GLOBAL RUST REFERENCE CENTER

SCIENCE AND TECHNOLOGY
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Report for *Puccinia striiformis* race analyses 2014, Global Rust Reference Center (GRRC), Aarhus University, Flakkebjerg, DK- 4200 Slagelse, Denmark.

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This is a preliminary report of non-European *Puccinia striiformis* race analyses activities at GRRC in 2014. The activities are based on an agreement between Aarhus University, CIMMYT and ICARDA to facilitate race analyses of *Puccinia striiformis* infecting wheat and other cereals, mainly from Africa and Asia. From 2012-2016, CIMMYT and ICARDA have each agreed to support the research by an annual contribution of USD 20,000 within the frame of the RUSTFIGHT project. Aarhus University is contributing with quarantine lab and green house facilities, consumables and substantial scientific and technical expertise. RUSTFIGHT, which is focusing on more basic research in host-pathogen interactions, is supported by the Danish Strategic Research Council 2012-2016. A summary of the results can be spread within relevant countries and organizations without delay, provided that the author of this report is acknowledged, along with funding institutions, i.e. "Hovmøller & Algaba 2015: Global Rust Reference Center: Research funded by: Aarhus University, Denmark; CIMMYT; ICARDA". Results from previous years are available as Pdf files from the GRRC home page.

From January 2014 most results became accessible via the database facilities provided by the Wheat Rust Toolbox, which is accessible at www.wheatrust.org. The site is being continuously improved by new analytical tools. A lot of progress in adding molecular data to improve the resolution and interpretation of results has been made although such data are not yet directly accessible online. For instance, identical or similar races sampled in distant areas (continents) do not necessary imply that these races are closely related genetically.

Submission and preparation of samples

Prior to submission of rust infected leaf sample, a request must be sent by e-mail to GRRC to get an import permit issued. This permit must be enclosed any sample submission. Information about details of collector (person), host variety, sampling date, location, disease severity in each plot from where samples were given. The details are given at http://wheatrust.org/submission-of-isolates/ . Focus sampling areas in 2015 will be selected by staff at ICARDA, CIMMYT and NARCs in Africa and Asia, with a focus on high risk epidemic areas. Since 2011, GRRC also accepted samples of stem rust (*Puccinia graminis tritici*) as agreed upon with the Borlaug Global Rust Initiative and the phase II of the Durable Rust Resistance in Wheat Project (DRRW). Since GRRC can only process samples according to available space and resources at any time, we cannot guarantee to process all wheat rust samples received. This report deals only with yellow rust.

A total of 250 yellow rust infected leaf samples from 12 countries entered the recovery process using susceptible seedlings of Cartago and Morocco. A total of 83 isolates were recovered and multiplied whereas 5 isolates from Pakistan were avirulent on both Cartago and Morocco. The recovery rates varied greatly from case to case emphasizing the importance of appropriate sample handling and preservation and submission without delay. In 2014 we had acceptable or good recovery rates from Afghanistan, Algeria, Ethiopia, Iran, Kenya and Rwanda. There may be multiple reasons for lack of viability, e.g., 1) emerging crop senescence, 2) long time between sample collection and arrival at GRRC and 3) non-favorable condition after sampling, i.e., during preparation and postage. We are aware that some courier services may use extensive radiation during the handling of parcels, which may explain a complete recovery failure for certain collections despite that the individual samples may look ok at arrival. This is a factor which should be explored further. Even in case a first recovery is successful, additional cycles of multiplication are often needed for getting a sufficient amount of spores for storage and race analyses, which were conducted according to Hovmøller & Justesen (2007).

Table 1. Number of *P. striiformis* samples submitted to GRRC, January – December 2014. A total of 83 isolates were recovered, and a subset of these were analysed for race ID (Table 2). Additional SSR analyses based on both recovered and non-recovered samples are in progress.

