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Erratum

Volume 17, Part 2 (1989).

Pages 49 and 56.

'Kernel bunt' should read 'Karnal bunt'.

Cereal Rusts and
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OCCURRENCE AND EPIDEMICS OF YELLOW RUST OF WHEAT IN ITALY

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INTRODUCTION

Wheat yellow rust (*Puccinia striiformis* West.) is generally considered less important in Italy than are brown rust and black rust. It is usually more common in Northern Italy and in mountainous areas, nevertheless it is also present in Central and Southern Italy, including Sardinia and Sicily (Montemartini, 1933; Govi, 1978; Vallega and Zitelli, 1979).

In the past, yellow rust epidemics have occurred in several countries of the Mediterranean basin; Portugal in 1957, 1960 (Zadoks 1965), Spain in 1957, 1960, 1978 (Zadoks, 1965; Nagarajan *et al*., 1984); Egypt in 1958 (Hassebrauk, 1959), Turkey in 1969 (Dutlu and Prescott, 1976).

During the past fifty years occurrence and epidemics of *P.striiformis* have been frequently reported in several Italian localities (Table 1).

The most damaging recent epidemic was recorded in 1977 in Umbria, a region of Central Italy, where it was particularly severe on the bread wheat variety Irnerio (Marte and Zazzerini, 1979; Montalbini *et al*., 1977; Monotti and Raggi, 1978). This epidemic was associated with a widespread infection on wheat crops in Western Mediterranean basin in 1977 and 1978 (Nagarajan *et al*., 1984).

In the last four years (1984-88) observations have been carried out on a trial including both *durum* and bread wheat varieties in a hilly locality in Umbria (Porano, Terni); the aim was to verify the occurrence and severity of yellow rust in an environment favourable to this pathogen.

MATERIAL AND METHODS

The trial included 25 bread wheat varieties and 18 *durum* wheat varieties distributed in randomised blocks with three replications; each plot measured 10 m^2; severity was evaluated as the percentage of infected leaf area, according to the Cobb's modified scale.

RESULTS AND DISCUSSION

A high level of infection was recorded in 1984-85; in 1985-86 traces of the disease were found only on the susceptible variety Irnerio, while in the following two years no infection was recorded. In 1984-85 (Table 2) bread wheat varieties were more severely attacked than *durum* wheats, especially Centauro, Concordia, Costantino, Gallo, Irnerio, Lario, Leopardo, Orso, Valle D'Oro. Durum wheat varieties confirmed their higher level of resistance (Vallega and Zitelli, 1979).

The conditions favourable to the development of the epidemic of 1984-85 may have included the unusual mild and rainy summer of 1984 that probably promoted the build up of inoculum. Similar conditions occurred during the summer preceding the epidemic of 1977 (Montalbini et al., 1977). Also, in 1984-85 there was cold and rainy weather during the wheat growing season. This was characterised by the occurrence of snow in January that could have protected the uredospores against the frost and by temperature and humidity suitable for the development of yellow rust during the spring.

During 1985-86, characterised by hot and dry summer, warm and relatively dry spring, as well as the following two years, the conditions were not conducive for the build up of the inoculum and yellow rust development.

CONCLUSIONS

Several factors may influence the occurrence of yellow rust epidemics; the minimum requirements are a susceptible host, a compatible rust race, suitable weather and the occurrence of primary inoculum (Nagarajan et al., 1984; Rapilly, 1979). In the Italian environments these conditions rarely occur together, but epidemics in the past and in the first year of observation show that, under suitable conditions, the attack can be severe and cause considerable losses, so that this disease could be considered potentially damaging as demonstrated by the occurrence and frequency of epidemics (Table 1).

Italian varieties, especially of bread wheat, have often been demonstrated to have inadequate resistance. During breeding programmes more emphasis should be given to achieving a sufficient level of resistance to yellow rust as well as other diseases. More information is also needed about possible sources of resistance and the virulence factors of the populations of yellow rust present in Italy.

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Table 1 Occurrence of yellow rust of wheat in Italy (1925-1987)

Year	Locality	Notes	Reference
1925-27	Apulia	Occurrence in 1925/26. Epidemic in 1927 with conditions of low temperature, high humidity of the air and soil and cloudy sky during March and April	Potenza, 1929
1926	Various	Presence on almost all the samples observed	Petri, 1927
1928	Perugia	Epidemic in a site particularly attacked every year for the high atmospheric humidity	Rivera and Corneli, 1929
1929	Rome	Occurrence on ears in June	Mencacci, 1929
1933	Sicily	Occurrence in sea-boards with warm weather and stagnant humidity	Montemartini, 1933
1935	Not given	Occurrence caused by the low temperature during the spring	Petri, 1936
1954	Rome Viterbo Rieti Frosinone Ancona	Occurrence in Central Italy	Sibilia, 1955
1959	Viterbo	Sample with a high level of attack, collected in a hilly site	Sibilia, 1959
1977	Umbria	Severe epidemic	Montalbini et al., 1977
1977	Lonigo (VI) Ozzano (BO) Deruta (PG) Rieti Foggia Cagliari Sassari S.Gabriele (BO) Medicina (BO)	Observed on nurseries; high level of infection on bread wheat	Govi, 1978

Table 1 (Continued)

