International Journal of Chemical Studies

P-ISSN: 2349–8528
E-ISSN: 2321–4902
www.chemijournal.com
IJCS 2021; SP-9(2): 31-35

Received: 02-12-2020
Accepted: 13-02-2021

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Assessment of some Indian wheat genotypes and breeding lines for adult plant resistance (APR) against stripe rust

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DOI: https://doi.org/10.22271/chemi.2021.v9.i2a.11902

Abstract
Stripe or yellow rust of wheat caused by *Puccinia striiformis* west end *f. sp. tritici* is devastating foliar disease and is considered of immense importance in cool and humid wheat growing parts of the world. A total of 41 wheat genotypes collected from different institutes of India were evaluated for Adult Plant Resistance to stripe rust. The field studies revealed fifteen genotypes *viz*: PBW 750, PBW 752, PBW 779, PBW 780, JAUW 672, WH 1184, HI 1619, 13th HTWYT 719, 25th HRWSN 2105, 47th IBWSN 1185, 32nd SAWSN 3011, HD 3086, 22nd SAWYT 316, PBW 763 and PBW 801 exhibiting resistant reaction with Average Coefficient of Infection (ACI) ranging from 0.45 to 2.

Keywords: Adult plant resistance, *Puccinia striiformis*, wheat, stripe rust, coefficient of infection (CI)

Introduction

The spectrum of biotic and abiotic stresses affecting wheat crop is increasingly becoming unpredictable and there is an alarming need for the preparedness towards overcoming these stresses. Stripe or yellow rust of wheat caused by *Puccinia striiformis* is devastating foliar disease and is considered of immense importance in almost all the wheat growing parts of the world (Khan *et al.*, 2012; Singh *et al.*, 2014) [1, 2]. In India, yellow rust severely affects wheat production in North-Western plain zone as well as Northern hills zone due to the favourable environment for rust pathogens (Saharan *et al.*, 2010) [6]. Wheat yield losses caused by *P. striiformis* f. sp. *tritici* ranges from 10–70% in different wheat producing areas depending upon the susceptibility of cultivars, time of the initial infection, rate of disease development and duration of the disease (Dedryver *et al.* 2009) [3]. Year after year, the susceptible wheat cultivars suffer from stripe rust (*Puccinia striiformis* Westend f. sp. *Tritici*) disease, which increases inoculum build up posing major threat to wheat cultivation of India. Although, remarkable progress has been made in breeding for stripe rust resistant varieties in India, the subsequent evolution of pathogen races at much greater pace has challenged this breeding programme (Khan *et al.*, 2009; Singh *et al.*, 2011) [4, 5] and stripe rust continues to pose a threat for wheat cultivation worldwide (Sareen *et al.*, 2012) [7]. Breeding for resistance is the most effective and efficient control strategy, as it does not add input cost of farmers and is environmentally safe (Yang and Liu, 2004) [11]. To date, 80 yellow rust resistance (Yr) genes have been permanently named in wheat, including the recently mapped *Yr79* (Feng *et al.*, 2018) [18] and Yr80 (Nsabiyera *et al.*, 2018) [9], and 67 stripe rust resistance genes have been temporarily designated, including all-stage resistance (also termed seedling resistance) and adult-plant resistance (APR) (Wang and Chen, 2017) [18]. Although these *Yr* genes have been identified in diverse wheat accessions, the race specificity of seedling resistance genes limits their efficacy against pathotypes (Kankwatsa *et al.*, 2017). In contrast, APR is generally considered to be durable, but APR genes represent a minority of known resistance genes (Kankwatsa *et al.*, 2017; Yuan *et al.*, 2018) [4]. Therefore, enhancing the resistance of adult plants to cope with evolving races of PST is the preferred strategy for resistance breeding.

Material and Method

A total of 41 wheat genotypes collected from different sources were used for screening under field conditions for stripe rust resistance. The mixture of bread wheat cultivar Agra local, PBW 343 and Kharchia which showed consistent susceptibility to stripe rust over years under screening tests, were used as susceptible check. The experiment was conducted following randomized complete block design for the field evaluation. Recommended agronomic practices were followed to raise a healthy crop. The artificial rust epidemic was created by repeated spray of inoculations using soap water solutions of mixture of races on experimental materials. The spray inoculations were done in evening on alternate days during mid January. Data pertaining to morpho-physiological and disease reactions was precisely recorded as per standard procedures. Details about the origin/pedigree of these genotypes are provided in Table 1.

