Indian J. Genet., **60**(1): 5-14 (2000)

ASSESSMENT OF 'SELECTION 212' - A WHEAT-RYE RECOMBINANT LINE FOR RESISTANCE TO LEAF AND STEM RUSTS

J. B. SHARMA AND D. SINGH

Division of Genetics,
Indian Agricultural Research Institute, New Delhi 110 012

(Received: July, 1999; accepted: January, 2000)

ABSTRACT

Selection 212, a wheat-rye recombinant between homoeologous chromosomes of wheat and rye, the parental lines and the stocks/ near-isogenic lines each carrying known leaf and stem rust resistance gene were tested against 25 pathotypes of *Puccinia recondita tritici* and *Puccinia graminis tritici* in seedlings. These lines were also tested at adult plant stage with highly virulent and prevalent pathotypes of leaf and stem rust pathogen. Sel.212 conferred resistance to all pathotypes of both the rust pathogens. A comparison of infection types spectrum produced on the parental lines, lines with known resistance genes and the recombinant (Sel.212) led to the postulation that Sel.212 carries resistance different from the known resistance genes which is presumably derived from rye. This study also forms the basis for selection of pathotypes for further genetic and cytogenetic analysis of this stock for rust resistance.

Key Words : Wheat, rye (*Secale cereale*), leaf rust (*Puccinia recondita*), stem rust (*Puccinia graminis*), resistance.

Rusts are the major diseases of wheat (*Triticum aestivum* L.) world over that cause substantial yield losses. Breeding for disease resistance is the most economical way of disease management. The inherent ability of the pathogen to evolve and acquire new virulences that can overcome resistance in newly developed cultivars is the basis for resistance breeding programme to be followed continuously by using new resistant sources. Several resistance genes from cultivated and alien germplasm have been extensively used for incorporating resistance to rusts, the alien genes are likely to be more useful for better and prolonged effectiveness.

Attempts were, therefore, made to enhance the genetic variability for rust resistance through the use of related species of wheat as well as rye (*Secale cereale*). Homoeologous recombination between chromosomes of wheat and rye resulted in 'Selection 212' [1]. Sel.212 was found resistant to both leaf and stem rusts caused by *Puccinia recondita* f. sp. *tritici* and *Puccinia graminis* f. sp. *tritici*, respectively [1, 2] at Wellington (South India), a hot spot for rust diseases. The present study reports the results of tests of Sel.212 and the parental lines with an array of leaf and stem rust pathotypes in seedlings and adult stage of plant growth.

MATERIALS AND METHODS

Sel.212 was developed by crossing a self incompatible, amber seeded diploid (2n=14) rye obtained through gamma-radiation from a red seeded, self compatible rye (USDA 366498) with monosomic line of cultivar Chinese Spring deficient for chromosome 5B. A 27 chromosomes (lacking chromosome 5B) F_1 hybrid exhibiting extensive homoeologous pairing was backcrossed to a hexaploid wheat Sonalika. Segregating population (BC_1F_2 to BC_1F_7) were screened for rust resistance. In BC_1F_7, a cytologically stable ($2n = 42 = 21^{II}$) line was designated Sel.212 [1].

Sel.212, the parental lines [Chinese Spring, Sonalika and a rye strain (USDA 366498) 2n = 14], the differential lines and the stocks each carrying single gene for leaf and stem rust resistance were tested against the 25 pathotypes of *P. recondita* f. sp. *tritici* and the 20 pathotypes of *P. graminis* f. sp. *tritici* in seedlings. The same set of material was also tested at adult plant stage with highly virulent and predominant pathotypes (77-5 of *P. recondita* f. sp. *tritici* and 40A of *P. graminis* f.sp. *tritici*).

Seedling Tests : Inoculum of each pathotype obtained from Directorate of Wheat Research, Regional Station, Flowerdale, Shimla was multiplied following the procedure described by Joshi *et al.*, [3]. Host lines were grown in rectangular trays (11" × 4" × 3"). Ten lines were sown in each tray and 10 seeds in each line. One week old seedlings were inoculated with the help of lanceolate needle. After inoculation, seedlings were incubated at high humidity for 24h and afterwards kept in a glass house at mean temperature 20°C-28°C. Reactions were classified after 12 days of inoculation, according to Stakman *et al.*, [4].

Sel. 212, Sonalika and Agra Local were also tested with pathotypes 77-1, 77-2, 77-3, 77-4 and 77-5 of *P. recondita tritici* separately at four temperature regimes. The mean minimum and maximum temperature during incubation for four regimes were 6°C-25.9°C, 9.9°C - 31.5°C, 13.6°C - 35.6°C and 15.4°C - 38.7°C.

