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Short Communication

Genetics of durable resistance to leaf rust in some exotic wheat cultivars

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Wheat crop is attacked by three rust pathogens out of which leaf rust caused by *Puccinia recondita* f. sp. *tritici* is the most important in north India. The use of race-specific hypersensitive resistance lead to boom and bust cycles making it necessary to quickly replace such cultivars after their release. Under such conditions, non-hypersensitive adult plant resistance which is known for its durable nature (McIntosh, 1) can be successfully exploited to manage this disease. Characterization of resistance in terms of nature and number of genes governing resistance is a pre-requisite for their systematic and efficient exploitation in breeding programme. The present report deals with the genetic studies on three exotic cultivars *viz.* Chris (USA) Banks and Egret (Australia) having such resistance.

The experimental material comprised of three cultivars Chris (PNTH/Condor Sib // Condor), Banks (Heron / 4 / 2X Lerma Rojo // Brevor 14 / 3 / 3X Andes) and Egret (Frontana / 3X Thatcher / 3 // Kenya 58/ Newthach // 2X Thatcher), showing adult plant resistance to leaf rust. The seedling and adult plant reaction of these cultivars were recorded. These cultivars were crossed with susceptible cultivar Agra local (a land race from Uttar Pradesh). The F_1 and F_2 generations obtained from the crosses were grown at the experimental areas of Punjab Agricultural University, Ludhiana. These were assessed for disease severity under artificial epiphytotic created by spraying uredospore suspension of the race 77A prepared in water. In addition, the plants in F_2 and F_3 generations were also evaluated for seedling reaction against the most avirulent leaf rust race 11. The avirulence/virulence formulae of the races are given below:

Race 11 (Seedling): *PLr1, Lr2a, Lr2b, Lr2c, Lr3(Bg), Lr3(Do), Lr3(Ka), Lr3(sin), Lr9, Lr10, Lr11, Lr12, Lr13, Lr14a, Lr14b, Lr15, Lr16, Lr17, Lr18, Lr19, Lr21, Lr22a, Lr22b, Lr23, Lr24, Lr26, Lr(27+31), Lr28, Lr30/Lr20, Lr29*

Race 77A (Seedling): *PLr9, Lr18, Lr19, Lr21, Lr24, Lr25/PLr1, Lr2a, Lr2b, Lr2c, Lr2d, Lr3(Bg), Lr3(do), Lr(Ka), Lr(Sin), Lr10, Lr11, Lr12, Lr13, Lr14a, Lr14b, Lr15, Lr16, Lr17, Lr20, Lr22a, Lr22b, Lr23, Lr26, Lr27+31, Lr28, Lr29, Lr30.*

Race 77A (Adult plant): *PLr3(Ka), Lr9, Lr12, Lr14b, Lr18, Lr19, Lr21, Lr22a, Lr23, Lr24, Lr25, Lr26, Lr29/PLr1, Lr2a, Lr2b, Lr2c, Lr2d, Lr3(Bg), Lr3(Do), Lr(Sin), Lr10, Lr11, Lr13, Lr14, Lr15, Lr16, Lr17, Lr20, Lr22b, Lr27+31, Lr28, Lr30.*

The observations on seedling infection-types and disease severity were recorded following Stakman *et al.* [2] and Peterson *et al.* [3], respectively. The genetic data were subjected to χ^2 test. The contribution of seedling resistance gene(s) towards terminal disease severity in field tests was examined by subjecting the infection-types and adult plant terminal disease severity data of each F_3 line to joint segregation tests as proposed by Lupton and Macer [4]. The seedlings of Banks, Egret and Chris were resistant (ITs = 0; to ;1) to race 11 but these were susceptible to race 77A. The disease severity of these lines against race 77A was 10S, 5S and 10S (IT = 3), respectively. The low terminal disease severity on these three cultivars against race 77A despite susceptible infection-types against the same race proves that these cultivars have non-hypersensitive resistance against race 77A.