Table 1: List of wheat cultivars and breeding lines used for the study

S.no	List of wheat germplasm lines.	Pedigree	Source
1	JAUW-584	PDW 233/Ae. crassa/ PBW 343	SKUAST, Jammu
2	JAUW-649	43rdIBWSN1047/43rdIBWSN1175	SKUAST, Jammu
3	JAUW-650	43rd IBWSN 1047/RSP-561	SKUAST, Jammu
4	JAUW-654	43rd IBWSN 1175/PBW550	SKUAST, Jammu
5	JAUW-665	IC296783/IC 296446//PBW550	SKUAST, Jammu
6	JAUW-666	44thIBWSN1047/44THIBWSN1175//DDW62150	SKUAST, Jammu
7	JAUW-667	PBW 175/IC546937	SKUAST, Jammu
8	JAUW-669	RSP81/DBSWY 42	SKUAST, Jammu
9	JAUW-672	44TH IBWSN1174	SKUAST, Jammu
10	RSP561	HD 2687/*Ae. crassa*//HD 2637	SKUAST, Jammu
11	WH1080	PARULA/2*PASTOR[4251];	CCSHAU, Hissar
12	PBW 779	PBW550//Yr15/6*AVOCET/3/2*PBW550/4/GLUPRO/3*PBW568//3*PBW550	PAU, Ludhiana
13	PBW 750	TOB/ERA//TOB/CNO67/3/PLO/4/VEE#5/5/KAUZ/6/FRET2/7/PASTOR// MILAN/KAUZ/3/BAV92	PAU, Ludhiana
14	PBW 780	HD2967/3/Yr15/6*AVOCET//3*BW9250/4/2*HD2967	PAU, Ludhiana
15	PBW 723	PBW343+Lr57/Yr40+Lr37/Yr17	PAU, Ludhiana
16	HD2967	ALD/COC/URES/HD2160M/HD2278	PAU, Ludhiana
17	WH1184	-	CCSHAU, Hissar
18	PBW 752	PBW621/4/PBW343//YR10/6*AVOCET/3/3*PBW343/5/PBW621	PAU, Ludhiana
19	WH1142	CHEN/Ae.Sq.(TAUS)/FCT/3/2*WEAVER	CCSHAU, Hissar
20	IBWSN-1080		
21	IBWSN-1057		-
22	HI1619	W15.92/4/PASTOR//HXL7573/2*BAU/3/WBLL1	-
23	RSP581	Magpie's'/Tessopeco 76	SKUAST, Jammu
24	13thHTWYT719	MUTUS*2//ND643/2*WBLL1	-
25	35THESWYT113	ND643/2*WBLL1/4/WHEAR/KUKUNA/3/C801/3*BATAVIA//2*WBLL1	-
26	25thHRWS2105	ND643/2*WBLL1/4/CHIBIA//PRLII/CM65531/3/SKAUZ/BAV92/5/BECARD	-
27	47thIBWSN 1185	PRL/2*Pastor//PBW343*2/KUKUNA/3/ROLF07/4/BERKUT//PBW 343*2/KUKUNA	
28	RAJ 3765	HD2402/VL639	SKRUS, Raipur
29	32ndSAWSN3011	ND643/2*WBLL1/VILLAJUAREZ F2009	-
30	22ndSAWYT 323	KACHU//WHEAR/SOKOLL	
31	JAUW-670	44TH IBWSN 1047/RSP581	SKUAST, Jammu
32	JAUW-671	44TH IBWSN 1174	SKUAST, Jammu
33	JAUW-673	45TH IBWSN 1214	SKUAST, Jammu
34	JAUW-674	45TH IBWSN 1088	SKUAST, Jammu
35	MP-1318	ATTILA/3*BCN//BAV92/3/TILHI/5/BAV92/3/PRL/SARA//TSI/VEE#5/4/CROC _1/AE.SQUARROSA(224)//2*OPATA	JNKVV, Powarkheda (M.P.)
36	HD3086	DBW14/HD2733//HUW468	IARI, New Delhi
37	22nd SAWYT 316	MUTUS*2//ND643/2*WBLL1	
38	WH1124	MUNIA/CHORLITO//AMSEL[4145];	CSHAU, Hissar
39	PBW-763	PBW621/3/YR10/6*AVOCET//4*PBW343/4/2*PBW621/5/PBW621/3/YR15/6*A VOCET//4*PBW343/4/2*PBW621	PAU, Ludhiana
40	PBW- 801	PBW621/3/Yr10/6*Avocet//4*PBW343/4/2*PBW621/5/PBW621/3/Yr15/6*Avoce t//4*PBW343/4/2*PBW 621	PAU, Ludhiana
41	Agra local	LV-Uttar- Pradesh[1313][1633]	-