1977-78	Lonigo (VI) Badia P (RO) Ozzano (BO) Medicina (BO) Perugia S.Gabriele (BO) Senigallia (AN) S.Pietro (BO)	Observed on nurseries; yellow rust more frequent during 1977 and 1978	Govi and Innocenti, 1981
1976-78	Roma Foggia Leonessa (RI) Cagliari Sassari	Observed on nurseries; epidemic in 1977 and 1978 especially on bread wheat	Vallega and Zitelli, 1979
1978-79	Cagliari Rieti	Observed on nurseries, especially on bread wheat	Basile *et al.*, 1979
1979-80	Sparacia (AG) Roma	Observed on nurseries, especially on bread wheat	Zitelli *et al.*, 1981
1979-81	Gravina (BA) Foggia Sibari (CS)	Observed on nurseries, especially on bread wheat in 1979-80	Siniscalco *et al.*, 1981
1981-82	Rieti Monterotondo (RM)	Observed on nurseries; low infection on bread wheat	Zitelli *et al.*, 1982
1982-83	Rieti Roma Leonessa (RI) Montelibretti (RI)	Observed on nurseries; low infection on bread wheat	Zitelli *et al.*, 1983
1983-84	Roma Rieti Leonessa (RI) Monterotondo (RM) Montelibretti (RI) Caltagirone (CT)	Observed on nurseries; low infection on bread wheat	Zitelli *et al.*, 1984
1983-84	Latina Frosinone Rieti Roma Potenza	Observed on nurseries; low infection on both bread and *durum* wheat	Corazza and Basile, 1985
1984-85	Roma Leonessa (RI) Monterotondo (RM) Montelibretti (RI)	Observed in nurseries on bread wheat	Zitelli *et al.*, 1985

Table 1 (Continued)

1985	Porano (TR)	Observed on nurseries on bread wheat and *Triticum dicoccum*	Corazza *et al*., 1986
1985-86	Leonessa (RI) Rieti	Observed on nurseries on bread wheat	Pasquini *et al*., 1986

Table 2 Field reaction (DA) to *P. striiformis* West. of several bread and *durum* wheat varieties in 1984-85 (Porano, Italy)

Bread wheat	DA	*Durum* wheat	DA
Adria	40	Aldura	5
Aurelio	20	Appio	0
Centauro	70	Castello	0
Chiarano	30	Chandur	0
Concordia	70	Duilio	0
Costantino	80	Karel	0
Etruria	30	Febo	0
Gallo	80	Gabbiano	5
Gemini	60	Iapigia	0
Gladio	40	Latino	0
Granarolo	10	Piceno	0
Irnerio	70	Produra	20
Lario	70	Quadruro	0
Leopardo	70	Rodeo	5
Livio	10	S.Pietro	0
Loreto	60	Valforte	0
Manital	50	Valgerardo	0
Mec	10	Vezio	0
Oderzo	5		
Orso	70		
Pandas	30		
Saliente	10		
Salmone	30		

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GENETIC DIVERSITY FOR STEM RUST RESISTANCE IN *TRITICUM AESTIVUM* L.

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ABSTRACT

Two to four genes were observed to condition the seedling resistance in six *aestivum* wheats, *viz* CPAN 1885, CPAN 1922, CPAN 1929, CPAN 1933, HW 517 and CC 505, to two Indian stem rust pathotypes, 21A-1 and 40. Dominance reversal was indicated in few R x s crosses involving Pissi Local as the susceptible parent. Allelic tests showed the presence of *Sr 5*, *Sr 8a*, *Sr 11* and *Sr 30*, either singly or in combinations. *Sr 31* has earlier been postulated in CPAN 1922 on the basis of the IT matching technique. Besides the above designated genes, the presence of additional genes for resistance to the two test pathotypes was apparent from the multiplicity of the genes involved. At least seven diverse factors for race 40 and at least ten diverse factors for race 21A-1 were indicated to be operative among the wheats studied. Thus the reported resistance being reasonably broad-based and diversified merits its planned utilisation in the breeding programmes.

INTRODUCTION

Breeding for multiple major gene resistance has been the principal strategy for combating the wheat rust pathogens. While wheats showing the low ACI (average coefficient of infection) values in the multilocation tests generally possess multiple genes for resistance, information regarding the nature of the gene action involved and their allelic relationships is essential for judicious pyramiding of the diverse genes in order to improve the durability of the resistance. The present paper attempts to generate such information in regard of resistance in six *aestivum* wheats to two of the prevalent and virulent Indian stem rust pathotypes.

MATERIALS AND METHODS

Six *aestivum* wheats, *viz*, CPAN Nos. 1885, 1922, 1929 and 1933; HW 517 and CC 505, showing stem rust resistance in the multilocational tests since 1979 and two susceptible wheats, NP-4 and Pissi Local, were used in the study. Their particulars are listed in Table-1. Crosses were attempted between resistant and susceptible wheats (RxS); between resistant wheats and the stocks carrying separately *Sr5*, *SR8a*, *Sr11* and *Sr30* genes (Rx*Sr*); and among the resistant parents in all combinations (RxR) without reciprocals. F1, F2 and F3 progenies were subsequently raised.

*Retired Wheat Breeder

The parental stocks were seedling tested with 15 different stem rust pathotypes of Indian origin. The F2 progenies from RxS as well as RxSr crosses and F3 lines from RxR crosses were seedling studied with two Indian stem rust cultures, 21A-1 and 40. The tests were conducted in a glass house at temperatures ranging between 11°C to 30°C. However, the temperatures remained in the range of 15°C to 25°C for a minimum of 18 hours a day during the test period. Standard procedures for inoculation of seedlings and recording of reactions were followed (Stakman et al, 1962). Nucleus inoculum of the test pathotypes was obtained from IARI, Regional Station, Flowerdale, Simla, India.

