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# Report for *Puccinia striiformis* race analyses and molecular genotyping 2017, Global Rust Reference Center (GRRC), Aarhus University, Flakkebjerg, DK- 4200 Slagelse, Denmark.

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## Key highlights

- South America: Three distinct genotypes were detected in severe yellow rust epidemics in Argentina in 2017. These genotypes have been associated with recent rust epidemics in Europe/northern Africa.
- Central Asia/East Africa: Region specific genotypes were prevalent in Central Asia. One of these (**PstS11**) was also detected in East Africa in 2016, and prevalent in severe epidemics in Ethiopia. The spread of **PstS11** was confirmed by identical races.
- Europe: *Warrior(-)* was the most prevalent race in Europe (lineage **PstS10**). Original *Warrior* (**PstS7**) and *Kranich* (**PstS8**) were less prevalent, but spreading to new areas.
- North Africa/South Europe: A distinct race (and genotype) in lineage **PstS14**, first detected in 2016, became widespread and caused severe yellow rust epidemics in Morocco 2017. A distinct race (and genotype) of **PstS13**, first detected in 2015, caused epidemics on both bread wheat and durum wheat in Italy.
- Virulence to *Yr5* and *Yr15* was not detected.
- SSR genotyping was successfully implemented as part of the *Pst* race surveys, expanding testing capacity significantly, and providing results for both recovered and non-recovered samples.
- Summary of SSR genotyping and race phenotyping results from GRRC (2008-2017), is available online (http://www.wheatrust.org/), including a new page with documentation of relationship between races and genetic lineages.

This report present results of GRRC race typing and molecular genotyping of samples of *Puccinia striiformis* from wheat and triticale collected in 2017 (main emphasis) with reference to 2016 results. The testing of additional samples collected in 2017 is ongoing. ‘Race’ is defined by the pattern of compatible and incompatible interactions between host and pathogen. The race phenotype is considered ‘virulent’ in case of a compatible interaction, conferred by ‘high’ infection type scores on one or more host differential lines carrying a common Yr-gene, and ‘avirulent’ in case of incompatible interactions conferred by ‘low’ infection types. Race typing requires access to spore samples of alive, pure isolates and strict and well-defined experimental conditions (Hovmøller et al. 2017). In contrast, Single Sequence Repeat (SSR) genotyping can be done using samples of rust infected plant material without prior recovery and spore multiplication.

The SSR genotyping results represent high-resolution genetic relationships within and among genetic lineages, whereas short-term evolution of new virulence is reflected by the race phenotype. Therefore, genetic lineages being present across large areas over many years often contain multiple races, whereas more recent lineages may contain only few or a single race. In the present dataset, there was a strong connection between genetic lineage and groups of races with similar virulence phenotypes.

Results from previous years are available as pdf files from the GRRC website, where the results are also available on maps and charts. New features and analytical tools have been implemented, e.g., separate maps showing results arising from molecular genotyping and race typing, respectively

## Nomenclature of races and genetic lineages

We have assigned common names based on the genetic lineage of significant races demonstrating epidemic potential. Important lineages have been named **Pst** followed by a digit. Race variants were designated by the additional virulence observed or (-) in case a new variant had fewer virulences than the first defined race within the considered lineage. Race names already adopted by the farming community in Europe were maintained, e.g., Warrior and Kranich, which are named according to the wheat variety where they caused the first confirmed epidemic outbreaks. A comprehensive justification and rationale for the naming of significant *P. striiformis* races and genetic groups has been published (Ali et al. 2017) and an updated summary is available on the GRRC website. The new mapping tools allow the user to highlight particular countries, years and races/genotypes. The occurrence of particular races/genotypes is shown on maps in case geographical coordinates have been provided.

## Submission and preparation of samples

Prior to submission of rust infected leaf samples, a request must be sent by e-mail to GRRC to obtain an import permit, which must be enclosed with any sample submission. Sampling information about, e.g., host variety, sampling date, location, and disease severity must be provided. The details of recommended sampling preparation are given at http://wheatrust.org/submission-of-isolates/. On this page you will find a YouTube video demonstrating ideal sampling procedures. Focus sampling areas in 2018 outside Europe will be selected in collaboration with staff at ICARDA, CIMMYT, NARCs in Africa and Asia, and FAO, with a focus on high-risk epidemic areas. Bilateral agreement with private/public enterprises is also possible. Since 2011, GRRC has accepted samples of both yellow rust, leaf rust and stem rust.