Morpho- physiological studies on stripe rust severity

All the selected genotypes were scored for stripe rust reaction in the field at the Experimental Farm of Division of Plant Breeding and Genetics located at the Main Campus, Chatha. All agricultural practices recommended for the wheat crop were followed. The artificial rust epidemic was created by repeated spray inoculations using soap water solutions of mixture of races on experimental materials. The spray inoculations were done in evening on alternate days during mid- January. The stripe rust severity was recorded as per cent of the rust infection on the wheat plants according to the modified Cobb's scale (Peterson *et al.*, 1948) [12] and the field response scale referred to the infection type (McIntosh and Arts, 1995; Roelf *et al.*, 1992) [12]. The data on disease severity and host reaction was combined to calculate the coefficient of infection (CI) by multiplying the severity value of 0.2, 0.4, 0.8, 1.0 for host response ratings R, MR, MS, S, respectively, (Pathan and Park., 2006) [13].

Table 2: Host response to stripe rust in field

Reaction	Description	Observations	R. value
Resistant	Visible chlorosis/necrosis, no uredia are present	R	0.2
Moderately Resistant	Small uredia surrounded by chlorotic or necrotic areas	MR	0.4
Moderately Susceptible	Medium sized uredia with no necrotic margins but possibly some distinct chlorosis	MS	0.8
Susceptible	Large uredia and little or no chlorosis present.	S	1.0

Results and Discussion

Screening of germplasm against stripe rust under field condition

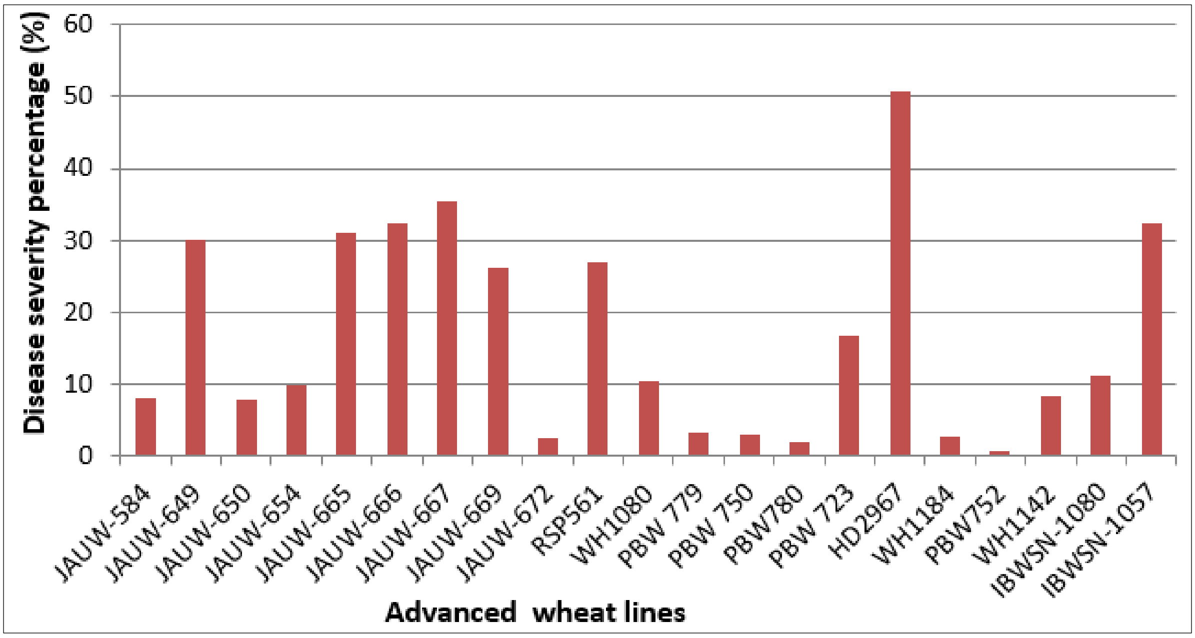
The data on average coefficient of infection (ACI) recorded during *rabi* 2017-2018 and 2018-2019 was used for phenotypic screening of test genotypes. The yellow rust severity and average coefficient of infection (ACI) of 41 genotypes is presented in the Table 3.

