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GENETICS OF STRIPE RUST RESISTANCE IN BARLEY

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ABSTRACT

The genetics of resistance to stripe rust races G and 57 was studied in a 4 x 4 diallel set of crosses involving three donors namely, Himani, EB 1556 and EB 1626, and a susceptible parent, Fongtein Barley. Himani carries one dominant gene, Ps1, to race G and one dominant (Ps1) and one recessive (ps4) genes to race 57. The seedling resistance of EB 1556 is governed by one recessive gene each for races G and 57. The recessive gene conferring resistance to race 57 was identified as ps4. Resistance of EB 1626 to race G is controlled by two recessive genes and to race 57 by one recessive gene. Isogenic lines are being developed in variety Fongtein Barley.

Key words: Resistance genes, stripe rust, barley.

The success of breeding barley cultivars resistant to stripe rust depends on the availability of basic information of the disease. Unfortunately, very little work has been done in India and abroad on the genetics of resistance to *P. striiformis*. No systematic genetic analysis has been done with the prevalent stripe rust races of barley. The present paper reports results of an extensive genetic analysis in three highly resistant cultivars Himani, EB 1556 and EB 1626, against the races G and 57 of stripe rust most prevalent in Northern India.

MATERIALS AND METHODS

The genetic analysis for stripe rust resistance was done in a 4 x 4 diallel set of crosses involving three resistant donors (Himani, EB 1556 and EB 1626) and a susceptible cultivar, Fongtein Barley.

The cultivars involved in the study are briefly described below:

Himani: India, cross (EB 489 x NP 109) x BHS 15-88, resistant to stripe rust, six rowed, hulled with medium maturity.

EB 1556: Ethiopia, six rowed, hulled, medium early, highly resistant to stripe rust.

EB 1626: Ethiopia, two rowed, hulled, grains purple, medium maturity, highly resistant to stripe rust.

Fongtein Barley: Susceptible, two rowed, hulled, medium late.

In addition to the above cultivars, two tester lines, namely, EB 410 (Ps1) and EB 438 (ps4) with already identified single gene for resistance, were used in the crosses to determine relationship between the known genes and the genes for stripe rust resistance in the materials under study.

Two most virulent and predominant races, G and 57, of stripe rust were used. Seedling responses in the glass house were recorded as per Gassner and Straib [1]. Relationships between various genes governing resistance to individual races were determined by inoculating the F_2 plants with two races on the same leaf, leaving a gap of 1-2 cm between the two races (space inoculation) as described by Luthra [2].

RESULTS

The results are presented separately for each cultivar.

Himani. The F_2 data on seedling resistance to the virulent races G and 57 in the cross Himani x Fongtein Barley (Tables 1, 2) show that resistance to race G in Himani is conferred by a dominant gene (3R : 1S). The 13R : 3S ratio obtained with race 57 indicates the presence of one dominant and one recessive factors. Joint segregation ratio of 12 resistant/resistant (R/R) : 1 susceptible/resistant (S/R) : 3 susceptible/susceptible (S/S) was obtained when the F_2 seedlings were space inoculated with race G on the top of leaf and with race 57 on the lower middle portion of the same leaf (G/57). The absence of seedling resistance to race G and susceptible reaction to race 57 supported the hypothesis that the dominant gene operative against race 57 was also operative against race G (Table 3). That is, if the loci were Ps1 and ps4, Ps1—ps4—ps4 operating against race 57 and Ps1Ps1 operating against race G, then the F_2 genotypes Ps1—Ps4— and Ps1—ps4ps4 would show resistance to race G as well as race 57, the genotypes ps1ps1Ps4- would be S/S and the genotypes ps1ps1ps4ps4 would express as S/R.

The seedling reaction of F_2 population derived from the crosses of Himani with the two tester lines, EB 410 (Ps1) and EB 438 (ps4), was also studied (Table 4), which showed the presence of one dominant gene (Ps1) for race G and one dominant and one recessive gene (Ps1 and ps4) for race 57 in variety Himani. No susceptible segregates were found in any of these crosses when tested with appropriate races.

EB 1556. The F_1 of the cross EB 1556 x Fongtein Barley gave susceptible reaction to both races, suggesting that resistance in EB 1556 is recessive.