Chi-square method was used for testing the goodness of fit of the observed F2/F3 ratios.

The studies were conducted during 1983 to 1988.

RESULTS AND DISCUSSION

The six resistant wheats under study showed low infection types (IT '0' to '2') to all the 15 stem rust pathotypes tested, viz, 11A, 14, 15, 21A-1, 24, 24A, 34, 40, 40A, 42B, 117A, 117A-1, 122, 184 and 295. Hence, no inferences could be drawn from the above tests in regard of their probable genotypes or the genetic diversity, if any, for stem rust resistance among these wheats.

Segregating F_2 ratios involving RxS crosses indicated that three to four genes conditioned the seedling resistance to the two test pathotypes, with the exception of CPAN 1929, in which a digenic control of resistance to race 40 was observed (Table-2).

Dominance reversal was observed in CPAN 1922 and HW 517 for race 21A-1 and in CPAN 1929 against race 40 when Pissi Local was involved as the susceptible parent in their crosses. Moreover, the 'p' values indicated that this phenomenon may also be operative in the crosses of CPAN 1933 and CC 505 with Pissi Local for the race 21A-1 and for both the test pathotypes respectively (Table-2). In an earlier study both Sr 8 and Sr 11 were observed to behave as recessive genes when their carrier stocks were crossed with Kharchia as the susceptible parent (Gandhi, 1967).

Likewise in the cross of resistant 'E 5883' with susceptible wheat PbC 591, Sr 8 behaved as a recessive gene against stem rust race 122 (Sawhney et al, 1979). It appears that the above susceptible wheats possess certain modifying factor(s) which render the specific genes recessive in action when brought into their background.

It was observed that among the Sr genes derived from *Triticum aestivum*, only Sr 5 and Sr 30 were resistant to race 21A-1 while Sr11 alone showed effectiveness to race 40 (Sawhney and Goel, 1981). Our tests confirmed the above observations except that Sr 8a (Mentana) too was effective to the culture of race 40 used in the present study (Mishra, unpublished data). The involvement of any alien genes is ruled out from the pedigree of these wheats but for CPAN 1922 which has Fundulea (carrying Sr 31) in its pedigree. Moreover Sr 5, Sr 6, Sr 8a, Sr 9b and Sr 11 were observed to be the most common stem rust resistance genes in the Indian breeding programme (Sawhney and Goel, 1981). Crosses were, therefore, attempted between the resistant parents and the wheat stocks carrying separately Sr 5, Sr 8a, Sr 11 and Sr 30 genes. F2 progenies from the crosses involving Sr 5 and Sr 30 were tested with race 21A-1 whereas those involving Sr 8a and Sr 11 were tested with race 40. While a uniformly resistant F2 population suggested the presence of the specific Sr gene in the respective stock, the occurrence of susceptible segregants pointed to its absence. Accordingly, the observations from the above tests revealed the presence of Sr 8a in CPAN 1885; Sr 11 in CPAN 1933; Sr 5 + Sr 11 in CPAN 1922; Sr 8a + Sr 11 in HW 517; Sr 11 + Sr 30 in CC 505; and Sr 5 + Sr 8a + Sr 30 in CPAN 1929 (Tables 3A and 3B).

Earlier studies using IT matching technique suggested the presence of Sr 31 in CPAN 1922 based on the postulation that Lr 26 is tightly linked with Yr 9 and Sr 31. (Nagarajan et al, 1987). Moreover, Kohinoor-83, a Pakistani cultivar, having originated from the same cross as 'CPAN 1922', has also been reported possessing Lr 26 (Hussain et al, 1989).

Besides the above designated genes, the presence of additional genes for resistance to the two test pathotypes was apparent from the multiplicity of the genes involved as indicated earlier (Table 2).

From a close perusal of the pedigrees of the above wheats, it appears that while Sr 8a in CPAN 1885 might have been derived from Era through Frontana (A. P. Roelfs, personal communication), the source of Sr 11 in CPAN 1933 and CC 505 could be Sonora 64. The latter is one of the parents of CPAN 1933 and is involved in the parentage of Correcaminos, Calidad and Saric F 70 (= Bluebird), the three parental stocks of CC 505. The source of Sr 30 in CC 505 was not clear from its pedigree. In CPAN 1929, while Sr 5 could have been donated by Zopilote through Son 64, Sr 8a and possibly Sr 30 appear to have come from Jupateco 73/Cocoraque 75 through Norteno 67 (=Inia 66'S') since the presence of Sr 30 is suspected in some CIMMYT produced wheats like Inia 66, Pavon and Cheel (McIntosh, 1988). While Sr 11 in CPAN 1922 appears to have been derived from Cocoraque 75 through 8156, the source of Sr 5 was not clear from the pedigree. Both Sr 8a and Sr 11 in HW 517 could have been contributed by Noroeste 66 (=Inia 66'S') and/or Sr 8a might have come from Pitic 62 and Sr 11 from Bluebird, Ciano or Correcaminos through Son 64.

As mentioned earlier, Sr 31 in CPAN 1922 would obviously have been donated by Fundulea, a Romanian wheat carrying Sr 31.