Out of 41 genotypes, 11 genotypes *viz*; JAUW 649, JAUW 665, JAUW 666, JAUW 667, JAUW 669, RSP 561, RSP 81, IBWSN 1057, JAUW 670, JAUW 671 and JAUW 674 were found susceptible accounting for 29.82% of total genotypes with Average Coefficient of Infection (ACI) ranging from 21 to 35. While, 2 genotypes *viz*; HD 2967 and check variety Agra local showed highly susceptible reactions with Average Coefficient of Infection (ACI) 50 and 85.36 respectively, over two successive years. Four genotypes *viz*; 22nd SAWYT 323, JAUW 673 and MP 1318 were found moderately resistant accounting for 9.76% of total genotypes with Average Coefficient of Infection (ACI) ranging from 4.76 to 5.78. Nine genotypes *viz*; JAUW 584, JAUW 654, WH 1080, PBW 723, WH 1142, IBWSN 1080, 35th ESWYT 113, RAJ 3765 and WH 1124 were found moderately susceptible accounting for 21.95% of total genotypes with Average Coefficient of Infection (ACI) ranging from 8.30 to 14.01. Fifteen genotypes *viz*; PBW 750, PBW 752, PBW 779, PBW 780, JAUW 672, WH 1184, HI 1619, 13th HTWYT 719, 25th HRWSN 2105, 47th IBWSN 1185, 32nd SAWSN 3011, HD3086, 22nd SAWYT 316, PBW 763 and PBW 801 were identified as potential donors for stripe rust resistance accounting for 36.58% of total genotypes with Average Coefficient of Infection (ACI) ranging from 0 to 3. The percentage of disease severity is also illustrated using bar chart in Figure 1.

Table 3: Morphological screening of Fourty one wheat genotypes against stripe rust

S. No	Wheat germplasm lines	Maximum Rust severity (2018)	Maximum rust severity (2019)	Average coefficient of infection (2018)	Average coefficient of infection (2019)	Average coefficient of infection over two successive years
1	JAUW 584	10S	20MS	8.81	8.11	8.46
2	JAUW 649	40S	50S	29.03	30.14	29.59
3	JAUW 650	5MS	10S	1.62	7.90	4.76
4	JAUW 654	10S	20S	9.11	10.03	9.57
5	JAUW 665	40 S	50S	27.94	31.21	29.58
6	JAUW 666	40 S	60S	30.27	32.45	31.36
7	JAUW 667	40S	60S	26.87	35.42	31.15
8	JAUW 669	30S	40S	19.8	26.31	23.06
9	JAUW 672	5S	10MS	1.81	2.60	2.21
10	RSP 561	30S	40S	17.50	26.92	22.21
11	WH 1080	20MS	20S	8.30	10.33	9.32
12	PBW 779	10MS	5S	2.11	3.19	2.65
13	PBW 750	5MR	5MS	2.30	3.10	2.70
14	PBW 780	5MS	5S	1.20	1.90	1.55
15	PBW 723	20S	30S	7.21	16.77	11.99
16	HD 2967	60S	80S	49.37	50.63	50.00
17	WH 1184	10MR	10MS	2.24	2.71	2.48
18	PBW 752	5R	5MR	0.26	0.63	0.45
19	WH 1142	20MS	20MS	8.30	8.30	8.30
20	IBWSN 1080	20S	30S	6.91	11.30	9.11
21	IBWSN 1057	40S	50S	25.90	32.41	29.16
22	HI 1619	5MS	10MS	1.23	2.94	2.09
23	RSP 81	40S	60S	28.61	31.52	30.07
24	13thHTWYT 719	5R	5R	0.50	0.72	0.61
25	35TESWYT 113	10S	20S	9.42	11.15	10.29
26	25thHRWSN 2105	MR	MS	0.41	0.84	0.63
27	47thIBWSN 1185	5MR	5MS	2.11	2.67	2.39
28	RAJ 3765	20S	30S	11.20	16.82	14.01
29	32ndSAWSN 3011	5R	5MR	0.47	0.84	0.66
30	22ndSAWYT 323	10MR	20MR	2.64	7.11	4.88
31	JAUW 670	30S	40S	17.20	24.80	21.00
32	JAUW 671	40S	60S	26.10	30.41	28.26
33	JAUW 673	10S	20MS	5.11	6.44	5.78
34	JAUW 674	40S	60S	31.94	38.61	35.28
35	MP 1318	10MR	10S	2.62	6.90	4.76
36	HD 3086	5S	10MS	1.91	3.63	2.77
37	22ndSAWYT 316	MR	MS	0.61	0.92	0.77
38	WH 1124	20MS	20S	7.90	9.91	8.91
39	PBW 763	5MR	5MS	1.92	2.60	2.26