The segregation for seedling and adult plant reaction in F_2 and F_3 generations in the crosses Chris/Agra local, Egret/Agra local and Banks/Agra local against races 11 and 77A are given in Table 1. The F_2 plants and F_3 generation of Chris/Agra local segregated in 9 resistant (R): 7 susceptible (S), and 1 homozygous resistant (HR): 8 segregating (Seg): 7 homozygous susceptible (HS) ratio, respectively against race 11. The F_2 from the cross Egret/Agra local was not tested. F_3 generation seedlings from this cross segregated in 1HR: 8 Seg. : 7HS against race 11 suggesting that resistance to this race in Chris and Egret was due to two dominant complimentary genes.

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Table 1. Segregation for seedlings and adult plant reaction in F_2 and F_3 generations from resistant/susceptible crosses against races 11 and 77A

Cross/race/stage/severity	Generation and segregation pattern								
	F_2				F_3				
	No. of plants		Expected ratio	χ^2	No. of families**			Expected ratio	χ^2
Chris/Agra local	R	S			HR	Seg.	HS		
Seedling stage (Race 11)	59	37	9:7	1.05	7	58	42	1:8:7	0.83
Adult plant stage (Race 77A) (severity 10S)	167	17	15:1	2.80	52	36	6	7:8:1	5.45
Banks/Agra local									
Seedling stage (Race 11)	85	25	3:1	0.30	29	68	35	1:2:1	0.66
Adult plant stage (Race 11) (severity 10S)	133	11	15:1	0.47	42	35	8	7:8:1	3.33
Egret/Agra local									
Seedling stage (Race 11)	-	-	-	-	10	69	56	1:8:7	0.49
Adult plant stage (Race 11) (severity 10S)	160	16	15:1	2.42	52	45	8	7:8:1	2.19

- = not tested, ** HR = Homozygous resistant, Seg. = Segregating, HS = Homozygous susceptible

Table 2. Joint segregation for seedling reaction to race 11 and disease severity against race 77A on adult plant in F_2 plant progenies from crosses Chris/Agra local, Banks/Agra local and Egret/Agra local

Chris/Agra local

		Race 11					
		HR*	3:1/9:7 (Seg.#)	HS	Total	χ^2	
Race 77A	HR*	3 (4.71)**	20 (18.85)	10 (9.42)	33	0.72	
		(4.00)	(18.00)	(4.57)			
	3:1/15:1 (Seg.)	1 (0.0)	15 (10.00)	4 (10.00)	20	6.10	χ^2 (7:8:1) = 5.30 (P = 0.1-0.09)
		(0.00)	(18.00)	2 (9.14)	3		
	HS**	0 (0.00)	0 (0.00)	0 (4.00)			
		(0.00)	(0.00)	2.28	3.0	0.33	
	Total	4	36	16	56		
	χ^2	0.25	0.72	9.37*			
		χ^2 (1:8:7) = 5.30 (P = 0.10-0.05)					

Banks/Agra local

		Race 11					
		HR	3:1:/9:7 (Seg.)	HS	Total	χ^2	
Race 77A	HR	9 (22.85)	22 (11.42)	9 (5.71)	40.0	20.09*	
		(16.00)	(10.00)	(4.85)			
	3:1/15:1	4 (0.00)	16 (20.25)	7 (6.75)	27.0	0.90	χ^2 (7:8:1) = 6.85 (P = 0.05-0.02)
		(0.00)	(30.00)	(9.50)			
	HS	3 (0.00)	2 (0.00)	3 (8.00)	8.0	31.12*	
		(0.00)	(0.00)	(4.75)			
	Total	16	40	19	75.0		
	χ^2	3.06	20.33	5.10			
		χ^2 (1:2:1) = 0.57 (P = 0.80-0.70)					

Egret/Agra local

		Race 11					
		HR	3:1/9:7 (Seg.)	HS	Total	χ^2	
Race 77A	HR	2 (3.99)	14 (15.99)	12 (7.99)	28.0	3.25	
		(3.00)	(13.50)	(6.57)			
	3:1/15:1 (Seg.)	1 (0.00)	13 (10.50)	7 (10.50)	21.0	1.76	χ^2 (7:8:1) = 2.28 (P = 0.50-0.30)
		(0.00)	(13.50)	(13.14)			
	HS	0 (0.00)	0 (0.00)	4 (4.00)	4.0	0.00	
		(0.00)	(0.00)	(3.28)			
	Total	3	27	23	53.0		
	χ^2	0.33	0.03	7.51			
		χ^2 (1:8:7) = 0.04 (P = 0.99-0.98)					

*Significant at 5% level. **Figures in parenthesis below and against observed number in each categories indicate expected number of F_2 plant progenies. HR = Homozygous resistant, #Seg. = Segregating. **HS = Homozygous susceptible.

