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GENETICS AND PLANT BREEDING

Adult Plant Resistance of Wheat Entries to Black Rust Race 40-A

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ABSTRACT

Genetic resistance is the most efficient, economical and environmental friendly approach against black rust of wheat. Although, evolution of new physiological races/pathotypes which can overcome the response of current resistant cultivar has engender to focus on evaluation of large number of wheat germplasms, breeding materials, cultivars for their reaction to black rust. Field based assessment for adult plant resistance in promising fifty entries against predominant pathotype 40-A of black rust revealed that forty eight entries showed resistance with lower AUDPC value in the range of 0 to 240 as compared to highly susceptible check varieties i.e. Lok 1 and Agra Local which showed AUDPC value of 1305 and 2000, respectively. But, amongst the forty eight resistant entries, forty entries showed durable resistance due to slower development of disease under high disease pressure which could be due to the presence of effective adult plant resistance *Sr* genes. Result of correlation coefficient between CI with both the disease parameters i.e. AUDPC (r=99**) and FRS (r=98**) also showed highly significant positive association.

Highlights

- Evolution of a new virulent race of black rust pose serious threat to wheat production
- Adult plant resistance leads to less development of rust under high disease pressure
- Slow rusters exhibit better field durability than those of vertical resistance genes only

Keywords: Adult Plant Resistance (APR), area under disease progress curve (AUDPC), durable resistance, final rust severity (FRS), pathotype/race, slow rusting

Black/stem rust of wheat caused by *Puccinia graminis* f. sp. *tritici* Eriks. and E. Henn., belonging to family Pucciniaceae of order Uredinales and class Basidiomycetes of Basidiomycotina, has historically been one of the major constraints in realizing stabilized yields of worldwide wheat production. It has historically caused devastating yield losses on spring wheat in the United States (Kolmer 2001). According to Prasada (1960), nearly one million tonnes of wheat costing about ₹ 392 million were damaged during 1958-59 due to black rust. In India, the Central and Peninsular southern part where the warmer temperature prevails during wheat growing season the crop is prone to black rust, but has not in the wheat belt of Northern Hill Zone and Northern Pain Zone (Joshi and Palmer 1973). Besides, many times wheat cultivars often appear to lose their resistance due to the changes in virulence pattern of pathogens by mutation that ultimately can overcome the effects of existing available resistance genes. Emergence of a new virulent race of black rust i.e. Ug99 reported in Uganda in 1999 can infect most of the resistance genes like *Sr 31*, *Sr 36*, *Sr 24* (Singh *et al*. 2008) and it has created a greatest threat to all of the wheat growing areas of world. But, under this situation relaying in genetic resistance is the most efficient, economical and environmental friendly approach to control wheat rust (Line and Chen 1995). Utilization of race-nonspecific resistance which is mainly polygenic has often been described as slow rusting or partial resistance (Parlevliet 1979) and is known to be long lasting and more durable than race specific resistance (Herrera-Fossel *et al.* 2007). Mainly, presence of non-race specific genes shows susceptibility at seedling stage but exhibits moderately to highly resistant responses at adult plant stages; like the presence of *Sr2* gene which is a slow rusting gene or adult plant resistance (APR) gene in wheat genotypes shows a characteristics phenotypic appearance of pseudo black chaff (PBC) (Nzuve *et al*. 2012). When the non-race specific genes are combined with 4 to 5 genes of minor or additive effect, a near immunity could be achieved (Singh *et al*. 2008). The emphasis on use of non-race specific genes formed the basis of durable resistance in wheat resistance breeding programs (Nzuve *et al*. 2012). Screening of genotypes by field based assessment is employed for partial resistance and can be assess through different measures, *viz.* final rust severity (FRS), area under disease progress curve (AUDPC) and coefficient of infection (CI) (Pathan and Park 2006). Slow rusting parameters can be used for grouping of different cultivars based on their resistance reaction (Ali *et al.* 2007; Sandoval-Islas *et al.* 2007; Shah *et al.* 2010). Thus, in present context broadening of resistance base by the utilization of genetically diverse source of resistance are essential for enhancing the durability of resistance to black rust due to continue evolution of pathogen especially in the perspective of the changing climatic scenario. A combination of several minor genes may confer durability of field resistance leading to contribute towards slow development of rust due to increase latent period, development of smaller pustule size and reduced number of uredia per unit area *etc*. (Tomar *et al.* 2014). Therefore, there is a need for the identification of new sources for durable resistance which exhibit a better field durability than those possessing the vertical resistance genes only. The present study was conducted to evaluate promising wheat entries at adult plant stage for exploiting new sources of durable resistance to predominant pathotype 40-A of black rust.