Antal af Running no. (local)				Status		
Country	Location	Sampled by	Recovery date	Failed	Recovered	Total
Afghanistan	Badambagh R S	Sharma, CIMMYT-AF	27.06.2014		2	2
	Darulaman R S				2	2
Afghanistan Total					4	4
Algeria	Ferdjioua	Chaneze	28.05.2014	1		1
	ITGC				7	7
Algeria Total				1	7	8
Azerbaijan	Absheron, Borku		18.06.2014	1		1
	Gobustan			1		1
	Salilabad			1		1
	Shaki			1		1
	Tartar			2		2
	Tovuz, Khatinle			1		1
Azerbaijan Total				7		7
Eritrea	Adi Abieto	Asmelash Wolday	06.11.2014	1		1
	Adi Arada			1		1
	Adi Etat			1		1
	Adi Gaedad			1		1
	Adi Gered			1		1
	Adi HaweSha			1		1
	Adi Ke			1		1
	Adi Mengonti			1		1
	Ahfsi			1		1
	Bardae			1		1
	Berakit			1		1
	Fiyasha			1		1
	Forto			1		1
	Geza Lamza			1		1
	Hamboka			1		1
	MAI NEFHI			1		1
	Mekayh			1		1
	METERA			1		1
	Serha			1		1
	Shiketi			1		1
	Tarika			1		1
	Zgeb			1		1
Eritrea Total				22		22
Ethiopia	Debre Zeit	D Hodson	29.04.2014		6	6
	Kulumsa		03.06.2014		1	1
	Meraro RS		02.12.2014	2		2
	Sembo		22.12.2014		1	1
	Sinana RS		02.12.2014	2		2
			16.12.2014		7	7
Ethiopia Total				4	15	19
Iran	Marvdasht	Goodarz Najafian	13.11.2014		1	1
	Mashhad				1	1
	Moghan				1	1
	Poldokhtar				1	1
	Zarghan				1	1
Iran Total					5	5
Iraq	Babylon-Emam Abudbaa20	Ahmed Neama Jwad	30.04.2014	1		1
	Babylon-Emam Abudbaa25			1		1
	Babylon-Emam Haydaria			1		1
	Babylon-Emam Shawaniya			1		1
	Baghdad-Rashidiya-Lukmani	Abid Al-Hameed Fayadh		1		1
	Baghdad-Zidan			4		4
	Diyala-Bani Saad	Hatem Mahmood Hassan		1		1
	Diyala-Gidaydat-Alshatt			2		2
	Erbil-Ainkawa	Dr. Emad Al-Maaroof			2	2
	Kirkuk-Dakuk	Laith Husain		1		1
	Ninavwa-Mousel	Abid Al-Hameed Fayadh		1		1
	Ninavwa-Nimrod			1		1
	Saladin-Toz	Hatem Mahmood Hassan		2		2
	Sulimaniyah-Bakrajo	Abid Al-Hameed Fayadh		1		1
		Dr. Emad Al-Maaroof		1		1
				1		1
		Laith Husain			1	1
	Wasit/Azizia/Jazera34	Dhia Muhsen Ali		3		3
Iraq Total				23	3	26

Table 1 (continued).

Kenya	**Kahehe (Olkalau)**	Wanyera, Wanga,Kinyanjui	18.07.2014	1		1
	KARI Njoro		11.06.2014		8	8
	Kinamba		18.07.2014	9		9
	Kisiriri		11.06.2014		1	1
	Kwamutongi (Timau)		18.07.2014	1		1
	Lesako (Olkalau)			1		1
	Maritati			1		1
	Mutethia Timau			1		1
	Ngushishi (Timau)			1		1
	Olopito		11.06.2014	1	1	2
	Ongechemi			1		1
	Rotian				2	2
	Stima				1	1
	Timau		18.07.2014	1		1
Kenya Total				**18**	**13**	**31**
Mexico	**Obregon**		02.04.2014	4	2	6
Mexico Total				**4**	**2**	**6**
Nepal	**Doti**	D.B.Thapa	28.05.2014	1	1	2
Nepal Total				**1**	**1**	**2**
Pakistan		Sajid Ali	20.05.2014		6	11
					2	2
Pakistan Total					**8**	**13**
Rwanda	**Busogo**	Innocent, Aloys, Athanase, Hodson	11.02.2014	2		2
	Gahunga		23.07.2014		1	1
	Gataraga		23.07.2014		1	1
	Guriro		26.08.2014		2	2
	Kinigi RS		11.02.2014	8	2	10
			23.07.2014	3		3
	Kitabi RS		11.02.2014		4	4
	Kivuye		23.07.2014		1	1
	Nyabwoma		26.08.2014		1	1
	Nyamiyaga		23.07.2014		1	1
	Rusarabuye		11.02.2014		3	3
	Rwerere		23.07.2014		1	1
	Rwerere RS		11.02.2014	4	5	9
			23.07.2014		2	2
	Sigira		11.02.2014	1	1	2
Rwanda Total				**18**	**25**	**43**
Tanzania	**Galijembe**	Rose Mongi, Salome W.Munissi	02.12.2014	2		2
	GETAGHUL			1		1
	Ifiga			1		1
	kilima tembo			1		1
	kitete			1		1
	Njombe			1		1
	SARI			1		1
Tanzania Total				**8**		**8**
Uganda	**Hamaurwa, Kabale**	Stephen, Lawrence, Gerald, Dave	31.07.2014	2		2
	Kalengyere RS, Kabale			3		3
	Kamuganguzi, Kabale			1		1
	Kitumba, Kabale			2		2
	Muko, Kabale			1		1
	Nyarusiza, Kisoro			1		1
				3		3
	Rubaya, Kabale			2		2
				1		1
Uganda Total				**16**		**16**
Uzbekistan			15.07.2014	8		8
Uzbekistan Total				**8**		**8**
Yemen	**Alaghabori- Alshaed/Ibb**	Musaed Eisa, Mohamed Alsadi, Rasha	03.12.2014	1		1
	Aljabjab- Almakhader/Ibb			1		1
	Bait Rashed/ Mabber			2		2
	Bir Alhashidi/ Mabber			2		2
	Dailami Valley		08.07.2014	1		1
	Dhabian-Banimattar/Sana'a		03.12.2014	1		1
	Dhomran-Yarim		08.07.2014	1		1
	Harf Alhormos-Badan/Ibb		03.12.2014	1		1
	Hetaqal- Yareem/Ibb			1		1
	Jarf Alnamer- Almadarah/Ibb			1		1
	Rebat Emran/ Dhamar			1		1
	Sherah/ Dhamar			1		1
	Sherra		08.07.2014	1		1
	Shibam village/Almahoit		03.12.2014	1		1
	Shibam/Almahoit			1		1
	Sorhah-Yareem/Ibb			1		1
	The Central Highlands Resear			10		10
	Tuesday market-Alsadah/Ibb			1		1
	Wadi Arab-Yareem/Ibb			1		1
	Yareem/Ibb			1		1
Yemen Total				**31**		**31**
Hovedtotal				**162**	**83**	**250**