The F_2 data of the cross EB 1556 x Fongtein Barley (Table 2) indicate that a single recessive gene in EB 1556 causes resistance to each race. Thus, a total of two recessive genes (one each) in cv. EB 1556 determine resistance to races G and 57.

The relationship studies between the genes conferring resistance to races G and 57 (Table 3) revealed that the genes are inherited independently.

Data of cross Himani x EB 1556 were also studied to identify genes for resistance in the varieties. The analysis against race G (Table 2) revealed that the recessive gene in EB 1556 is nonallelic to the dominant gene Ps1 of Himani. Susceptible segregates were not obtained in this cross when tested against race 57, indicating that the single recessive gene in EB 1556 is allelic to the recessive gene ps4 reported earlier in Himani.

Table 1. Infection types on the parents and F_1 seedlings to races G and 57 of barley stripe rust

Parent/F_1	Reaction to race	
	G	57
Himani	0;	0;
Himani x Fongtein Barley	0;	0;
EB 1556	0;	0;
EB 1556 x Fongtein Barley	4	4
EB 1626	0;	0;
EB 1626 x Fongtein Barley	4	4
Himani x EB 1556	0;	0;
Himani x EB 1626	0;	0;
EB 1556 x EB 1626	0;	0;
EB 410 (tester)	0;	0;
EB 410 x Himani	0;	0;
EB 410 x EB 1556	0;	0;
EB 410 x EB 1626	0;	0;
EB 438 (tester)	4	0;
EB 438 x Himani	0;	0;
EB 438 x EB 1556	4	0;
EB 438 x EB 1626	4	0;
Fongtein Barley	4	4

The F_2 populations derived from the crosses of EB 1556 with the two tester lines, EB 410 (Ps1) and EB 438 (ps4), indicate that the recessive gene for resistance to race G in EB 1556 is nonallelic to gene Ps1 of EB 410. We propose to designate this gene as yr EB 1556 1. Similarly, the recessive gene for resistance to race 57 in EB 1556 also appears to be nonallelic to Ps1 of EB 410. However, EB 438 carrying gene ps4 is susceptible to race G. Thus, gene yr EB 1556 1 of EB 1556 should also be nonallelic to the gene present in EB 438. Absence of segregation in the cross EB 1556 x EB 438 (ps4) with race 57 indicates that the genes for resistance in these varieties are allelic. It is concluded that EB 1556 has two recessive genes, yr EB 1556 1 and ps4, for resistance to races G and 57, respectively.

EB 1626. The F_1 of the cross EB 1626 x Fongtein Barley (Table 1) was susceptible to races G and 57, again suggesting that resistance is recessive. The F_2 data (Table 2) further indicate that the cv. EB 1626 possesses complementary recessive genes for resistance to race G and one recessive gene to race 57.

Relationship studies between the genes conferring resistance to races G and 57 (Table 3) revealed that the genes are inherited independently.

Table 2. Inheritance in F_2 of 4 x 4 diallel set of crosses for resistance against races G and 57 of barley stripe rust

Cross	Race	No. of seedlings			Expected ratio	P
		R	S	total		
Himani x Fongtein Barley	G	299	112	411	3R : 1S	0.30–0.20
–Do–	57	216	58	274	13R : 3S	0.50–0.30
Himani x EB 1556	G	295	76	371	13R : 3S	0.50–0.30
–Do–	57	282	0	282	—	—
Himani x EB 1626	G	382	71	453	55R: 9S	0.50–0.30
–Do–	57	204	34	238	55R: 9S	0.95–0.90
EB 1556 x Fongtein Barley	G	100	321	421	1R: 3S	0.70–0.50
–Do–	57	104	277	381	1R: 3S	0.50–0.30
EB 1556 x EB 1626	G	171	116	287	37R: 27S	0.70–0.50
–Do–	57	232	103	335	11R: 5S	0.90–0.80
Eb 1626 x Fongtein Barley	G	103	146	249	7R: 9S	0.50–0.30
–Do–	57	63	182	245	1R: 3S	0.50–0.30

The seedling reactions of the F_2 populations from the crosses of EB 1626 with the other two resistant cultivars were also studied and the results are summarised in Table 2. The segregation was in the ratio of 55R : 9S in the cross Himani x EB 1626 and 37R : 27S in the cross EB 1556 x EB 1626 to race G. Two recessive genes for resistance to race G in EB 1626 appear to be nonallelic to Ps1 of Himani and yr EB 1556 1 of EB 1556. It is proposed that these may be designated as yr EB 1626 1 and yr EB 1626 2. Again, the gene for resistance to race 57 in EB 1626 is nonallelic to those carried by Himani and EB 1556. Therefore, this gene may be designated as yr EB 1626 3. Consequently, EB 1626 carries three recessive genes.