The above references with regard to the presence of different Sr genes in the various stocks under discussion, unless otherwise indicated, were mostly based on the information compiled by Nagarajan et al, 1987.

In an earlier study, Sonora 64 was found to possess possibly five or more genes for seedling resistance to stem rust races 21 and 21A-1 (Jha, 1970) which may account for the observed broad-based resistance as most of these wheats are having Son 64 in their pedigree as discussed above.

The F_3 segregation established that the genes were not common among the following RxR crosses for resistance to the two test pathotypes as listed below (Tables 4A and 4B).

Observed diversity for race 21A-1	Observed diversity for race 40
CPAN 1885/CPAN 1922	CPAN 1885/CPAN 1922
CPAN 1885/CPAN 1929	CPAN 1929/CPAN 1933
CPAN 1885/HW 517	
CPAN 1922/CC 505	
CPAN 1929/CPAN 1933	
CPAN 1933/HW 517	
HW 517/CC505	

More than the expected number of segregating lines observed in the cross HW 517/CC 505 for race 21A-1 and in both the above segregating crosses for race 40 could not be explained. However, the non-allelic relationship of the genes involved was evident from the observed segregants.

Furthermore, with the exception of the F3 tests with race 40 of CPAN 1922/CPAN 1929, the possible diversity for resistance can not be ruled out in the other non-segregating RxR crosses, with·none of the known genes common, because of inadequate number of lines studied (Tables 4A and 4B).

Thus, even at a conservative estimate based on the above information, at least seven diverse factors including Sr 8a, Sr 11 and Sr 31 for race 40 and at least ten diverse factors including Sr 5, Sr 30 and Sr 31 for race 21A-1 were indicated to be operative among the wheats studied. (Table 5). Further studies on the race relationship are required to find out which gene(s) other than Sr 31 were common for the two races. An earlier study indicated the presence of seven new non-allelic genes besides Sr 5, Sr 8 and Sr 11 among eight donors of resistance viz 'E' Nos. 4849, 5535 and 5550; Raj 848, HD 2028, Tr 373, Safed Lerma and Timgalen, when tested with stem rust races 21 and 40 (Nathawat et al, 1978). In another study, eleven diverse factors were identified among eight different resistant stocks viz 'HD Nos. 2009, 2177 and 2189; HW 142, WH 169, TZpp MJI and E 8643 against stem rust race 40 (Kaushal, 1982).

Thus, the stem rust resistance under report being reasonably broad-based and diversified merits its planned utilisation in the breeding programmes. Moreover, four of the six wheats studied, viz, CPAN Nos 1885, 1922, 1929 and 1933 showed adult plant resistance to leaf and stripe rusts also. Additional resistance to powdery mildew and/or leaf blight was also observed in the above lines (Agrawal, 1986). These wheats, therefore, hold promise as sources of multiple disease resistance.

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Table 1. Particulars of the wheat stocks under study

S.No.	Wheat stock	Source	Origin	Parentage/pedigree*
1.	CPAN 1885	NGSN 7/81	Minnesota (ISWRN 48/77)	ERA/CHR MUT. (ECM 403)
2.	CPAN 1922	NGSN 13/81	Mexico (IBWSN 383/78)	ORE F_1 158/FDL// MFO"S"/2*TIBA/3/ COC(CM 37987)
3.	CPAN 1929	NGSN 14/81	Mexico (BWELN 53/78)	JUP/ZP"S"//COC (CM 37614)
4.	CPAN 1933	NGSN 15/81	Mexico (BWELN 16/78)	PATO/3/SON 64/PDUE// CNO/INIA 66/4/HD832/BB
5.	HW 517	NGSN 9/81	India	BB/CC/3/CNO"S"//NO/PI
6.	CC 505	NGSN 10/81	Mexico	CC/CAL//SR(CM 10630)
7.	NP-4	Germplasm, IARI, Reg. Station, Indore	India	Selection over local 'Mundia'
8.	Pissi Local	Germplasm, IARI, Reg. Station, Indore	India	Not known

* Parentage/Pedigree coding refer Villareal and Rajaram, 1988
CPAN = Co-ordinated Project Accession Number (New Delhi, India)
HW = Hybrid Wellington (India) CC = Co-ordinating Centre (N. Delhi, India)
NP = New Pusa (IARI, New Delhi, India)
NGSN = National Genetic Stock Nursery (All India Co-ordinated, Wheat Improvement Project)
ISWRN = International Spring Wheat Rust Nursery
IBWSN = International Bread Wheat Screening Nursery
BWELN = Bread Wheat Elite Lines Nursery

Table 2. Segregation of F_2 seedlings from RxS crosses when tested with stem rust races 21A-1 and 40