A total of 209 samples of yellow rust infected leaves from 11 countries in Africa and Asia went into recovery procedures using susceptible seedlings of Cartago, Morocco and Anja (Table 1). Ninety isolates from these countries were recovered, and occasionally sub-cultured for further purification prior to multiplication of spore samples for race typing. Recovery rates varied from case to case, emphasizing the importance of optimal handling and preservation of samples, and submission without delay. A total of 312 samples were submitted from 10 European countries (Table 2), and 45 samples from Argentina, South America. A total of 190 isolates were recovered from Europe, and few additionally from Argentina.

Multiple factors may influence viability and recovery rates, e.g., 1) emerging crop senescence at time of sampling, 2) delayed time between sample collection and arrival at GRRC and 3) non-favorable condition during sample preparation and shipment.

**Table 1.** Number of samples of yellow rust handled in 2017, Africa and Asia.

| Africa, C&W Asia | Dead | Recovered | Grand Total |
|---|---|---|---|
| Azerbaijan | 5 | | 5 |
| Eritrea | 7 | 2 | 9 |
| Ethiopia | 41 | 24 | 65 |
| Iraq | 10 | 1 | 11 |
| Kenya | 11 | 11 | 22 |
| Morocco | 13 | 23 | 36 |
| Russia | 4 | | 4 |
| Rwanda | 3 | 1 | 4 |
| Tanzania | | 4 | 4 |
| Turkey | | 4 | 4 |
| Uzbekistan | 25 | 20 | 45 |
| **Grand Total** | **119** | **90** | **209** |

**Table 2.** Number of samples of yellow rust handled in 2017, Europe.

| Europe | Dead | Recovered | Grand Total |
|---|---|---|---|
| Austria | | 1 | 1 |
| Belgium | | 4 | 4 |
| Denmark | 31 | 68 | 99 |
| France | 3 | 8 | 11 |
| Italy | 17 | 37 | 54 |
| Latvia | 47 | 3 | 50 |
| Netherlands | | 14 | 14 |
| Norway | 13 | 20 | 33 |
| Poland | 4 | 4 | 8 |
| Sweden | 7 | 31 | 38 |
| **Grand Total** | **122** | **190** | **312** |

Certain couriers may use radiation during the handling of parcels, which may result in poor recovery or failure. Several cycles of multiplication were needed to obtain sufficient amount of spores for storage and race analyses, which were conducted according to our long-term experience recently published in the Springer series of Methods and Protocols, downloading accepted for non-commercial and educational purposes. The genotyping of isolates based on DNA extraction from infected leaves (single lesions) was generally successful, following the procedures of Thach et al. 2016. The methodology proved very useful for generating results based on 'original samples' in case of poor recovery, and for confirming genetic purity and assignment of races to specific genetic lineages.

## 2017 results

SSR genotyping: A total of 315 samples were SSR genotyped, collected in 2017 in 28 countries from four continents. In Table 3a,b,c, results are compared with results for samples collected in 2016, some of which were finalized in 2017. New common names have been suggested for lineages **PstS11** to **PstS14**, which represent distinct genetic groups with significant impact, **PstS11** provisionally designated "AF2012" in the 2016 report, **PstS12** (*Hereford* race), **PstS13** (*Triticale2015* race), and **PstS14**, provisionally termed "Pst(new)" in the 2016 report.