MATERIALS AND METHODS

During 2017-18 crop season, screening of wheat entries was conducted at Wheat Research Station, Vijapur (Latitude of 23° N and longitude of 72° E, meteorological data are provided in table 5) to identify promising wheat entries exhibiting durable resistance against specific pathotype 40-A of black rust. The materials under study consist of fifty entries including released varieties, advanced breeding materials *viz*. BDW4, BDW8, GW1, GW11, GW173, GW322, GW451, GW474, GW475, GW477, GW478, GW496, GW505, GW506, GW509, GDW1255, GW1318, GW1319, GW1320,GW1321, GW1339, GW 1343, GW1348, GW1349, J-2013-09, J-2013-14, J-2013-26, J-2013-28, J-2013-30, J-2013-46, VA-2013-44, VA-2013-45,VA-2013-46, VA-2013-48, VA-2013-49, VA-2013-50, VA-2013-53, VA-2013-57, VA-2013-59, VA-2017-02, VA-2017-03, VA-2017-04,VA-2017-05,VA-2017-06, VA-2017-07, VA-2017-08, VA-2017-09 and VA-2017-10 including highly susceptible varieties i.e. Lok1, Agra Local as checks. Inoculum suspension was prepared by diluting urediospores of predominant pathotype 40-A, received from ICAR-IIWBR, Regional Station, Flowerdale, Shimla, in sterile water followed by adding of few drops of tween 20 as an emulsifying agent. Injections of inoculum suspension to each entry at boot leaf stage were practiced with the help of hypodermal syringe. After successfully development of black rust, disease severities were recorded for four times at 10 days intervals as per cent of infection in each individual entry, according to Peterson scale (Peterson *et al*. 1948) (Table 1). The severity was determined by visual observations, below 5 per cent severity, the intervals were Trace and usually 5 per cent interval was used from 5 to 20 per cent and 10 per cent interval between 20-100 per cent severity. The coefficient of infection (CI) was calculated by multiplying severity score with constant values of response type *viz*. 0.2, 0.4, 0.6, 0.8, 1 for R, MR, X, MS and S respectively as shown in Table 1. Afterwards by using following formula, area under disease progress curve (AUDPC) was calculated for all the test entry under study.

$$\text{AUDPC} = \sum_{i-1}^{n}\left\{\left(X_i + X_{i+1}\right)\times t_j\right\}/2$$

where, X_i and X_{i+1} are severities on date i and date i+1, respectively

t_i is the number of days in between date i and date i+1

n is the number of observation recorded

RESULTS AND DISCUSSION

Twenty two entries with trace severity and three entries with 5 to 10 per cent severity of different

Table 1: Scale for scoring rusts

Reaction type	Response value	Category	Visible symptoms
0	0.0	Immune	No visible infection
R	0.2	Resistance	Necrotic areas with or without uredia
MR	0.4	Moderately resistance	Necrotic areas with small uredia
X	0.6	Intermediate	Variable sized uredia with necrosis or chlorosis and fully susceptible
MS	0.8	Moderately susceptible	Medium sized uredia with no necrosis but some chlorosis
S	1.0	Susceptible	Large sized uredia with no necrosis and chlorosis