S.No.	Cross	Tests with race 21A-1				Tests with race 40			
		No of seedlings		Expected ratio (R:S)	P value	No of seedlings		Expected ratio (R:S)	P value
		R	S			R	S		
1.	CPAN 1885/NP-4	162	1	63:1	0.5-0.3	163	2	63:1	0.9-0.7
2.	CPAN 1885/PL*	194	3	63:1	0.98-0.95	422	2	63:1	0.1-0.05
3.	CPAN 1922/NP-4	203	-	255:1	0.5-0.3	333	9	63:1	0.2-0.1
4.	CPAN 1922/PL	247	9	247.9	1.00	408	10	63:1	0.2-0.1
5.	CPAN 1929/NP-4	268	5	63:1	0.8-0.7	250	18	15:1	0.8-0.7
6.	CPAN 1929/PL	221	1	63:1	0.2-0.1	209	38	13:3	0.2-0.1
7.	CPAN 1933/NP-4	261	7	63:1 or 61:3	0.2-0.1 0.2-0.1	279	1	255:1	0.95-0.9
8.	CPAN 1933/PL	140	7	61:3	0.98-0.95	324	-	255:1	0.3-0.2
9.	HW 517/NP-4	173	1	63:1	0.3-0.2	327	11	61:3	0.3-0.2
10.	HW 517/PL	146	18	55:9	0.3-0.2	297	13	61:3	0.7-0.5
11.	CC 505/NP-4	169	1	63:1	0.5-0.3	339	-	255:1	0.3-0.2
12.	CC 505/PL	211	7	63:1 or 61:3	0.1-0.05 0.5-0.3	385	3	255:1 253:3	0.3-0.2 0.5-0.3

*PL = Pissi Local wheat

Table 3A. Segregation of F_2 seedlings from R x *Sr* crosses when tested with stem rust race 21A-1

S.No.	'R' Stock	'R'/*Sr 5* Reliance No of seedlings R	Int.	S	Expected ratio (R:S)	P value	'R'/*Sr 30* Festiguay No of seedlings R	Int.	S	Expected ratio (R:S)	P value
1.	CPAN 1885	1285	-	3	255:1	0.5-0.3	1226	9	8	255:1	0.2-0.1
2.	CPAN 1922	1564	-	-	No Seg.	-	1449	7	3	1023:1	0.2-0.1
3.	CPAN 1929	1431	-	-	No Seg.	-	1105	2	-	No Seg.	-
4.	CPAN 1933	1455	3	4	255:1	0.5-0.3	1518	4	11	255:1	0.05-0.02
5.	HW 517	1529	5	7	255:1	0.7-0.5	1261	17	4	255:1	0.7-0.5
6.	CC 505	1182	1	4	255:1	0.9-0.7	1342	5	-	No Seg.	-

Infection types '0' to '2' classified as 'R', '2+' to '3C' as 'Int', '3' and '4' as 'S'

Intermediate ('Int') ones merged with Resistant ('R') class.

Table 3B. Segregation of F_2 seedlings from R x *Sr* crosses when tested with stem rust race 40

	'R' Stock	'R'/*Sr* *8a* Mentana					'R'/*Sr* *11* Gabo				
		No of seedlings			Expected ratio (R:S)	P value	No of seedlings			Expected ratio (R:S)	P value
		R	Int.	S			R	Int.	S		
1.	CPAN 1885	1206	–	–	No Seg	–	1105	2	2	255:1	0.3-0.2
2.	CPAN 1922	1354	3	8	255:1	0.3-0.2	1454	–	–	No Seg	–
3.	CPAN 1929	1173	–	–	No Seg	–	1518	21	30	63:1	0.3-0.2
4.	CPAN 1933	1430	2	2	1023:1	0.7-0.5	1237	–	–	No Seg	–
5.	HW 517	1229	–	–	No Seg	–	1321	–	–	No Seg	–
6.	CC 505	1142	4	1	1023:1	0.95-0.9	1507	–	–	No Seg	–

1T '0' to '2' classified as 'R'; '2+' to '3C' as 'Int'; '3' and '4' as 'S'

Intermediate ('Int') ones merged with the Resistant ('R') class.

Table 4A. Segregation of F_3 lines from RxR crosses when tested with stem rust race 21A-1

S.No	Crosses	No of lines R	Seg	S	Expected ratio (R:Seg*:S)	P value	Remarks
1.	CPAN 1885/CPAN 1922	106	2	-	16285:98:1	0.3-0.2	Genes diverse
2.	CPAN 1885/CPAN 1929	117	1	-	4023:72:1	0.9-0.7	Genes diverse
3.	CPAN 1885/CPAN 1933	115	-	-	4023:72:1	0.5-0.3	IPS**
4.	CPAN 1885/HW 517	104	2	-	4023:72:1	0.98-0.95	Genes diverse
5.	CPAN 1885/CC 505	94	-	-	4023:72:1	0.5-0.3	IPS
6.	CPAN 1922/CPAN 1929	125	-	-	-	-	_Sr_ _5_ Common
7.	CPAN 1922/CPAN 1933	98	-	-	16285:98:1	0.9-0.7	IPS
8.	CPAN 1922/HW 517	118	-	-	16285:98:1	0.7-0.5	IPS
9.	CPAN 1922/CC 505	101	1	-	16285:98:1	0.9-0.7	Genes diverse
10.	CPAN 1929/CPAN 1933	105	1	-	4023:72:1	0.9-0.7	Genes diverse
11.	CPAN 1929/HW 517	95	-	-	4023:72:1	0.5-0.3	IPS
12.	CPAN 1929/CC 505	120	-	-	-	-	_Sr_ _30_ Common
13.	CPAN 1933/HW 517	89	1	-	4023:72:1	0.9-0.7	Genes diverse
14.	CPAN 1933/CC 505	99	-	-	4023:72:1	0.5-0.3	IPS
15.	HW 517/CC 505	85	7	-	4023:72:1	<0.001	Genes diverse***

* Lines segregating with 1/16 or more'S' plants only considered.