**Table 3a-c.** SSR genotyping of samples of yellow rust collected in 2016 and 2017. Results are shown by number of isolates and frequency. For lineage nomenclature, see Ali et al., 2017 and wheatrust.org [click here]. Cross references to significant races and virulences are shown in Table 4. Graphical presentation of results available on www.wheatrust.org.

| **a)** | | | | **Number of isolates** | | |
|---|---|---|---|---|---|---|
| **Geographic group** | **Country** | **Genetic lineage (common name)** | **2016** | **2017** | **Total** | **%** |
| Africa, C&W Asia | Azerbaijan | **PstS2** | 5 | | 5 | 3,4 |
| | | **PstS7** | 2 | | 2 | 1,4 |
| | Eritrea | Other | 6 | | 6 | 4,1 |
| | Ethiopia | **PstS11** | 17 | | 17 | 11,6 |
| | Iraq | Other | | 4 | 4 | 2,7 |
| | | **PstS2** | 7 | 6 | 13 | 8,9 |
| | Morocco | **PstS14** | 6 | 36 | 42 | 28,8 |
| | Russia | Other | | 1 | 1 | 0,7 |
| | Rwanda | **PstS2** | | 4 | 4 | 2,7 |
| | Tanzania | **PstS2** | 4 | 4 | 8 | 5,5 |
| | Uzbekistan | Other | 1 | | 1 | 0,7 |
| | | **PstS11** | 2 | 1 | 3 | 2,1 |
| | | **PstS9** | 17 | 23 | 40 | 27,4 |
| **Africa, C&W Asia Total** | | | **67** | **79** | **146** | **100,0** |

| **b)** | | | | **Number of isolates** | | |
|---|---|---|---|---|---|---|
| **Geographic group** | **Country** | **Genetic lineage (common name)** | **2016** | **2017** | **Total** | **%** |
| South America | Argentina | **PStS13** | | 30 | 30 | 78,9 |
| | | **PStS14** | | 5 | 5 | 13,2 |
| | | **PstS7** | | 1 | 1 | 2,6 |
| | | Others (to be confirmed) | | 2 | 2 | 5,3 |
| South America Total | | | | 38 | 38 | 100,0 |

The **PstS14** lineage, containing a single race only, was first detected in spring 2016 in Morocco (non-epidemic situation) and in Sicily. Later the same year, **PstS14** was detected in three Scandinavian countries (low frequency) and probably elsewhere in Europe. In 2017, **PstS14** gave rise to widespread in severe epidemics in Morocco, and it was also detected in Argentina.

Table 3 (continued).

| **c)** | | | **Number of isolates** | | | |
|---|---|---|---|---|---|---|
| **Geographic group** | **Country** | **Genetic lineage (common name)** | **2016** | **2017** | **Total** | **%** |
| Europe | Austria | **PstS7** | | 1 | 1 | 0,3 |
| | Belgium | **PstS10** | | 2 | 2 | 0,5 |
| | | **PstS7** | | 1 | 1 | 0,3 |
| | Croatia | **PstS10** | 1 | | 1 | 0,3 |
| | Denmark | - | 1 | | 1 | 0,3 |
| | | **PstS0** | 1 | | 1 | 0,3 |
| | | **PstS10** | 51 | 76 | 127 | 33,2 |
| | | **PstS13** | 14 | 10 | 24 | 6,3 |
| | | **PstS14** | 3 | 1 | 4 | 1,0 |
| | | **PstS7** | 3 | 2 | 5 | 1,3 |
| | | **PstS8** | 5 | 2 | 7 | 1,8 |
| | Finland | **PstS10** | 3 | | 3 | 0,8 |
| | | **PstS14** | 1 | | 1 | 0,3 |
| | | **PstS7** | 2 | | 2 | 0,5 |
| | France | **PstS7** | | 4 | 4 | 1,0 |
| | | **PstS8** | | 2 | 2 | 0,5 |
| | | - | | 1 | 1 | 0,3 |
| | Germany | **PstS10** | 4 | | 4 | 1,0 |
| | Hungary | **PstS10** | 1 | | 1 | 0,3 |
| | | **PstS4** | 1 | | 1 | 0,3 |
| | | **PstS7** | 1 | | 1 | 0,3 |
| | Italy | **PstS10** | 2 | 2 | 4 | 1,0 |
| | | **PstS13** | 1 | 46 | 47 | 12,3 |
| | | **PstS14** | 1 | 1 | 2 | 0,5 |
| | Latvia | **PstS10** | 1 | 2 | 3 | 0,8 |
| | | **PstS13** | | 2 | 2 | 0,5 |
| | | **PstS14** | | 6 | 6 | 1,6 |
| | | **PstS4** | | 1 | 1 | 0,3 |
| | | **PstS7** | 4 | 1 | 5 | 1,3 |
| | Lithuania | **PstS7** | 1 | | 1 | 0,3 |
| | Netherlands | **PstS10** | | 11 | 11 | 2,9 |
| | | **PstS13** | | 1 | 1 | 0,3 |
| | | **PstS7** | | 1 | 1 | 0,3 |
| | Norway | **PstS10** | 9 | 4 | 13 | 3,4 |
| | | **PstS13** | 3 | | 3 | 0,8 |
| | | **PstS14** | 1 | | 1 | 0,3 |
| | | **PstS7** | | 1 | 1 | 0,3 |
| | | **PstS8** | 1 | | 1 | 0,3 |
| | Poland | **PstS13** | | 1 | 1 | 0,3 |
| | | **PstS7** | | 2 | 2 | 0,5 |
| | Spain | **PstS10** | 10 | | 10 | 2,6 |
| | | **PstS13** | 1 | | 1 | 0,3 |
| | | **PstS7** | 3 | | 3 | 0,8 |
| | Sweden | **PstS0** | 3 | | 3 | 0,8 |
| | | **PstS10** | 9 | 7 | 16 | 4,2 |
| | | **PstS12** | 1 | | 1 | 0,3 |
| | | **PstS13** | 6 | 3 | 9 | 2,3 |
| | | **PstS14** | 1 | 1 | 2 | 0,5 |
| | | **PstS4** | | 1 | 1 | 0,3 |
| | | **PstS7** | 2 | 2 | 4 | 1,0 |
| | | **PstS8** | 9 | 10 | 19 | 5,0 |
| | UK | **PstS0** | 1 | | 1 | 0,3 |
| | | **PstS10** | 3 | | 3 | 0,8 |
| | | **PstS8** | 1 | | 1 | 0,3 |
| | Ukraine | **PstS13** | 1 | | 1 | 0,3 |
| | | **PstS2** | 1 | | 1 | 0,3 |
| | | **PstS4** | 6 | | 6 | 1,6 |
| | | **PstS7** | 1 | | 1 | 0,3 |
| **Europe Total** | | | **175** | **208** | **383** | **100,0** |