Adult plant tests : The material for adult plant tests was planted in two nurseries separately for testing against leaf and stem rusts. The seeds were sown in one meter long rows with a row to row distance of 30 cm. Every 10th row was planted with a mixture of highly susceptible varieties to produce inoculum and to serve as spreader. The nurseries were also surrounded by three rows of spreader. Spreader rows were inoculated with urediospore suspension using hypodermic syringe. Fields were irrigated adequately to ensure sufficient humidity for the spread of the pathogen. Reactions were recorded as severity (percentage of infection) and response (pustule type) according to scale proposed by Peterson *et al.* [5].

RESULTS AND DISCUSSION

Seedling reactions of Sel.212, constituent parents, differential sets comprising near-isogenic lines and the stocks each carrying known genes for resistance against 25 pathotypes of *P. recondita tritici* are given in Table 1. Infection types produced on Sel.212 with 25 pathotypes of leaf rust pathogen demonstrated that Sel.212 was resistant to all the pathotypes producing a range of resistance reaction (IT';' to IT 'x^{++}'). The mesothetic infection types ('x') and its variations were observed for groups 77, 104 and 108 pathotypes. Chinese Spring was susceptible (ITs '33^{+}' - '3^{+}') to all the pathotypes. Sonalika showed susceptible reaction to group 77 pathotypes and different pattern of infection to other pathotypes. Rye strain, the donor of resistance in Sel.212 was resistant to all the pathotypes (ITs ';' - 'x^{-}').

The avirulence/virulence pattern of each pathotype on differential lines confirm the purity of pathotypes. Transec, a line carrying leaf rust resistance gene *Lr25* derived from rye, was highly resistant to all the pathotypes and produced IT ';1' to most of the pathotypes. Lines carrying *Lr23* were susceptible to pathotypes 12-2, 77-2, 77-4, 77-5, 104B and 104-2. Thatcher near-isogenic line carrying *Lr16* was susceptible to pathotypes 12-1, 12-3, 20, 77, 77-1, 77-2, 77-3, 77-4, 77-5, 104B, 162 and 162A. Cultivar Gatcher carrying complementary genes (*Lr27* + *Lr31*) were susceptible to pathotypes 12-1, 12-2, 77-1, 77-2, 77-3, 77-4, 77-5, 104B, 162 and 162A.

The spectrum of infection types produced on Sel.212 differed from the spectrum of infection types produced on the differential lines and the stocks carrying different known resistance genes. It was thus considered that resistance gene(s) in Sel.212 is different to that of already designated genes.

A comparison of infection types produced on Sel.212 (ITs 'x^{-}'-'x^{++}') and the parental line Sonalika (ITs '33^{+}'-'3^{+}') against pathotypes 77, 77-1, 77-2, 77-3, 77-4 and 77-5 revealed that resistance in Sel.212 presumably is contributed by rye strain used in the development of Sel.212. Although Sel.212 and Sonalika both show resistant reaction to group 12 pathotypes, Sel.212 showed much lower infection types (ITs ';'-';1') than Sonalika (ITs 'x^{+}' - '3^{-}'), indicating the presence of additional resistance gene(s) in Sel.212 to group 12 pathotypes. Similar infection type spectrum was produced on Sel.212 and parental rye strain. However, reduced resistance in Sel.212, as compared to parental rye was observed against most of the pathotypes. This may be due to the suppressing effect of D-genome when resistance genes were transferred from alien sources to aestivum wheat. Bai and Knott [6], Dyck [7] also reported the suppression of rust resistance in bread wheat by D-genome chromosomes.

Table 1. Seedling infection types of selection 212, its constituent parental lines, differentials and other tester lines against 25 pathotypes of *Puccinia recondita* f.sp. *tritici* at mean temperature 20-28°C and their adult plant response