infection types, remaining twenty five entries with no infections were recorded in first day of data observation (Table 2). With the progress of disease, twenty one entries *viz*. BDW 4, BDW8, GW1, GW478, GW505, GW509, GW1320, GW1343, J-2013-26, J-2013-28, J-2013-46, VA2013-46, VA2013-48, VA2013-57, VA2017-02, VA2017-04, VA2017-05, VA 2017-06, VA2017-07, VA2017-08, and VA2017-09 were observed with resistance reaction ranging from trace to 10 per cent severity, while, ten entries *viz*. GW173, GW496, GW451, GW477, GW506, GDW1255, J-2013-09, VA2013-49, VA2017-03, and VA2017-10 were observed with moderately resistance type of infection ranging from trace to 20 per cent severity according to final rust severity score (Table 2). Moreover, five entries *viz*. GW11, GW322, GW1319, GW1339, and GW1349 were observed as moderately susceptible type of reaction which ranged from 5 to 10 per cent severity according to final rust severity score (Table 2). Four entries *viz*. GW1318, GW1321, GW1348, and J-2013-30 were recorded with susceptible type of infection but their per cent of severity i.e. 5 to 10 per cent, were under considerable level for resistance as compared to check varieties i.e. Lok 1 and Agra local which showed susceptible reaction of 100 per cent severity in final rust severity score (Table 2). On the other hand, eight entries *viz*. GW474, GW475, J-2013-14, VA 2013-44, VA 2013-45, VA2013-50, VA2013-53, and VA2013-59 were found with no infection under high inoculum pressure at final rust severity score at adult plant stage (Table 2). Entries were categorized based on the values of AUDPC. There were eight entries whose AUDPC values were 0 followed by thirty two entries having AUDPC values ranging from 1-100 and six entries showed AUDPC values ranging from 101-200. Two entries showed AUDPC values varying from 201-500 as compared to check varieties whose AUDPC values ranged from 1000-2000 (Table 3). Although, eight entries which showed no infection represents high level of resistance, but it may be controlled by major genes and so, they can't be considered as a source for durable resistance. But, all the entries in groups '1-100', '101-200' and '201-500' showed final rust severity ranging from TR to 10S and so they can be termed as slow rusters, since the development of rust occurred at a very slow rate as compared to check varieties. Thus such entries may be considered due to presence of adult plant resistance genes in addition to the vertical resistance genes (Anonymous 2014; Sharma *et al*. 2015). Since, all the tested forty entries showing various types of responses to black rust were associated with lower values of AUDPC as compared to check and hence, these forty entries could be a valuable source for durable resistance against the tested predominant pathotype 40-A of black rust.

Moreover, linear relationship between three parameters *viz*. final rust severity and AUDPC with CI were explained by coefficient of determination with 96 and 99 per cent, respectively as depicted in Fig. 1 and 2.