** Inadequate population size studied, gene(s) may or may not be common.

***No. of segretating lines more than the expected.

Table 4B. Segregation of F_3 lines from RxR crosses when tested with stem rust race 40

S.No	Crosses	No of lines R	Seg	S	Expected ratio (R:Seg*:S)	P value	Remarks
1.	CPAN 1885/CPAN 1922	94	14	-	4023:72:1	<0.001	Genes diverse***
2.	CPAN 1885/CPAN 1929	110	-	-	-	-	*Sr 8a* Common
3.	CPAN 1885/CPAN 1933	112	-	-	16285:98:1	0.9-0.7	IPS**
4.	CPAN 1885/HW 517	104	-	-	-	-	*Sr 8a* Common
5.	CPAN 1885/CC 505	93	-	-	16285:98:1	0.9-0.7	IPS
6.	CPAN 1922/CPAN 1929	125	-	-	973:50:1	<0.05	Gene(s) Common
7.	CPAN 1922/CPAN 1933	96	-	-	-	-	*Sr 11* Common
8.	CPAN 1922/HW 517	115	-	-	-	-	*Sr 11* Common
9.	CPAN 1922/CC 505	100	-	-	-	-	*Sr 11* Common
10.	CPAN 1929/CPAN 1933	99	6	-	4023:72:1	<0.01	Genes diverse***
11.	CPAN 1929/HW 517	90	-	-	-	-	*Sr 8a* Common
12.	CPAN 1929/CC 505	118	-	-	4023:72:1	0.5-0.3	IPS
13.	CPAN 1933/HW 517	87	-	-	-	-	*Sr 11* Common
14.	CPAN 1933/CC 505	98	-	-	-	-	*Sr 11* Common
15.	HW 517/CC 505	91	-	-	-	-	*Sr 11* Common

* Lines segregating with 1/16 or more'S' plants only considered.

** Inadequate population size studied, gene(s) may or may not be common.

***No. of segretating lines more than the expected.

Table 5. Genetic diversity for resistance to stem rust races 21A-1 and 40 among the wheats studied

S.No.	Genetic stock	Probable SR genotypes* Race 21A-1	Race 40
1.	CPAN 1885	Sr A + Sr B + Sr C	Sr 8a + Sr A + Sr B
2.	CPAN 1922	Sr 5 + Sr 31 + Sr D + Sr E	Sr 11 + Sr 31 + Sr C
3.	CPAN 1929	Sr 5 + Sr 30 + Sr F	Sr 8a + Sr C
4.	CPAN 1933	Sr A + Sr B + Sr D	Sr 11 + Sr A + Sr B + Sr D
5.	HW 517	Sr E + Sr F + Sr G	Sr 8a + Sr 11 + Sr C
6.	CC 505	Sr 30 + Sr A + Sr B	Sr 11 + Sr B + Sr C + Sr D

* Additional factors, tentatively designated by different letters, represent the diversity for resistance to an individual race as indicated by the available information (Refer, Tables 2,3 and 4). Factors designated by the same letter are not necessarily allelic for the two races.

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PROBABLE GENETIC ARCHITECTURE OF RESISTANCE TO STEM AND LEAF RUSTS IN SOME WHEATS SHOWING SR 2- ASSOCIATED PSEUDO-BLACK CHAFF PHENOTYPE

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ABSTRACT

Seven *Sr* genes, namely, *Sr 5*, *Sr 6*, *Sr 7a*, *Sr 8a*, *Sr 11*, *Sr 30*, and *Sr 36*, and five to six *Lr* genes, *viz*, *Lr 1*, *Lr 3*, *Lr 10*, *Lr 13* and *Lr 14a*/*Lr 15*, either independently or in combinations, were postulated on the basis of 'IT' matching technique using multistrain tests in eleven rust resistant accessions of common wheat including seven lines developed in India and four introduced stocks showing a very consistent *Sr 2* - associated pseudo-black chaff phenotype. Moreover, a clear postulation of *Sr 9b*, a gene believed to be common in Indian breeding programme, could not, however, be made due to the overlapping effects of *Sr 5* in four of the accessions studied. Besides the above designated genes, the presence of additional genes/'modifiers' for seedling/adult plant resistance was also indicated. Effectiveness of *Sr 2* complex for stem rust and *Lr 13* complex for leaf rust in contributing to the durability of resistance in Indian wheats is discussed.

INTRODUCTION

It is widely believed that the *Sr 2* complex i.e. *Sr 2* and associated genes, has contributed to the durability of stem rust resistance in many parts of the world including the Indian subcontinent due to the extensive use of CIMMYT germplasm in the global breeding programme, since *Sr 2* is very common in wheats developed by CIMMYT, Mexico (McIntosh, 1988; Rajaram *et al*, 1988). The present communication attempts to identify the various *Sr* genes probably associated with *Sr 2* in eleven sources of resistance in the Indian context.

Further, studies were undertaken to probe into probable genetic architecture of these wheats for leaf rust resistance also since both stem and leaf rust diseases are important from the viewpoint of realising stabilised wheat yields in central and peninsular India.