Host line/ Pathotype	SEEDLING INFECTION TYPES 10 13R19	110 R8	12A 5R13	12-1 5R37	12-2 1R5	12-3 49R37	17 6IR24	20 5R27	63 0R8-1	77 45R31	77-1 109R63	77-2 109R31-1	77-3 125R55
Wheat-Rye recombinant													
Selection 212	;1	;	;$^{-}$	;$^{+}$	;	;1^{-}	;1=N	;1	;$^{-}$	X2	X^{-}	X^{+}	X
Parental lines													
Rye	;	;		;1^{-}	X$^{=}$	X$^{=}$	;1$^{=}$	;	;	;1^{-}	;1^{-}	;1	;1^{-}
Sonalika	X^{+}3	;1$^{=}$	X^{+}	X^{+}3^{+}	X^{++}	3^{-}	13^{-}	;1^{-}	;$^{+}$	33^{+}	3^{+}	3^{+}	33^{+}
Chinese Spring	33^{+}	33^{+}	33^{+}	3^{+}	3^{+}	33^{+}	33^{+}	33^{+}	33^{+}	3^{+}	3^{+}	3^{+}	3^{+}
Susceptible line													
Agra Local	3^{+}	33^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	33^{+}	33^{+}	3^{+}	3^{+}	3^{+}	3^{+}
Differentials													
Set A													
Lr14a-Tc	33^{+}	;X	3^{+}	3^{+}	3^{+}	3^{+}	33^{+}	3^{+}	X	3^{+}	3^{+}	33^{+}	3^{+}
Lr24 (Agent)	;1$^{=N}$	;1$^{=}$	;^{N}	;1^{-}	;1$^{=N}$	;1$^{=}$	;1^{-}	;^{N}	;^{N}	;1$^{=}$	;^{N}	;1^{-N}.	;1^{-N}
Lr18-Tc	33^{+}	;3	3^{+}	3^{+}	;3^{-}	13^{-}	3^{+}	3^{+}	;1^{-}	3^{+}	3^{+}	3^{+}	3^{+}
Lr13-Tc	33^{+}	;1	X^{+}3	X^{+}3	X^{++}	13^{-}	33^{+}	X^{+}3	;1^{-}	3^{+}	3^{+}	33^{+}	3+
Lr17-Tc	;13^{-}	;1	13	X^{+}	X^{++}	3^{+}	33^{+}	X^{+}	;1^{-}	X^{+}3	X^{+}3^{+}	X^{+}3^{+}	3^{+}
Lr15-Tc	23^{-}	;	;1	;	;	3^{+}	33^{+}	;	;1^{-}	3^{+}	3^{+}	33^{+}	33^{+}
Lr10-Tc	;	;	;12	;1	;12	;1	;1^{-}	;1	;	;1	3^{+}	33^{+}	3+
Lr19 (Agatha)	0;	0;	0;	;	;	;	;$^{-}$	0;	0;	0;	;	0;	0;
Set B													
Lr2c (Loros)	3^{+}	;1$^{=}$	3^{+}	33^{+}	3^{+}	3^{+}	;	33^{+}	;	3^{+}	3^{+}	3^{+}	3^{+}
Lr2a (Webster)	33^{+}	;1	;1	;1	;1	;12	;	3^{+}	;1	33^{+}	3^{+}	3^{+}	3^{+}
Lr3 (Democrate)	;1	;	3^{+}	3^{+}	33^{+}	3^{+}	;1$^{=N}$	;1^{-}	;	3^{+}	3^{+}	33^{+}	3^{+}
Lr20 (Thew)	;	3^{+}	3^{+}	X	;1^{N}	X$^{=N}$	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	;1
Lr1 (Malakoff)	3^{+}	;1$^{=}$	;1$^{=}$	;	;	;^{N}	33^{+}	3^{+}	;	3^{+}	3^{+}	3^{+}	3^{+}
Lr26 (Benno)	;	;	0;	3^{+}	;	3^{+}	;1^{-}	0;	0;	;	3^{+}	0;	3^{+}
Other lines													
Lr23 (IWP94)	;1	;1	X^{+}3	X$^{=}$	33^{+}	X$^{=}$	X	;1^{-}	;1	;1	;1	3^{+}	X
Lr10,Lr23 (Gabo)	;12^{-}	;1$^{=}$	X^{+}	;1^{N}	3^{+}	;1	;1	;1^{-}	;1$^{=}$	;1^{-}	;1^{-}	3^{+}	X^{-}
Lr23-Tc	X^{+}3	;12	X^{+}3^{+}	3	3^{+}	X^{+}3	23^{-}	X^{+}	;1^{+}	X$^{=}$	X^{+}	3+	X^{+}3^{+}
Lr16-Tc	X2	;1^{-}	X2	3^{+}	3^{+}	3^{+}	X^{+}	33^{+}	;1$^{=}$	3^{+}	3+	33^{+}	33^{+}
Lr25 (Transec)	;1	;	;	;1	;1$^{=N}$	;	;1^{+}	;1–	0;	;	;1	;1	;1
Lr27 + Lr31 (Gatcher)	;1	;1^{+}	X^{++}	33^{+}	33^{+}	X^{+}3^{+}	;1$^{=N}$	X$^{=}$	;	X	3^{+}	3^{+}	3^{+}