**PstS11** (designated AF2012 in the 2016 report), was first detected in Afghanistan in 2012, later spreading to other countries in the region, including Uzbekistan. **PstS11,** containing a single race, was detected in East Africa in 2016, where it caused new epidemics in Ethiopia (2017 results pending). A different lineage, **PstS9** (with *Yr27* virulence), has been involved in epidemics in Central Asia in recent years, including Uzbekistan, where it was the most frequent genotype in 2017.

Isolates of **PstS13**, first detected on Triticale in Europe (2015), proved highly epidemic, previously giving rise to significant epidemics on triticale in Northern Europe, and in 2017 resulting in severe epidemics on bread wheat and durum wheat in Italy (Table 3b-c). Only a single race has been detected in the **PstS13** lineage, in 2017 observed in Italy, Ukraine, Spain, Poland, Netherlands, and three Scandinavian countries (Table 3a-c). **PstS13** was also detected in Argentina (Table 3b), where unusual severe and widespread epidemics of yellow rust affected wheat crops in many areas (Fig 1). Results of the particular race(s) of **PstS13** in Argentina is pending.

**PstS7** (*Warrior* race) has become less frequent in Europe, but now also detected in Azerbaijan and Ukraine. **PstS7** was detected in a single sample in Argentina in 2017, confirming first detection in a non-epidemic situation in 2015. The **PstS7** samples from Argentina (both 2015 and 2017) were unique, diverging by 1-2 alleles from **PstS7** in Europe and West Asia.

**PstS10** was dominating in Central- and northern Europe, race: Warrior(-). A new distinct genotype and race (not yet assigned a name) was detected at a single VCU trial site in France, confirmation of the exact virulence phenotype is pending. The aggressive high-temperature adapted strain, **PstS2** is still prevalent in Central/West Asia and East Africa; several additional lineages (termed 'Other') were observed in low frequencies.