Table 3. Relationship between genes governing resistance to races G and 57 of barley stripe rust

Races	G		χ^2 and P for independence	χ^2 for joint segregation (12 : 1 : 3)
	R	S		
Race 57:				
	Himani x Fongtein Barley			
Res.	82	10	χ^2=75.958	χ^2=2.092
Sus.	0	26	P = 0.001	P = 0.50–0.30
	EB 1556 x Fongtein Barley			
Res.	6	20	χ^2 = 1.337	
Sus.	18	70	P = 0.80–0.70	
	EB 1626 x Fongtein Barley			
Res.	13	25	χ^2=1.577	
Sus.	47	65	P = 0.70–0.50	

The seedling reactions of the F_2 populations of the crosses between EB 1626 and EB 410 (Ps1) and EB 438 (ps4) in

Table 4 show that the three recessive genes of EB 1626 are nonallelic to the genes Ps1 and ps4 already identified in the tester lines.

Table 4. Segregation of seedlings for stripe rust reaction in the cross involving cvs. Himani, EB 1556 and EB 1626 with tester lines EB 410 (Ps1) and EB 438 (ps4) of barley

Cross	Race	F_2 segregation		
		R	S	total
EB 410 (Ps1) x Himani	G	132	0	132
–Do–	57	186	0	186
EB 410 (Ps1) x EB 1556	G	220	60	280
–Do–	57	502	110	612
EB 410 (Ps1) x EB 1626	G	342	60	402
–Do–	57	276	72	348
EB 438 (ps4) x Himani	G	—	—	—
–Do–	57	643	0	643
EB 438 (ps4) x EB 1556	G	—	—	—
–Do–	57	320	0	320
EB 438 (ps4) x EB 16262	G	—	—	—
–Do–	57	221	106	327

Note. EB 438 is susceptible to race G.

DISCUSSION

Genetics of resistance to stripe rust of barley has been the subject of several studies. Nover and Scholz [3] and Johnson [4] identified four loci conferring seedling resistance to pathotypes 23 and 24. These were designated as yr and numbered yr1, yr2, yr3 and yr4 in the cultivars Abyssinian 14, Deba Abed, I.5 and Cambrinus, respectively. Bakshi and Luthra [5] on the other hand, found eight loci causing resistance to five races in the varieties EB 410, EB 438 and EB 145. They designated these loci as Ps1 – Ps8 (*Puccinia striiformis*). Correspondence between the Ps and yr genes has not been established, but is under investigation in our laboratory. At present, the additional genes identified in the study are designated with provisional symbols [6].

A summary of genes for resistance in the 5 barley accession is given below:

Cultivar	Genes for resistance against two races	
	race G	race 57
Himani	Ps1	Ps1, ps4
EB 1556	yr EB 1556 1	ps4
EB 1626	yr EB 1626 1, yr EB 1626 2	yr EB 1626 3
EB 410 (tester)	Ps1	Ps1
EB 438 (tester)	+ susceptible	ps4

The genes Ps1 and ps4 were possibly contributed to Himani by its progenitors EB 410 and EB 438 through BHS 15-88 and NP 109, respectively.

EB 1556 has an additional gene yr EB 1556 1 which determines resistance against race G. EB 1556 has been reported to contain two recessive gene pairs [7]. The genes conferring resistance at seedling stage possibly continue to operate in the adult plant also.

It will be important to transfer new genes for resistance to a universally susceptible variety to obtain the maximum advantage of the knowledge gained. The isogenic lines so produced will have a great potential for further work. Isogenic lines are being developed in the variety Fongtein Barley for the genes identified in EB 410, EB 438 EB 1556 and EB 1626. Two isogenic lines carrying the gene Ps1 and ps4 have already been developed. The four recessive genes present in EB 1556 and EB 1626 have been transferred to the susceptible variety Fongtein Barley. At present, the material is in the segregating stage and may become homozygous after 2–3 selfings.

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