(*Table 1 cont.*)

Host line/ Pathotype	SEEDLING INFECTION TYPES												ADULT PLANT RESPONSE
	77-4 125R 23-1	77-5 121R 63-1	104 17R23	104A 21R31	104B 29R23	104-2 21R55	107 45R3	107-1 45R35	108 13R27	108-1 57R27	162 93R7	162A 93R15	77-5 121R 63-1
Wheat-Rye recombinant													
Selection 212	X^{++}	X	X^{-}	X^{+}	X^{+}	X^{+}	;1	$;1^{-}$	$X^{=}$	X	1^{-}	;	5R
Parental lines													
Rye	;1	$X^{=}$	$X^{=}$	$;1^{+}$	$X^{=}$	X^{-}	;	;	$;1^{=}$	;	;	;	0
Sonalika	33^{+}	3^{+}	X	X	3	X	;12	$;13^{-}$	X^{-}	X^{-}	12^{+}	2^{+}	70S
Chinese Spring	3^{+}	3^{+}	33^{+}	33^{+}	3^{+}	3^{+}	33^{+}	33^{+}	3^{+}	3^{+}	3^{+}	3^{+}	50MR MS
Susceptible line													
Agra Local	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	33^{+}	3^{+}	3^{+}	33^{+}	3^{+}	3^{+}	80S
Differentials													
Set A													
Lr14a-Tc	3^{+}	3^{+}	3^{+}	3	3^{+}	3^{+}	3+	3^{+}	33^{+}	3+	3^{+}	3+	90S
Lr24 (Agent)	$;1^{N}$	$;1^{-N}$	$;1^{-}$	$;1^{=}$	$;1^{-}$	$;1^{=N}$	$;1^{-}$	$;1^{=N}$	$;1^{=N}$	$;1^{-}$	$;1^{=}$	$;1^{-}$	TR
Lr18-Tc	3^{+}	23	3^{-}	33^{+}	4	3^{+}	3^{+}	3^{+}	33^{+}	X	3^{+}	3^{+}	20MR
Lr13-Tc	3^{+}	3^{+}	X	$X^{+}3$	33^{+}	$X^{+}3$	33^{+}	3^{+}	33^{+}	33^{+}	3^{+}	3^{+}	70S
Lr17-Tc	3^{+}	3^{+}	3^{+}	33^{+}	3^{+}	33^{+}	$;1^{+}$	12^{N}	$;13^{-}$	3^{+}	3^{+}	3^{+}	80S
Lr15-Tc	33^{+}	33^{+}	;1	$;1^{-}$	;1	;	3^{+}	33^{+}	;	33^{+}	;	;	80S
Lr10-Tc	3^{+}	3^{+}	$;1^{-}$	;1	;12	;1	;	$;1^{+}$	;1	$;12^{-}$	3^{+}	3^{+}	80S
Lr19 (Agatha)	0;	;	0;	;	;	;	0;	;	;	0;	0;	0;	TR
Set B													
Lr2c (Loros)	3^{+}	3^{+}	3^{+}	3^{+}	33^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	60S
Lr2a (Webster)	3^{+}	3^{+}	12	$;3^{+}$	23^{-}	23	3^{+}	3^{+}	33^{+}	3^{+}	3^{+}	3^{+}	80S
Lr3 (Democrate)	3^{+}	3^{+}	33^{+}	3^{+}	3^{+}	3^{+}	;	$;^{N}$	;	$;1^{=N}$	3^{+}	3^{+}	80S
Lr20 (Thew)	;1	3^{+}	$;1^{-}$	3^{+}	X^{-N}	;1	;1	$;1^{-}$	33^{+}	3^{+}	;1	3^{+}	80S
Lr1 (Malakoff)	3^{+}	3^{+}	3^{+}	3^{+}	4	3^{+}	0;	;	3^{+}	3^{+}	0;	0;	90S
Lr26 (Benno)	0;	3^{+}	;	0;	$;1^{-}$	3^{+}	$;1^{-}$	33^{+}	;	;	0;	0;	80S
Other lines													
Lr23 (IWP94)	3^{+}	3^{+}	X	X^{+}	3^{+}	3^{+}	1	$;1^{-}$	X	X^{+}	3	3	NG
Lr10,Lr23 (Gabo)	3^{+}	3^{+}	X^{-}	X^{-}	4	3^{+}	;	$;1^{N}$	X2	X^{+}	3	3	NG
Lr23-Tc	3^{+}	3^{+}	X^{+}	$X^{+}3$	3^{+}	3^{+}	;1	X^{-}	3	$X^{+}3$	33^{+}	3^{+}	NG
Lr16-Tc	3^{+}	3^{+}	23^{-}	23^{-}	33^{+}	-	;1	$X^{+}3$	X2	X^{-}	3^{+}	3+	80S
Lr25 (Transec)	;1	;1	$;1^{-}$	$;1^{N}$	$X^{=N}$	$;1^{-}$	;1	;	;1	$;1^{N}$	;1	;1	TR
Lr27 + *Lr31* (Gatcher)	3^{+}	3^{+}	X^{N}	X^{+}	3^{+}	$X^{+}3^{+}$	;1	;1	X^{-}	X^{++}	33^{+}	3^{+}	70S