<u>Race typing</u>: A subset of recovered isolates were multiplied during 2-3 cycles to produce spores for race typing on wheat differential lines carrying resistance genes to *P. striiformis*. A combination of lines from 'World' and 'European' differential sets and NILs in an Avocet background gave a high resolution in terms of virulence determination despite additional resistance genes were detected in a number of differential lines, including the Avocet NILs. For commonly used resistance genes like *Yr1*, *Yr2*, *Yr6*, *Yr7*, *Yr8*, *Yr9*, *Yr17*, *Yr25*, *Yr27*, *Yr32* and *Yr(Sp)*, respectively, two differential lines were included to confirm race phenotype.

The race typing results in Table 4 were in full agreement with SSR genotyping results, allowing subdivision of genetic lineages into specific races. Correspondence between SSR genotype and race is presented in Table 4, results split for Central- and West Asia/Africa, and Europe. So far, only a single race has been detected in each of the lineages **PstS7** (*Warrior*), **PstS8** (*Kranich*), **PstS11**, **PstS12** (*Hereford*), **PstS13** (*Triticale2015*), and **PstS14**, respectively. In contrast, several races were detected in **PstS0**, **PstS2** (aggressive), and two lineages with races of complex virulence profiles, **PstS5** and **PstS9**, prevalent in Central Asia. Virulence corresponding to *Yr5* and *Yr15* was not detected, *Yr10*-virulence present in **PstS4** (**Triticale2006**) and in some races in **PstS2** in previous years (data not shown). A variant of the Warrior(-) race (**PstS10**), which was diagnosed only based on additional commercial wheat varieties, was detected at several locations in Denmark.

A full summary of prevalent races in each genetic lineage is presented in Table 5 (also available on www.wheatrust.org

**Table 4.** GRRC race analyses of *P. striiformis* in 2016 and 2017 shown by number of isolates and frequency per race and country in Africa/Asia and Europe. Virulence phenotype indicates virulence matching *Yr* resistance genes, which are considered ineffective for yellow rust control. Testing of additional 2017 isolates is ongoing. Graphic presentation of results and comparisons to previous years are accessible at www.wheatrust.org.