Table 2. GRRC race analyses of *Puccinia striiformis* in 2013 and 2014 shown by number of isolates pr race/country/year. Pathotype code corresponds to virulence matching YR resistance genes. Yr-genes corresponding to a virulent race are considered ineffective for yellow rust control. Global Rust Reference Center, Aarhus University, Denmark

Antal af Running no. (local)		Crop season (Year)			Aggressive strain according to Milus	
Country	Pathotype code short	2013	2014	Total	et al. 2009	Additional comments
Afghanistan	-,2,-,4,-,6,7,8,-,-,-,17,-,-,27,32,-,AvS	3		3		
	1,2,-,-,-,6,7,8,9,-,-,17,-,-,27,-,-,Avs		3	3		
	1,2,-,4,-,6,7,8,9,-,-,17,-,-,27,32,-,AvS	1		1		Likely part of
	1,2,3,4,-,6,-,-,9,-,-,-,-,25,27,32,-,AvS		1	1		recombining population
Afghanistan Total		**4**	**4**	**8**		
Algeria	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS		5	5		Warrior race
Algeria Total			**5**	**5**		
Bhutan	-,2,-,-,-,6,7,-,-,-,-,-,25,-,-,-,AvS	1		1		
Bhutan Total		**1**		**1**		
Egypt	-,2,-,-,-,6,7,8,-,-,-,-,-,-,-,-,-,AvS	2		2		
	-,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS	2		2	x	
	-,-,-,-,-,6,7,8,-,-,-,-,-,-,-,-,-,AvS	1		1		
Egypt Total		**5**		**5**		
Ethiopia	-,-,-,-,-,6,7,8,-,10,-,-,*,-,-,-,-,-		1	1		* V24 not assessed
	-,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,Avs	1	1	2	x	
	-,2,3,-,-,6,7,8,-,-,-,-,-,25,27,-,-,Avs		1	1		
	-,2,3,-,-,6,7,8,-,10,-,-,24,25,27,-,-,Avs	1		1		
	-,2,3,-,-,6,7,8,9,10,-,-,24,25,27,-,-,Avs	1		1	x	
	1,2,-,-,-,6,7,-,9,-,-,-,-,-,27,-,-,AvS	4	1	5		Common during the 2010-epidemic
	1,2,-,-,-,6,7,-,9,-,-,17,-,-,27,-,-,Avs		1	1		
Ethiopia Total		**7**	**5**	**12**		
Iraq	-,2,-,-,-,6,7,8,9,-,-,-,-,25,-,-,-,AvS	1		1	x	
	-,2,-,-,-,6,7,8,9,-,-,-,-,25,27,-,-,AvS	9	3	12	x	
Iraq Total		**10**	**3**	**13**		
Kenya	-,2,-,-,-,6,7,8,-,-,-,-,-,25,-,-,-,Avs	1		1		
	-,2,-,-,-,6,7,8,-,-,-,17,-,-,-,-,-,Avs		1	1		
	1,2,-,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,AvS	2	10	12	x	
Kenya Total		**3**	**11**	**14**		
Mexico	-,2,-,-,-,6,7,8,9,-,-,-,-,-,25,-,-,-,AvS		1	1	x	
Mexico Total			**1**	**1**		
Morocco	-,2,-,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,AvS	2		2	x	
	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS	5		5		Warrior race
Morocco Total		**7**		**7**		
Nepal	1,2,3,4,-,6,7,-,9,-,-,17,-,25,-,32,Sp,AvS		1	1		Warrior-like race
Nepal Total			**1**	**1**		
Pakistan	-,2,-,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,Avs		1	1	x	
	-,2,3,-,-,6,7,8,9,-,-,-,-,-,25,-,-,-,Avs		1	1	x	
	-,2,3,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,Avs		2	2	x	Likely partly of
	1,2,-,-,-,6,7,8,9,-,-,-,-,-,27,-,-,Avs		2	2		recombining population
Pakistan Total			**6**	**6**		
Rwanda	-,2,-,-,-,6,7,8,9,10,-,-,24,25,-,-,-,Avs		2	2	x	
	-,2,3,-,-,6,7,8,9,-,-,-,-,-,25,-,-,-,Avs		7	7	x	
	-,2,3,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,Avs		3	3	x	
	1,2,-,-,-,6,7,-,9,-,-,17,-,-,27,-,-,Avs		2	2		
	1,2,-,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,AvS		1	1	x	
	1,2,3,4,-,6,7,8,9,-,-,-,-,-,25,27,32,-,Avs		1	1		
Rwanda Total			**16**	**16**		
Tajikistan	1,2,3,4,-,6,-,-,9,-,-,17,-,25,27,32,-,AvS	1		1		
Tajikistan Total		**1**		**1**		
Tanzania	-,2,3,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,AvS	1		1	x	
	1,2,-,-,-,6,7,8,9,-,-,-,-,-,25,-,-,-,AvS	2		2	x	
	1,2,-,-,-,6,7,8,9,-,-,-,-,-,25,27,-,-,AvS	1		1	x	
Tanzania Total		**4**		**4**		
Uzbekistan	1,2,3,4,-,6,-,-,9,-,-,-,-,-,25,-,32,-,AvS	3		3		Likely part of
	1,2,3,4,-,6,-,-,9,-,-,-,-,-,25,27,32,-,AvS	23		23		recombining population
Uzbekistan Total		**26**		**26**		
Hovedtotal		**68**	**52**	**120**		