NG = Nil germination

Based on the above mentioned differential infection types produced on Sel.212 and Sonalika, pathotypes 12-2, 77-1, 77-2, 77-3, 77-4 and 77-5 were selected for further genetical and cytogenetical analysis of this wheat-rye recombinant.

Table 2. Seedling infection types of Selection 212, its parental line Sonalika and susceptible check Agra Local against 6 pathotypes of *P. recondita* f. sp. *tritici* at four temperature regimes

Line	Temperature regime	Mean temp. (°C)		Pathotype					
		Min.	Max.	12-2	77-1	77-2	77-3	77-4	77-5
Selection 212	Low	6.0	25.9	;	$X^{+}3$	;33^{+}	$X^{+}3^{+}$	3	3
	Medium	9.9	31.5	;	X^{++}	3^{-}	13	$3^{=}$	$X^{+}3$
	High	13.6	35.6	;	X^{-}	X^{++}	X	X^{+}	X^{-}
	Very high	15.4	38.7	;	;1^{N}	X^{-}	;1^{+}	$X^{=}$	;1
Sonalika	Low	6.0	25.9	$X^{+}3$	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}
	Medium	9.9	31.5	X^{++}	3^{+}	3^{+}	3^{+}	3^{+}	33^{+}
	High	13.6	35.6	X^{-}	33^{+}	3^{+}	33^{+}	3^{+}	33^{+}
	Very high	15.4	38.7	$X^{=}$	3	33^{+}	33^{+}	33^{+}	3
Agra Local	Low	6.0	25.9	3^{+}	3^{+}	4	3^{+}	3^{+}	3^{+}
	Medium	9.9	31.5	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}
	High	13.6	35.6	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}	3^{+}
	Very high	15.4	38.7	33^{+}	33^{+}	33^{+}	33^{+}	33^{+}	33^{+}

However, pathotype 77-5 which is the most virulent strain that attacks most of the aestivum derived leaf rust resistance genes such as *Lr1, Lr2a, Lr2b, Lr2c, Lr3, Lr3bg, Lr3ka, Lr10, Lr11, Lr12, Lr13, Lr14a, Lr15, Lr16, Lr17, Lr20, Lr23, Lr27, Lr31* and *Lr33*, was selected for adult plant tests. Adult plant tests with pathotype 77-5 exhibited resistance response (5R) on Sel.212 and susceptible (70S) on Sonalika. Chinese Spring, though susceptible in seedlings showed moderately resistant response (50MRMS) in adult plants which can be attributed to adult plant resistance gene *Lr34* in Chinese Spring [12]. Among tester lines, Tc + *Lr18*, Agent (*Lr24*), Agatha (*Lr19*) and Transec (*Lr25*) were resistant while the other lines were susceptible.

Of the parental lines involved in the development of Sel.212, rye strain carries unknown gene(s) for leaf rust resistance and Sonalika is known to possess leaf rust resistance genes *Lr13* and *Lr14a* [8, 9]. Chinese Spring carries *Lr31* [10, 11]. All the three leaf rust resistance genes (*Lr13, Lr14a* and *Lr31*) are ineffective against pathotype 77-5.