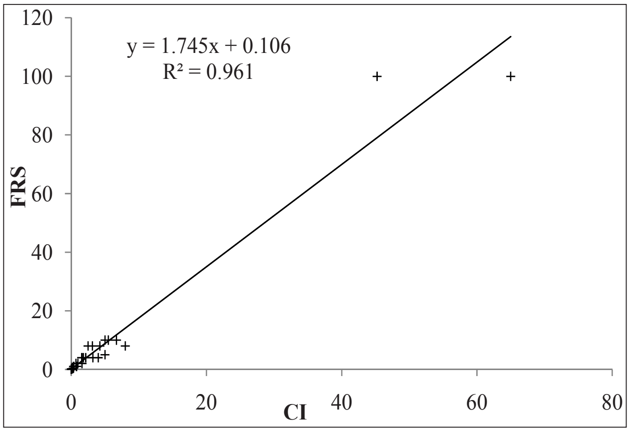

Fig 1: Association of final rust severity and coefficient of infection

Table 2: Reaction of entries against pathotype 40-A of black rust during 2017-18

S. N.	Entry	Severity score (10 days interval) 3/2/18	13/2/18	23/2/18	5/3/18	CI	AUDPC
1	BDW 4	0	TR	TR	TR	0.15	5
2	BDW 8	0	TR	TR	TR	0.15	5
3	GW 1	TR	TR	TR	5R	0.40	10
4	GW 11	TR	TMS	10MS	10MS	4.25	129
5	GW 173	0	TR	10R	10MR	1.55	42
6	GW 322	TMS	5MS	5MS	5MS	3.20	104
7	GW 451	0	TR	10R	10MR	1.55	42
8	GW 474	0	0	0	0	0.00	0
9	GW 475	0	0	0	0	0.00	0
10	GW 477	0	TR	10R	10MR	1.55	42
11	GW 478	0	TR	TR	TR	0.15	5
12	GW 496	TR	TMR	10MR	10MR	2.15	65
13	GW 505	0	TR	TR	5R	0.35	9
14	GW 506	TMR	5MR	5MR	5MR	1.60	52
15	GW 509	0	TR	TR	5R	0.35	9
16	GDW 1255	TR	TMR	10MR	20MR	3.15	85
17	GW 1318	TS	TS	10S	10S	5.50	165
18	GW 1319	0	0	10R	10MS	2.50	60
19	GW 1320	0	0	10R	10R	1.00	30
20	GW 1321	TS	TS	10MS	10S	5.00	145
21	GW 1339	5MS	5MS	5MS	5MS	4.00	120
22	GW 1343	TR	5R	5R	5R	0.80	26
23	GW 1348	5S	5S	5S	5S	5.00	150
24	GW 1349	10MS	10MS	10MS	10MS	8.00	240
25	J-2013-09	TR	TR	10R	10MR	1.60	43
26	J-2013-14	0	0	0	0	0.00	0
27	J-2013-26	0	TR	TR	10R	0.15	5
28	J-2013-28	0	TR	TR	TR	0.15	5
29	J-2013-30	TMS	10MS	10MS	10S	6.70	214
30	J-2013-46	0	TR	TR	TR	0.15	5
31	VA 2013-44	0	0	0	0	0.00	0
32	VA 2013-45	0	0	0	0	0.00	0
33	VA 2013-46	0	TR	TR	TR	0.15	5
34	VA 2013-48	0	TR	TR	TR	0.15	5
35	VA 2013-49	TR	TMR	TMR	TMR	0.35	11
36	VA 2013-50	0	0	0	0	0.00	0
37	VA 2013-53	0	0	0	0	0.00	0
38	VA 2013-57	0	0	0	TR	0.05	1
39	VA 2013-59	0	0	0	0	0.00	0
40	VA 2017-02	TR	TR	TR	TR	0.20	6
41	VA 2017-03	TR	TR	TMR	TMR	0.30	9
42	VA 2017-04	TR	5R	5R	5R	0.80	26
43	VA 2017-05	TR	5R	5R	5R	0.80	26
44	VA 2017-06	TR	5R	10R	20R	1.80	51
45	VA 2017-07	0	5R	5R	5R	0.75	25
46	VA 2017-08	TR	TR	TR	5R	0.40	10
47	VA 2017-09	TR	TR	TR	TR	0.20	6
48	VA 2017-10	TR	TR	TMR	5MR	0.70	17
49	Lok 1	TS	20S	60S	100S	45.45	1305
50	Agra Local	20S	60S	80S	100S	65.00	2000

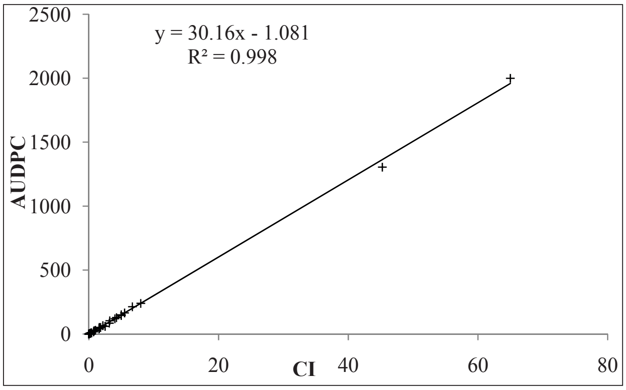

Fig. 2: Association of area under disease progress curve and coefficient of infection

Besides, significantly positive correlation coefficients (*r*) were observed between CI with final rust severity (r = 98**) and AUDPC with CI (r = 99**) for all the test promising entries (Table 4).

Table 3: Categorization of entries based on AUDPC

Range of AUDPC	Entries
0	GW474, GW475, J-2013-14, VA-2013-44, VA-2013-45, VA-2013-50, VA-2013-53, VA-2013-59
1-100	BDW4, BDW8, GW1, GW173, GW451, GW477, GW478, GW496, GW505, GW506, GW509, GDW1255, GW1319, GW1320, GW1348, J-2013-09, J-2013-26, J-2013-28, J-2013-46, VA-2013-46, VA-2013-48, VA-2013-49, VA-2013-57, VA-2017-02, VA-2017-03, VA-2017-04, VA-2017-05, VA-2017-06, VA-2017-07, VA-2017-08, VA-2017-09, VA-2017-10
101-200	GW11, GW322, GW1318, GW1321, GW1339, GW1343
201-500	GW1349, J-2013-30
501-1000	Nil
1001-2000	Lok 1, Agra Local

Table 4: Correlation coefficients (r) between slow rusting parameters

Parameter	Parameter	
	FRS	AUDPC
CI	0.98**	0.99**

Significant at 0.01 levels.