2014 results

A subset of 52 isolates from 2014 and 10 additional isolates collected in 2013 were pathotyped using an extended set of 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 that additional previously unreported resistance genes were detected in a number of differential lines including some of the Avocet NILs. For commonly used resistance genes like *Yr1, Yr2, Yr6, Yr7, Yr8, Yr9, Yr17, Yr25, Yr27, Yr32* and *Yr*(Sp), respectively, at least two differential lines were included.

Races of the aggressive strain (likely *Pst*S2) were also in 2014 common across many sampling areas in East Africa and Asia. So far isolates of *Pst*S2 always share virulence to *Yr2, Yr6, Yr7, Yr8* and *Yr9*, often being combined with virulence to *Yr27*. *Pst*S2 was detected frequently in Ethiopia, Kenya, Tanzania and Rwanda, often with additional virulence to *Yr1* or *Yr10*. Another group of *Yr27*-virulent races were observed in East Africa, e.g., Rwanda and Ethiopia, where it was often detected during the big epidemics in east Africa in 2010. Thus, the combination of virulence for *Yr27* and aggressiveness has proven to increase the epidemic risks in many areas.

The races in Central Asia often combined multiple virulences and many isolates produced huge amounts of telia, which may suggest a recent evolutionary origin from a sexual population. The same applied for the 'Warrior' race, which was detected in Morocco and Algeria. This race has been widespread in Europe since 2011. Recent research has shown that isolates of the Warrior race are aggressive on fully susceptible wheat at the same level as *Pst*S1 and *Pst*S2 reported earlier. In Europe, the Warrior race has caused significant changes in yellow rust susceptibility of a high number of varieties of both wheat and triticale, i.e., some previously resistant or partly resistant varieties became susceptible, and some previous susceptible and highly susceptible varieties became less susceptible (Sørensen *et al.*, 2014). Very similar races have been observed in Bhutan (2012) and in 2014 also in Nepal. However, these Warrior-like races from South Asia differed from the Warrior race in Europe by DNA markers and in response to additional, non-standard differentials. The evolutionary origin and spread of the Warrior race is currently being further investigated. Further information and tools to explore pathogen variability are available at http://wheatrust.org/yellow-rust-tools-maps-and-charts/.

Finally, we occasionally observe quantitative pathogenic variability within individual races of different geographical origin, in addition to general differences in aggressiveness on susceptible varieties. It is, therefore, essential to include additional quantitative tests for the assessment of epidemic potential of pre-dominant races in different regions. We are currently researching in developing rapid and reproducible methods for the assessment of aggressiveness of isolates. In collaboration with other European and international research groups we are also developing robust DNA-based markers which will facilitate a more rigorous analysis of genetic variability among *Pst* isolates, including quantitative differences.

Literature cited

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