Table 3. Seedling infection types of Selection 212, its constituent parental lines and differentials against 20 pathotypes of *Puccinia graminis* f.sp. *tritici* at mean temperature 20-28°C and their adult plant response

Host line/ Pathotype	SEEDLING INFECTION TYPES									
	11 79G31	11A 203G15	14 16G2	21 9G5	21-1 24G5	21A-2 75G5	34-1 10G13	40A 62G29	40-1 62G29-1	42 19G35
Wheat-Rye recombinant										
Selection 212	;	12^{-}	;	;	$;1^{=}$	$;^{-}$	;	$12^{=}$	$12^{=}$	0;
Parental lines										
Rye	;	1^{-}	;	1	;	1	1	;	;	0;
Sonalika	$;1^{-}$	$12^{=}$	1^{-}	$12^{=}$	$;1^{=}$	$;1^{-}$	$;1^{-}$	33^{+}	3	;
Chinese Spring	4	3^{+}	3^{+}	4	4	4	3^{+}	4	3^{+}	4
Susceptible line										
Agra Local	33^{+}	3^{+}	33^{+}	3^{+}	4	33^{+}	3^{+}	4	33^{+}	4
Differentials										
Set A										
Mq-*Sr13*	3^{+}	33^{+}	;	33^{+}	23^{C}	3^{+}	;1	;1	$;1^{-}$	4
Mq-*Sr9b*	4	4	1	1	3^{-}	3^{+}	4	4	3^{+}	4
Mq-*Sr11*	4	12^{-}	$;1^{-}$	;1	$;1^{-}$	;	;1	4	3^{+}	1
Mq-*Sr28*	4	4	;	33^{+}	33^{+}	4	4	4	33^{+}	1^{+}
Mq-*Sr8a*	12^{-}	12^{-}	33^{+}	2	4	2	2	3^{+}	4	4
Vernstein (*Sr9e*)	3^{+}	;	;	0;	0;	$12^{=}$	$12^{=}$	3^{+}	4	;
Webster (*Sr30*)	2^{-}	3^{+}	1	$2^{-}2$	23^{C}	4	2	1	12^{-}	12^{-}
Line W (*Sr37*)	$;1^{-}$	33^{+}	;	$;1^{=}$	;1	;1	$;1^{-}$	$;1^{-}$	$;1^{+}$	$;1^{-}$
Set B										
Marquis (*Sr7b,18,19,20*)	3^{+}	33^{+}	2^{+C}	4	4	3^{+}	4	3^{+}	3^{+}	4
Einkorn (*Sr21*)	3^{+}	3^{+}	3^{+}	$;1^{=}$	0;	;	$;1^{-}$	0;	;	4–
Kota (*Sr7b,19,28*)	4	3^{+}	0;	33+	33+	4	4	3+	3^{+}	1
Reliance (*Sr5,16,18,20*)	4	4	0;	0;	;	0;	4	3^{+}	3^{+}	0;
Charter (*Sr11*$^{+}$)	33^{+}	;1	;	$;1^{-}$	;1	;1	;1	3^{+}	4	1
Khapli (*Sr7a,13,14*)	;1	12^{-}	;	$12^{=}$	;	;1	;1	0;	;	4
Other lines										
WRT238-5 (*Sr27*)	;	;	0;	0;	;	;	;	;	;	0;
Kavkaz (*Sr31*)	0;	;	0;	0;	;	0;	0;	;	;	0;