Since, all these three disease parameters i.e. final rust severity, coefficient of infection and area under disease progress curve were strongly and positively correlated in the present study, so, it can be concluded that these are the most appropriate parameters for field based assessment for durable resistance to black rust.

Table 5: Week wise meteorological data during 2017-18 *Rabi* season at Vijapur

Meteorological week	Max. Temp.	Min. Temp.	Morning RH-I	Afternoon RH-II
44	33.7	25.7	90.3	21.4
45	34.7	25.0	92.6	20.4
46	31.9	25.0	90.0	31.9
47	33.1	24.4	91.7	21.6
48	34.8	21.2	92.0	23.0
49	33.7	18.6	91.1	26.9
50	34.0	17.0	94.1	28.1
51	33.4	15.6	96.0	27.6
52	32.0	15.1	94.6	27.9
1	28.0	13.0	95.6	33.3
2	24.7	10.7	86.0	31.1
3	26.3	12.2	81.4	33.9
4	29.4	14.7	94.4	33.4
5	30.5	13.0	92.0	25.7
6	27.5	10.0	86.0	22.1
7	32.6	16.6	88.7	29.0
8	32.7	15.2	86.7	20.0
9	34.3	15.8	83.3	18.4
10	31.8	16.1	73.6	17.3
11	34.5	16.8	51.4	15.7
12	38.2	20.1	68.4	17.0
13	40.2	22.0	50.4	14.6
14	37.5	22.2	67.6	19.4
15	42.1	20.9	28.6	8.7
16	40.0	24.4	75.6	21.4
17	38.6	24.8	85.0	23.3
18	41.8	25.4	48.3	16.0
19	42.5	27.3	66.3	17.6
20	41.4	27.5	81.3	22.0
21	41.4	28.8	82.1	28.9
22	40.8	30.1	81.4	33.0

No rainfall was received during the season

The above findings were also supported by similar findings which reported that the slow rusters entries with terminal rust score upto 30S are desirable in situations where no resistant materials are available, and slow ruster lines against *Ug99* resistance were also identified based on AUDPC values which may be utilized for improving resistance against *Ug99* in popular Indian wheat cultivars (Sharma *et al.* 2015). Similarly, the genotypes which exhibit resistant to moderately resistant responses were of great importance while selecting for durable resistance to stem rust for enhancing more effective breeding program (Nzuve *et al.* 2012). Durum lines generally showed resistance to bread wheat virulent pathotypes 40-A and 40-1 among the Indian *Pgt* population (Mishra *et al.* 2009). Moreover, lines with acceptable level of partial or durable resistance restrict the evolution of new virulent races due to extremely rare chance of occurring multiple point mutations in nature inside the pathogen (Ali *et al.* 2007). Earlier, report also suggest that germplasm accessions exhibiting moderate resistance to resistance reaction may confer durable resistance which may be presence of some effective adult plant resistance (APR) genes against rust (Bhardwaj *et al*, 2006; Elangbam *et al*. 2015; 2016). Many resistance genes for black rust have been designated (McIntosh *et al.* 2009) and among them genes *Sr 2* (Rajaram *et al*. 1988), *Sr 55* (Sybil *et al*. 2014), *Sr 57*(Singh *et al.* 2012) contribute to adult plant resistance to black rust of wheat.

CONCLUSION

In order to combat the threat of evolution of new virulent races of black rust, exploitation of genetic resistance in wheat breeding programme became a critical tool. Hence, from the present findings it can be concluded that all the tested forty entries acquired partial or durable resistance by exhibiting good response of resistance with low AUDPC values under high disease pressure against predominant pathotype 40-A of black rust. Thus, it is important to assess critically the utility of such great diversity of entries for sources of durable resistance at adult plant stage for enhancing work of resistance breeding programme against black rust of wheat.

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