The F_2 and F_3 generations from crosses Banks/Agra local segregated in a 3 R : IS and 1 HR : 2 Seg.: 1 HS ratio indicating a dominant gene in cv Banks against race 11. The low terminal severity against race 77A in each of the three cultivars is ascribed to two dominant genes because the F_2 and F_3 generations against this race segregated in 15 R : 1S and 7 HR : 8 Seg.: 1 HS ratios.

The joint segregation for seedling infection-types against race 11 and disease severity at adult plant stage against race 77A of the same F_3 families in crosses of Chris, Egret and Banks with Agra Local is given in Table 2. In Chris, out of the 4 progenies, homozygous resistant against race 11, 3 were homozygous resistant and 1 segregated for disease severity against race 77A. Out of the 36 families, segregating in 3R : 1S/9R:7S ratio against race 11, 20 were homozygous resistant, 15 segregated in a 3R:1S/15R:1S ratio and 1 was homozygous susceptible to race 77A. Out of the 16 F_3 families homozygous susceptible against race 11, 10 were homozygous resistant, 4 segregated and 2 were homozygous susceptible for disease severity against race 77A at adult plant stage. This indicated that one of the two dominant complementary genes effective against race 11 was similar to one of the two independently inherited dominant genes effective against race 77A. Only two unexpected F_3 families were obtained in this cross which appear to have arisen due to variation in environment. Genes *Lr 13* and *Lr 34* have been reported from cultivar Chris [5]. Gene *Lr 34* is one of the two dominant complementary genes identified from cultivar Frontana [6]. Since, gene *Lr 34* was effective against race 77A under field conditions [7], one of the dominant complimentary genes operative at adult plant stage in Chris may be *Lr 34*.

Out of the 16 families homozygous resistant to race 11 from the cross Banks/Agra local at the seedling stage, 9 were homozygous resistant, 4 segregated and 3 were homozygous susceptible against race 77A. Out of the 40 families segregating in a 3R:1S/9R:7S ratio against race 11, 22 families were homozygous resistant, 16 segregating and 2 were homozygous susceptible against race 77A. Similarly, out of 19 families homozygous susceptible for infection-type against race 11, 9 families were homozygous resistant, 7 segregated in a 3R:1S/15R:1S and 3 were homozygous susceptible against race 77A. Highly significant values for different observed categories and presence of large number of unexpected F_3 families in this cross indicated that two adult plant resistance genes effective against race 77A are different from the seedling resistance genes.

Out of the 3 F_3 families homozygous resistant against race 11 in the cross Egret/Agra local, 2 were homozygous resistant and one segregated for disease severity against race 77A. Out of 27 F_3 families segregating in 3R:1S/9R:7S ratios against race 11, 14 were homozygous resistant and 13 segregated in 3R:1S/15R:1S ratio in terms of disease severity against race 77A. Out of 23 families homozygous susceptible to race 11, 12 families were homozygous resistant, 7 segregated while 4 were homozygous susceptible against race 77A in terms of disease severity. These results indicated that similar to cultivar Chris, one of the two dominant complimentary genes in Egret which is effective against race 11 may be *Lr 34*. The expected presence of gene *Lr 34* in Chris, Egret and Banks suggested these as ideal stocks for use in breeding programme aimed at evolving durable leaf rust resistant varieties. Further, the gene *Lr 34* is linked with adult plant stripe rust resistance gene *Yr 18* [8]. These associations will be useful for simultaneous improvement of wheat for durable resistance to leaf rust and stripe rust resistance.

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