Host line/ Pathotype	SEEDLING INFECTION TYPES										ADULT PLANT RESPONSE
	117 37G3	117A 36G2	117A-1 38G18	117-1 166G2	117-3 167G3	117-4 166G3	117-5 166G2-2	122 7G11	184 53G1	295 7G43	40A 62G29
Wheat-Rye recombinant											
Selection 212	12^{-}	$12^{=}$	$12^{=}$	$12^{=}$	;	12^{-N}	12^{-}	1^{+}	12^{-}	;$12^{=}$	TR
Parental lines											
Rye	$12^{=}$	$12^{=}$	1	$12^{=}$	$12^{=}$	1^{+}	1	;1^{-}	;1^{-}	;1^{-}	0
Sonalika	12^{-}	$12^{=}$	;	12^{-}	1	123^{-}	$12^{=}$	33^{+}	$2^{+}3^{-}$	$2^{+}3^{-}$	60MS
Chinese Spring	3^{+}	3^{+}	4	3^{+}	4	4	3^{+}	4	3^{+}	3^{+}	80S
Susceptible line											
Agra Local	3^{+}	33^{+}	3^{+}	33^{+}	3^{+}	4	3^{+}	4	3^{+}	4	90S
Differentials											
Set A											
Mq-*Sr13*	33^{+}	2^{+}	$2^{+}3^{-}$	$2^{+}3^{-}$	4	23^{-}	23^{c}	3^{+}	33^{+}	3^{+}	NG
Mq-*Sr9b*	$23^{=}$	1	33^{+}	33^{+}	3^{+}	33^{+}	3^{+}	33^{+}	23	3^{+}	80S
Mq-*Sr11*	3^{+}	3^{+}	33^{+}	33^{+}	4	3^{+}	4	33^{+}	4	3^{+}	80S
Mq-*Sr28*	;	;	;	;	;	;	;$^{-}$	1^{-}	;1^{-}	1^{-}	70S
Mq-*Sr8a*	12	1^{+}	12	12	12^{-}	1^{+}	12^{+}	12	4	12	70S
Vernstein (*Sr9e*)	4	4	4	4	4	33^{+}	3^{+}	$12^{=}$	4	;$12^{=}$	70S
Webster (*Sr30*)	12^{-}	;1	23^{-c}	23^{-c}	2+c	12	23^{-c}	2	2^{+}	23–	10R
Line W (*Sr37*)	;1^{-}	;1	;1^{-}	4	4	3^{+}	4	;1	;1^{-}	;1^{+}	20MRMS
Set B											
Marquis (*Sr7b,18,19,20*)	33^{+}	2^{+}	2^{+}	2^{+}	3^{+}	33^{+}	$2^{+}3$	33^{+}	4	4	70S
Einkorn (*Sr21*)	4	3	3^{+}	3^{+}	3^{+}	3^{+}	33^{+}	33^{+}	;$1^{=}$	3^{+}	10MR
Kota (*Sr7b,19,28*)	;	0;	;	;	;	;	;	;	;	;	70S
Reliance (*Sr5,16,18,20*)	0;	0;	0;	0;	0;	0;	0;	33^{+}	0;	33^{+}	80S
Charter (*Sr11*$^{+}$)	$2^{=}$	1	33^{+}	;1^{+}	;1	;1	2^{+}	;$12^{=}$	;12^{-}	;1^{+}	90S
Khapli (*Sr7a,13,14*)	12^{-}	1	1^{+}	1^{+}	1	;1^{+}	1	;1	;12^{-}	33^{+}	20R
Other lines											
WRT238-5 (*Sr27*)	0;	;	0;	;	;	0;	;	0;	;	;	TR
Kavkaz (*Sr31*)	;	0;	;	;	;	0;	;	;	;	;	5MR

The lines Sel.212, Sonalika and Agra local were tested individually with pathotypes 12-2, 77-1, 77-2, 77-3, 77-4 and 77- 5 of *P. recondita tritici* at four temperature regimes (Table 2). Agra local was found susceptible to all the pathotypes at all the four temperature regimes. Sonalika showed susceptible reaction to group 77 pathotypes at four temperatures. Resistant reaction to pathotype 12-2 at higher temperatures in Sonalika can be attributed to expression of temperature sensitive gene *Lr13* [13]. Resistance in Sel.212 was observed to be temperature sensitive to pathotypes 77-1, 77-2, 77-3, 77-4 and 77-5 conferring gradual increase in the degree of resistance with the increase in temperature. Resistance of Sel.212 to 12-2, however, was not influenced by the temperature, IT ';' was observed at all four temperature regimes. Temperature sensitivity of non-alien leaf and stem rust resistance genes, *Lr13, Lr17, Sr17, Sr30* were reported by Dyck and Johnson [13], Roelfs and McVey [14]. Though most of the resistance genes of alien origin are stable to environmental fluctuations, a few were reported to be temperature sensitive such as *Lr18* (Source : *T. timopheevi*) becomes ineffective at 25°C [13], *Lr37* in *T. ventricosum* is more effective at low temperatures and gives best expression at 17°C.

All these materials were also tested with 20 pathotypes of *P. graminis tritici* (Table 3) at seedling stage. Sel.212 was resistant to all the 20 pathotypes with infection types ranging ';' to '12^{-}'. Sonalika was susceptible to pathotypes 40A and 122 and showed resistance to other 18 pathotypes (ITs ';' - '$2^{+}3$'). The rye strain was resistant to all pathotypes (ITs '0;' - '$12^{=}$'). All the lines in differential sets produced standard reactions and thus the possibility of urediospores impurity is ruled out. Lines WRT 238-5 (*Sr27*) and Kavkaz (*Sr31*) that carry two of the known rye genes were resistant to all the pathotypes (ITs '0;' - ';').

The comparison of infection type pattern for Sel.212 and the lines carrying single gene revealed that resistance in Sel.212 is different from known stem rust resistance genes. Additional resistance to pathotypes 40A and 122 in Sel.212 to which Sonalika is susceptible accounts for resistance derived from rye. Therefore, pathotypes 40A and 122 were selected for further genetic and cytogenetic analysis of Sel.212. Among the parental lines of Sel.212, the rye strain is the carrier of unknown gene(s) for stem rust resistance and Sonalika has stem rust resistance gene *Sr11* [16, 17].

