Sayeras		x
	Sweden	Alf Djurberg	x	
		Anna von Heideken	x	
		Annika Sohlman	x	
		Anton Hampl	x	
		Ebba Hellstrand	x	
		Elin Almén	x	
		Eva mellqvist	x	
		Gunilla Berg	x	
		Lars Johansson	x	
		Lina Norrlund	x	
		Linda Geijersstam	x	
		Louise Aldén	x	
		Lovisa Eriksson	x	
		Mahboobeh Yazdani		x
		Mahbubjon Rahmatov		x
		Oskar Gustafsson	x	
		Petter Gustafsson	x	
		Robert Dinwiddie	x	
		Therese Christerson	x	
	Switzerland	Nicole Togni		x
	United Kingdom	Amelia Hubbard	x	
		Clare Lewis		x
		Sarah Wilderspin	x	

x