| Geographic group | Country | Race (common name) | Genetic lineage | Virulence phenotype | Number of isolates | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | 2016 | 2017 | Total | % |
| Africa, C&W Asia | Azerbaijan | PstS2 | **PstS2** | -,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,- | 2 | | 2 | 3,3 |
| | | PstS2,v27 | **PstS2** | -,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | 2 | | 2 | 3,3 |
| | | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 3 | | 3 | 4,9 |
| | Ethiopia | PstS11 | **PstS11** | -,2,-,(4),-,6,7,8,-,-,-,17,-,-,27,32,-,AvS,- | 8 | | 8 | 13,1 |
| | Morocco | PstS14 | **PstS14** | -,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,Sp,AvS,- | 7 | 8 | 15 | 24,6 |
| | Rwanda | PstS2,v1,v27 | **PstS2** | 1,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | | 1 | 1 | 1,6 |
| | Tanzania | PstS2,v27 | **PstS2** | -,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | 3 | | 3 | 4,9 |
| | | PstS2,v3,v27 | **PstS2** | -,2,3,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | | 2 | 2 | 3,3 |
| | Uzbekistan | Other | - | -,2,-,4,-,6,7,8,-,-,-,-,-,25,27,-,-,AvS,- | 1 | | 1 | 1,6 |
| | | PstS11 | **PstS11** | -,2,-,(4),-,6,7,8,-,-,-,17,-,-,27,32,-,AvS,- | 3 | 1 | 4 | 6,6 |
| | | PstS5,v17,v27 | **PstS5** | 1,2,3,4,-,6,-,-,9,-,-,17,-,25,27,32,-,AvS,Amb | 2 | | 2 | 3,3 |
| | | PstS9 | **PstS9** | 1,2,3,4,-,6,-,-,9,-,-,-,-,25,27,32,-,AvS,Amb | 1 | | 1 | 1,6 |
| | | PstS9,v17 | **PstS9** | 1,2,3,4,-,6,-,-,9,-,-,17,-,25,27,32,-,AvS,Amb | 11 | 6 | 17 | 27,9 |
| **Africa, C&W Asia Total** | | | | | **43** | **18** | **61** | **100** |
| Europe | Austria | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | | 1 | 1 | 0,4 |
| | Belgium | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | | 1 | 1 | 0,4 |
| | Croatia | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 1 | | 1 | 0,4 |
| | Denmark | Kranich | **PstS8** | 1,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,-,AvS,Amb | 2 | 1 | 3 | 1,3 |
| | | PstS14 | **PstS14** | -,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,Sp,AvS,- | 3 | | 3 | 1,3 |
| | | Triticale2015 | **PstS13** | -,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,Avs,- | 17 | 2 | 19 | 8,3 |
| | | Triticale2016 | - | -,-,-,-,-,6,-,8,-,-,-,-,-,-,-,-,-,-,- | 2 | | 2 | 0,9 |
| | | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 2 | | 2 | 0,9 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS | 50 | 37 | 87 | 38,2 |
| | Finland | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 1 | | 1 | 0,4 |
| | France | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | | 1 | 1 | 0,4 |
| | | Other | - | to be confirmed | | 1 | 1 | 0,4 |
| | Germany | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 4 | | 4 | 1,8 |
| | Hungary | Triticale2006 | **PstS4** | -,2,-,-,-,6,7,8,-,10,-,-,24,-,-,-,-,-,- | 1 | | 1 | 0,4 |
| | | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 1 | | 1 | 0,4 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 1 | | 1 | 0,4 |
| | Italy | PstS14 | **PstS14** | -,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,Sp,AvS,- | 2 | 2 | 4 | 1,8 |
| | | Triticale2015 | **PstS13** | -,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,Avs,- | 1 | 8 | 9 | 3,9 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 3 | 1 | 4 | 1,8 |
| | Latvia | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 1 | | 1 | 0,4 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 1 | | 1 | 0,4 |
| | Lithuania | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 2 | | 2 | 0,9 |
| | Netherlands | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | | 3 | 3 | 1,3 |
| | Norway | Kranich | **PstS8** | 1,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,-,AvS,Amb | 1 | | 1 | 0,4 |
| | | PstS14 | **PstS14** | -,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,Sp,AvS,- | 1 | | 1 | 0,4 |
| | | Triticale2015 | **PstS13** | -,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,Avs,- | 1 | | 1 | 0,4 |
| | | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | | 1 | 1 | 0,4 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 13 | 4 | 17 | 7,5 |
| | Spain | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 5 | | 5 | 2,2 |
| | Sweden | Hereford | **PstS12** | -,2,3,-,-,6,7,8,-,-,-,17,-,25,-,32,-,AvS,- | 2 | 1 | 3 | 1,3 |
| | | Kranich | **PstS8** | 1,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,-,AvS,Amb | 3 | 8 | 11 | 4,8 |
| | | PstS14 | **PstS14** | -,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,Sp,AvS,- | | 1 | 1 | 0,4 |
| | | Triticale2006 | **PstS4** | -,2,-,-,-,6,7,8,-,10,-,-,24,-,-,-,-,-,- | | 1 | 1 | 0,4 |
| | | Triticale2015 | **PstS13** | -,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,Avs,- | 3 | 2 | 5 | 2,2 |
| | | Tulsa | **PstS0** | -,-,3,4,-,6,-,-,-,-,-,-,-,25,-,32,-,AvS,- | 5 | | 5 | 2,2 |
| | | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 1 | 3 | 4 | 1,8 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 2 | 3 | 5 | 2,2 |
| | UK | Solstice_Oakley | **PstS0** | 1,2,3,4,-,6,-,-,9,-,-,17,-,25,-,32,-,AvS,- | 1 | | 1 | 0,4 |
| | | Warrior(-) | **PstS10** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | 3 | | 3 | 1,3 |
| | Ukraine | PstS2,v27 | **PstS2** | -,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | 1 | | 1 | 0,4 |
| | | Triticale2006 | **PstS4** | -,2,-,-,-,6,7,8,-,10,-,-,24,-,-,-,-,-,- | 5 | | 5 | 2,2 |
| | | Triticale2015 | **PstS13** | -,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,Avs,- | 1 | | 1 | 0,4 |
| | | Warrior | **PstS7** | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,Amb | 3 | | 3 | 1,3 |
| **Europe Total** | | | | | **146** | **82** | **228** | **100** |
| **Grand Total** | | | | | **189** | **100** | **289** | **-** |