The pathotype 40A being most virulent, was used for field tests. Adult plant response to infection with 40A was highly resistant (5R) for Sel. 212 and immune (O) for rye strain. Sonalika, however, showed 60MS infection response. This level of adult plant resistance in Sonalika was attributed to an adult plant resistance gene *Sr2* reported in Sonalika [18, 19]. Chinese Spring was highly susceptible (90S). The two lines WRT 238-5 and Kavkaz carrying known rye genes *Sr27* and *Sr31* respectively expressed resistant response.

The inheritance and chromosome location of these leaf and stem rust resistance genes will be reported in subsequent papers.

REFERENCES

1. D. Singh. 1991. Wheat rye recombinant, resistance to all three rusts of wheat. Ann. Wheat Newsl., 37: 68.

2. D. Singh. 1993. Gene(s) for rust and powdery mildew resistance in wheat-rye recombinant. Ann. Wheat Newsl., **39**: 176.

3. L. M. Joshi, D. V. Singh and K. D. Srivastava. 1988. Manual of Wheat Diseases. Malhotra Publishing House, New Delhi: pp 75.

4. E. C. Stakman, D. M. Stewart and W. Q. Loegering. 1962. Identification of physiological races of *Puccinia graminis* var. *tritici*. USDA, Agric. Res. Serv. E 617 (Rev.): pp 53.

5. R. F. Peterson, A. B. Campbell and A. E. Hannah. 1948. A diagrammatic scale for estimating rust intensity on leaves and stems of cereals. Can J. Res., **26**: 496-500.

6. D. Bai and D. R. Knott. 1992. Suppression of rust resistance in bread wheat *Triticum aestivum* by D-genome chromosomes. Genome., **35**: 276-282.

7. P. L. Dyck. 1987. The association of a gene for leaf rust resistance with the chromosome 7D suppresser of stem rust resistance in common wheat. Genome, **29**: 467-469.

8. S. Rajaram, R. P. Singh and E. Torres. 1988. Current CIMMYT approaches in breeding wheat for rust resistance. *In*: Breeding strategies for resistance to the rusts of wheat (eds. N.W. Simmonds and S. Rajaram). Mexico: 101-108.

9. R. A. McIntosh, C. R. Wellings and R. F. Park. 1995. Wheat Rusts: An atlas of resistance genes, CSIRO, Australia : pp 200.

10. R. P. Singh and R. A. McIntosh. 1984. Complementary genes for resistance to *Puccinia recondita Tritici* in *triticum aestivum*. II. Cytogenetic studies. Can. J. Genet. Cytol., **26**: 736-742.

11. R. A. McIntosh, G. E. Hart and M. D. Gale. 1995. Catalogue of gene symbols of wheat. Proc. 8th Intl. wheat Genet. Symp., Beijing, China: 1333-1500.

12. P. L. Dyck. 1991. Genetics of leaf rust resistance in 'Chinese Spring' and 'Sturdy' cultivars. Crop Sci., **31**: 309-311.

13. P. L. Dyck and R. Johnson. 1983. Temperature sensitivity of genes for resistance in wheat to *Puccinia recondita*. Can. J. Plant Pathol., **5**: 229-234.

14. A. P. Roelfs and D. V. McVey. 1979. Low infection types produced by *Puccinia graminis* f. sp. *tritici* and wheat lines with designated genes for resistance. Phytopathol., **69**: 722-730.

15. H. S. Bariana and R. A. McIntosh. 1993. Cytogenetic studies in wheat. XV. Location of rust resistance genes in VPM 1 and their genetic linkage with other disease resistance genes in chromosone 2A. Genome., **36**: 476-482.

16. R. G. Saini. 1988. research report : Genetics and breeding for rust resistance in wheat. Plant Breed. Inst., Univ. Sydney, Australia: pp 53.

17. P. Bahadur, K. D. Srivastava, D. V. Singh and J. B. Sharma. 1993. Postulation of genes for stem rust resistance in Indian wheats. Cereal Rusts and Powdery Mildew Bull., **21**: 3-9.

18. R. A. McIntosh. 1988. The role of specific genes in breeding for durable stem rust resistance in wheat and triticale. *In*: Breeding strategies for resistance to rusts of wheat. (eds. N.W. Simmonds and S. Rajaram). CIMMYT, Mexico : 1-9.

19. A. P. Roelfs. 1988. Resistance to leaf and stem rusts in wheats. *In*: Breeding strategies for resistance to rusts of wheat (eds. N.W. Simmonds and S. Rajaram). CIMMYT, Mexico : 10-22.