MATERIALS AND METHODS

The presence of *Sr 2* in wheat is shown by its association with the development of black pigmentation in the stems below the nodes, glumes and peduncles, a physiological condition called pseudo-black chaff (Hare and McIntosh, 1979). Regular observations have been made from 1984 onwards to check for its presence in the wheat germplasm grown at Indore Station. Accordingly, eleven accessions of *Triticum aestivum*

* Retired Wheat Breeder

including seven lines developed in India, viz HI 840, HI 1027, HW 888, MP 843, MP 844, NI 9056, and VL 649; and four introducted stocks of exotic origin, namely, CPAN 1842 (Peru), CPAN 1887 (S.Afric), CPAN 1929 (Mexico) and CPAN 2041 (Place of origin not known), showing a very consistent pseudo-black chaff phenotype were identified on the basis of the above observations. Their particulars are listed in Table 1. Their adult plant responses to stem and leaf rusts were also recorded every year under artificially created rust ephiphytoics using mixtures of all prevalent and virulent Indian pathotypes of the two rusts. The near-isogenic line 'Sr 2 CS/Hope 3B' was planted as check throughout the period of study.

The above wheats as well as the various stocks carrying different Sr/Lr gaenes were seedling studied with 13 stem rust pathotypes and 12 leaf rust pathotypes of Indian origin. The tests were conducted in a glass house at temperatures not exceeding 30°C. However, the temperatures remained in the range of 15°C to 25°C for a minimum of 18 hours a day during the test period.

Standard procedures for inoculation of seedlings and recording of reactions were followed (Stakman et al, 1962). Presence of different Sr/Lr genes was postulated by comparing the infection types on the 'control' and the 'tester line' following Browder, 1973.

RESULTS AND DISCUSSION

It was observed that while the accessions CPAN 2041 and NI 9056 as well as the 'check' line Sr 2 CS/Hope 3 B rusted slowly in the field showing terminal disease severities in the range of 10S to 30S, the remaining wheat stocks under study manifested high levels of resistance characterised by low infection types or at the most trace to 10% susceptibility.

The seedling studies revealed that while CPAN 1929 was resistant to all the stem rust pathotypes tested, CPAN 2041 lacked the hypersensitive type of resistance showing mesothetic response to the test pathotypes characterised by the infection types varying from 1 to 4 on the same leaf. The remaining nine resistant stocks showed a clear-cut differential host-parasite interaction. Sr 2 CS/Hope 3B was susceptible to all the stem rust cultures studied (Table 2). As regards seedling responses to leaf rust, while CPAN 1842 was susceptible to all the leaf rust cultures tested, the remaining genotypes interacted differentially with the latter (Table 3).

Seven Sr genes, viz, Sr 5, Sr 6, Sr 7a, Sr 8a, Sr 11, Sr 30, and Sr 36 and five to six Lr genes including Lr 1, Lr 3, Lr 10, Lr 13, and Lr 14a/Lr 15, either independently or in combinations, were postulated in the resistant wheats under study on the basis of the number of stem rust and leaf rust pathotypes giving low infection types (L) or high infection types (H) on the pairs of host lines ('control' and the 'tester') following Browder, 1973. (Tables 4A and 4B).

Moreover, Sr 9b, believed to be common in the Indian breeding programme (Sawhney and Goel, 1981), might be present in four of the accessions studied, viz, CPAN 1929, HW 888, NI 9056 and VL 649. The same, however, could not be confirmed due to the 'overlapping' range of effectiveness exhibited by Sr 5 present in these wheats. Likewise, the seedling responses of Sr 6 might have been overlapped in the above mentioned four wheats by those of Sr 5, and in HI 840 by the combined responses of Sr 8a + SR 30. (Table 2). Similar difficulty exists with regard to determining the probable presence of Lr 13 and Lr 14a/Lr 15 in various wheats studied. (Table 3).

Besides the above designated genes, the presence of additional genes for seedling/adult plant resistance for both stem and leaf rusts was also evident from the above observations (Tables 4A and 4B).

The parentage of the above wheats was studied critically to identify the possible donors of resistance as discussed below. The gene(s) in parentheses are ones whose probable presence could not be confirmed due to the overlapping effects of other associated gene(s) as explained earlier.

CPAN 1929:

Sr 2 and (Sr 6) could have been contributed by Jupateco 73/Cocoraque 75 through Lerma Rojo 64. While Sr 5 might have come from Zopilote through Sonora 64, Sr 8a and possibly Sr 30 also were inherited from Jup 73/Coc 75 through Norteno 67 (=Inia 66 "S"). Presence of Sr 5 + Sr 8a + Sr 30 has been confirmed through allelic tests (Mishra et al, 1990). Source of (Sr 9b) was not clear from the pedigree. Lr 3 and Lr 13 (Agrawal, 1986) might have been donated by Jup 73/Coc 75 through 8156 and Nor 67 respectively.

VL 649:

Sr 2 would have been donated by VL 421 through Yaqui 50. Sr 5 and Sr 11 also possibly came from VL 421 through Sonora 64. Moreover, the presence of Sr 2 + Sr 5 + Sr 11 was indicated in VL 421 from the joint Indo-Australian studies on wheat rust genetics (Nayar et al, 1989). (Sr 6) and Sr 8a + (Sr 9b) appear to have been contributed by CPAN 1666 (Sparrow "S") through LR 64 and Frontana respectively. Lr 1 and Lr 13 probably originated from VL 421 (Agrawwal, 1986; Anonymous, 1988 b). Lr 13 + has earlier been postulated in VL 649 (Anonymous, 1989).

NI 9056:

Sr 2 and (Sr 6) would have been contributed by Lermaz Rojo. Sr 5 + Sr 8a + (Sr 9b) might have been donated by HW 142 through FKN-E4870-HW 113. Sr 11 also might have originated from HW 142 (Kaushal, 1982) or from NI 6989 through NP 824 (Rajaram, 1970). Both Lr 1 and Lr 3 might have been donated by Saric F 70 through Son 64 and 8156 respectively. Alternatively, Lr 1 could have come from HW 142 through E 4870-HW 113 (Anonymous, 1988a).