40	PBW 801	5MS	10MS	2.02	2.40	2.21
41	Agra local	80S	90S	82.61	88.11	85.36



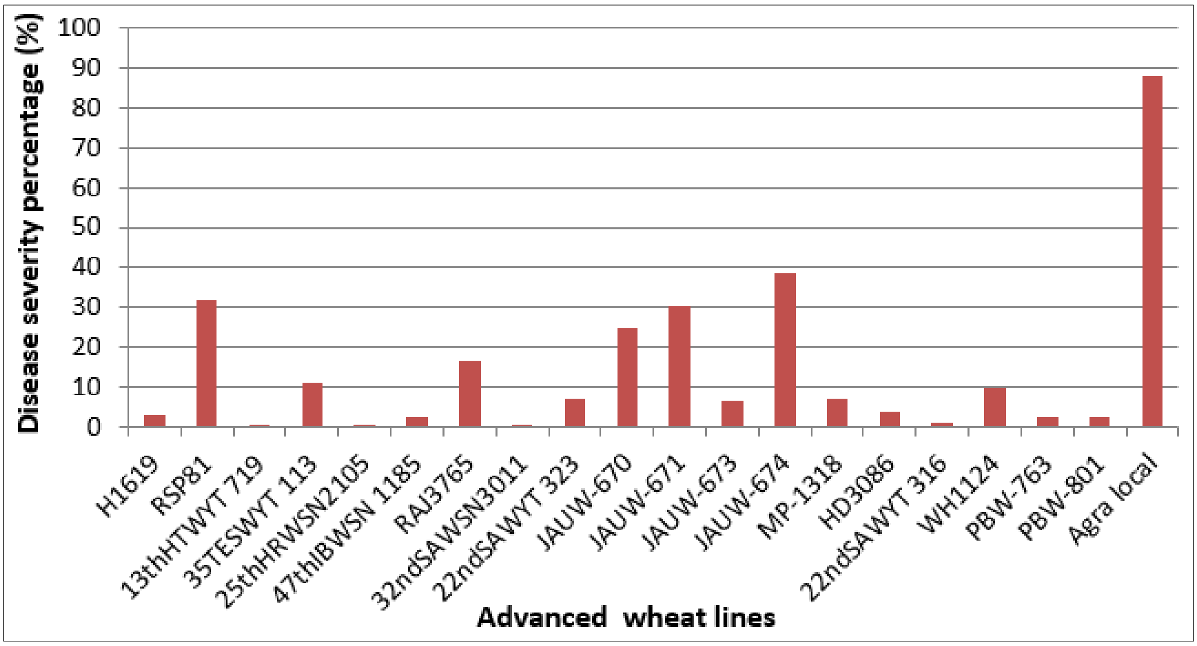


Fig 1: Percent contribution of *Yr* genes to the total resistance in wheat genotypes

These 15 promising genotypes identified in the present characterization study might be useful as parental lines for diversifying *Pst* resistance sources in wheat breeding. However, there is further need of involving larger number of genotypes to have better picture of germplasm structure to exploit for crop improvement programmes. Saini *et al.* (2002) [17] screened 20 Indian and 61 exotic wheat cultivars, 8 near-isogenic lines and 2 leaf rust-susceptible wheat cultivars (Agra Local and Morocco) against stripe rust artificially inoculated with the pathogen in experiments conducted at Ludhiana, Punjab and Bajaura, Himachal Pradesh, India. Zeng *et al.* (2014) [14] also screened a set of wheat germplasm lines for subsequent molecular validation of stripe rust resistance genes *Yr5*, *Yr9*, *Yr10*, *Yr15*, *Yr17*, *Yr18* and *Yr26*.The terminal disease severity (TDS) was recorded at adult plant stage following standard procedures and scales developed by McNeal *et al.* (1971) [16] and Peterson *et al.* (1948) [12]. This was in accordance to the procedures followed for screening of germplasm lines in the present study.

Conclusion

The promising genotypes identified in the present characterization study exhibited effective adult plant resistance. These cultivars should be improved/developed further by accumulating 4-5 minor genes to achieve near-immunity prior to deployment as a control strategy for managing the yellow rust problem. However, further studies for the development of diagnostic molecular markers to assess the adult plant resistance (APR) gene are still needed for genotypic characterization and field evaluations in the current era. Wheat lines, selected on the basis of resistance could be used in a hybridization program to develop new rust resistant cultivars.

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