**Table 5.** Correspondence between genetic lineages and prevalent races in *P. striiformis* tested at the Global Rust Reference Center 2008-2017. Definitions, click here

| **Common names of prevalent genetic lineages and races in yellow rust** | | | |
|---|---|---|---|
| **Genetic lineage** | **Race** | **Virulence phenotype*** | **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 |
| | *Robigus,v7* | 1,2,3,4,-,-,7,-,9,-,-,17,-,25,-,32,-,AvS,- | Europe |
| | *Solstice_Oakley* | 1,2,3,4,-,6,-,-,9,-,-,17,-,25,-,32,-,AvS,- | Europe |
| | *Solstice_Oakley,v7* | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,-,AvS,- | Europe |
| | *Tulsa* | -,-,3,4,-,6,-,-,-,-,-,-,-,25,-,32,-,AvS,- | Europe |
| | *other* | other | Europe, South America |
| **PstS1** | *PstS1,v10,v24,v27* | -,2,-,-,-,6,7,8,9,10,-,-,24,25,27,-,-,AvS,- | East Africa |
| | *PstS1,v17* | -,2,-,-,-,6,7,8,9,-,-,17,-,25,-,-,-,AvS,- | North America |
| | *PstS1,v17,v27* | -,2,-,-,-,6,7,8,9,-,-,17,-,25,27,-,-,AvS,- | North America |
| | *PstS1,v3,v17,v27* | -,2,3,-,-,6,7,8,9,-,-,17,-,25,27,-,-,AvS,- | North America |
| | *PstS1,v3,v17,v27,v32* | -,2,3,-,-,6,7,8,9,-,-,17,-,25,27,32,-,AvS,- | North America |
| | *other* | other | North America |
| **PstS2** | *PstS2* | -,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,- | East Africa, West Asia, South Asia |
| | *PstS2,v1* | 1,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,- | East Africa, West Asia |
| | *PstS2,v3* | -,2,3,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS,- | East Africa |
| | *PstS2,v27* | -,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | East Africa, West Asia, North Africa |
| | *Pst2,v1,v27* | 1,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | East Africa, West Asia |
| | *PstS2,v3,v27* | -,2,3,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS,- | East Africa |
| | *PstS2,v10,v24* | -,2,-,-,-,6,7,8,9,10,-,-,24,25,-,-,-,AvS,- | East Africa, West Asia |
| | *PstS2,v3,v10,v24,v27* | -,2,3,-,-,6,7,8,9,10,-,-,24,25,27,-,-,AvS,- | East Africa |
| | *PstS2,v10,v24,v27* | -,2,-,-,-,6,7,8,9,10,-,-,24,25,27,-,-,AvS,- | West Asia |
| | *Other* | other | East Africa & West Asia |
| **PstS3** | *PstS3* | -,-,-,-,-,6,7,8,-,-,-,-,-,-,-,-,-,AvS,- | North Africa, West Asia |
| | *PstS3,v10,v24* | -,-,-,-,-,6,7,8,-,10,-,-,24,-,-,-,-,AvS,- | West Asia |
| | *PstS3(-)* | -,-,-,-,-,6,7,8,-,-,-,-,-,-,-,-,-,-,- | Europe, South Asia |
| **PstS4** | *Triticale2006* | -,2,-,-,-,6,7,8,-,10,-,-,24,-,-,-,-,-,- | Europe |
| | *Other* | other | 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 |
| | *Other* | other | 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 |
| **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 |
| | *Other* | other | Central Asia |
| **PstS10** | *Warrior(-)* | 1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS,- | Europe, North Africa |
| **PstS11** | *PstS11* | -,2,-,(4),-,6,7,8,-,-,-,17,-,-,27,32,-,AvS,- | Central Asia, East Africa |
| **PstS12** | *Hereford* | -,2,3,-,-,6,7,8,-,-,-,17,-,25,-,32,-,AvS,- | Europe |
| **PstS13** | *Triticale2015* | -,2,-,-,-,6,7,8,9,-,-,-,-,-,-,-,-,AvS,- | Europe |
| **PstS14** | *PstS14* | -,2,3,-,-,6,7,8,9,-,-,17,-,25,-,32,(Sp),AvS,- | Europe, North Africa |

* 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.

**Fig. 1** Yellow rust epidemics in early cropping season, 30th September 2017, Los Cisnes, La Carlota, provincia de Cordoba, Argentina. Wheat cultivar: Klein Serpiente. Photo: Juan Pablo Ioele.

## Litterature

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A summary of the results can be shared within relevant countries and organizations providing appropriate citation of this report.

**Table 6.** People contributing to sampling and submission of rust infected leaves in 2017.

| Country | Sampled by |
|---|---|
| Argentina | Marcelo Carmona, FAUBA (Sampling Coordinator) |
| | Carlos Grosso, VMV Siembras |
| | Francisco Sautua, FAUBA, Rancagua, Bs As |
| | Diego Alvarez |
| | Duarte, DZD Agro |
| | Fabricio Mock, BASF |
| | Jonathan Damiani, Independent consultant |
| | Julián Garcia, Oro Verde |
| | Lucrecia Couretot, INTA Pergamino |
| | Marcos Mitelsky (LIM Agro) |
| | Mariano Vence, CREA Loberías Grandes |
| | Norma Formento, INTA Paraná |
| | Alejandro Porfiri, Independent consultant |
| | Roxana Maumary, UNL |
| | Andrea Rosso, CEANAGRO SA |
| Austria | |
| Azerbaijan | Konul Aslanova |
| Belgium | Rossana Bacchetta |
| Denmark | Anders Almskov |
| | Erik Silkjær Pedersen |
| | Gitte Skovgaard, LMO |
| | Lise Nistrup Jørgensen |
| | Martin Nielsen |
| | Pia Bay |
| | Susanne Sindberg |
| | Tine Thach |
| Eritrea | Ashmelash Wolday |
| Ethiopia | Dave Hodson & Yoseph Alemayehu |
| | Bekele Abejo |
| | Ayele Badebo |
| | Fikrte Yirga |
| | Tsegaab Tesfaye |
| France | Barrais Solène (GEVES) |
| | Emmanuel Heumez (INRA) |
| | Maigniel Jean-Philippe (GEVES) |
| | Valérie Cadot (GEVES) |
| | Jerome Auzanneau |
| | Laurent Pageaud (INRA-GEVES) |
| Iraq | Emad Al-Maaroof |
| Italy | Angela Iori |
| | Fabrizio Quaranta |
| | Mauro Fornara |
| | Carla Cristofori |
| | Antonietta Sacomanno |
| | Biagio Randazzo |
| | Fabio Finiguerra |
| | Francesca Nocente |
| | Giuseppina Goddi |
| | Marco Gallinelli |
| | Virgilio Balmas |
| Kenya | R. Wanyera |
| Latvia | Anita Maija Plukse |
| | Elina Anna Brauna |
| | Inese Liepina |
| | Liga Feodora-Fedotova |
| | Janis Landorfs |
| | Livija Sostaka |
| | Mara Berzina |
| | Vija Graube |
| Morocco | Ezzahiri Brahim |
| Netherlands | J. van der Woude |
| | L. van den Brink |
| Norway | Chloe Grieu |
| | Ingvild Evju |
| | Morten Lillemo |
| | Ole Jakob Ulberg |
| | Tina Fallet |
| | Unni Abrahamsen |
| | Andrea Ficke |
| Poland | |
| Russia | |
| Rwanda | Jean Marie, Obed, Theoneste, Eliane, Felicien, Innocent |
| Sweden | Amanda Ahlqvist |
| | Anders Lindgren |
| | Anna Gerdtsson |
| | Aron Westlin |
| | Danira Behaderovic |
| | Elin Nilsson |
| | Gunilla Berg |
| | Gunnel Andersson |
| | Johanna Holmblad |
| | Lars Johansson |
| | Lina Norrlund |
| | Länstyrelsen Örebro/Helena |
| | Robert Dinwiddie |
| | VSC Linköping/Anders/Jorunn,Lovisa, Sigrid |
| Tanzania | Rose Mongi |
| | Okinyi Moses |
| Turkey | |
| Uzbekistan | Zafar Ziyaev |
| | Diyor Juraev |
| | Safar Alikulov |