HI 840

Sr 2 and Sr 8a appear to have their origin in Ciano 67 through Chris and Pitic 62 respectively. (Sr 6) could have come from Tobari 66 through TzPP (Kaushal, 1982). Sr 30 might have been donated by Tanager through Pavon since the presence of Sr 30 is suspected in CIMMYT produced wheats like Inia 66, Pavon and Cheel (McIntosh, 1988).

Further, Tanager appears to have contributed Lr 3 through PJ-NAD-Siskin.

MP 843 and MP 844:

Sr 2 + Sr 8a + Sr 11 could have originated from WH 147 (Nayar et al, 1989). Lr 10 and additional gene(s) might have been contributed by Nacozari 76 since the latter has been shown to possess Lr 10 and slow rusting genes (Rajaram et al, 1988). Moreover, Sr 8a + Sr 11 as well as Lr 10 + were postulated in MP 843 based on the tests conducted at Simla (Anonymous, 1989).

HW 888:

Sr 5 + (SR 6) + Sr 36 could have been inherited from Timgalen. Although its detailed pedigree is not known, only P-118 could have been the possible source of Sr 2 + (Sr 9b) since these genes are not present in Timgalen (Singh and McIntosh, 1984); McIntosh, 1983). Likewise Lr 13 and additional gene(s) for leaf rust resistance might have been derived from P118. However, studies conducted at Ludhiana suggested the presence of only gene(s) for adult plant resistance (Lr APR) in HW 888 (Anonymous, 1988a).

HI 1027:

While Sr 2 and Lr 13 could have come from Bluebird through Ciano, Sr 6 appears to have been contributed by Kalyansona.

CPAN 1887:

While Sr 11 could have been contributed by Raven (Ferns et al, 1975), the source of Sr 2 and Lr 14a/Lr 15 was not clear from the pedigree. Presence of Lr 15 in CPAN 1887 has been indicated in studies at Simla (Anonymous, 1988c).

CPAN 1842 and CPAN 2041:

The sources of resistance in these two genotypes could not be identified from their pedigrees.

The above references with regard to the presence of different Sr/Lr genes in the various stocks under discussion, unless otherwise indicated, were mostly based on the information compiled by Nagarajan et al, 1987.

It is being increasingly realised that while formulating the strategies aimed at breeding for durable rust resistance, the ideal situation would be to identify a gene or set of genes that may prove to have provided durable resistance as a foundation and then continually combine additional genes for resistance to ensure genetic diversity. Sr 2 complex for stem rust and Lr 13 complex for leaf rust have been shown to be such a foundation of resistance durability in the CIMMYT germplasm (Rajaram et al, 1988). The same may hold good for the semidwarf wheats developed in India due to the extensive involvement of CIMMYT germplasm and evidence is forthcoming in support of this reason (Gupta and Saini, 1987; Anonymous 1988a and 1988b; Nayar et al, 1989 and J B Sharma, Personal Communication).

However, Sr 2 is a recessive gene and its slow rusting response permits the development of variable levels of disease (McIntosh, 1988). This is evident from the differences in the degree of infection observed among the lines studied. While wheats like CPAN 1842, CPAN 1887, CPAN 1929, HI 840 and HW 888 have been maintaining high levels of resistance for the past ten or more years of multilocation testing, lines such as CPAN 2041 and NI 9056 although showing consistently moderate degrees of infection at Indore since 1986, did develop high levels of disease at other hot-spot location(s).

Furthermore, the effectiveness of Sr 2 in imparting durable stem rust resistance appears to depend much upon other gene(s) associated with it. For instance, highly susceptible Indian wheat varieties like UP 262, VL 401, VL 421, WH 147, WH 283 and WL 410 were reported carrying such resistance genes as Sr 5, Sr 8a, Sr 9b, Sr 11 and Sr 17 in different combinations in conjunction with Sr 2 (Nayar et al, 1989). Lok-1 is another highly susceptible cultivar shown carrying Sr 2 (J B Sharma, personal communication). It appears that one or more of the above designated genes and/or additional 'modifier(s)' present in the background of the aforesaid varieties tend to inhibit the expression of Sr 2-resistance since all these wheats showed significantly higher levels of stem rust infection, year after year, at Indore as compared with the near-isogenic line carrying Sr 2 gene (Mishra, unpublished data). On the other hand, additional gene(s) for resistance and/or 'modifier(s)' appear to be operative in the resistant wheats under report which obviously enhanced the levels of resistance imparted by Sr 2. An inheritance study did suggest that Sr 2 may have been modified by alleles at an additional locus (Hare and McIntosh, 1979). Moreover, presence of two to four additional genes which may or may not be modifiers in conjunction with Sr 2 was indicated in most of the CIMMYT-lines included in the international nurseries (Rajaram et al, 1988). Identification of such 'modifiers' merits further investigation.

The gene Lr 13, either independently or in combinations, was postulated in HI 1027, VL 649, CPAN 1929 and HW 888 (Table 4B). Presence of Lr 13 in CPAN 1929 has been reported on the basis of Ne2 tests (Agrawal, 1986). Furthermore, the possible occurrence of Lr 13 in MP 843 and MP 844 can not be ruled out as allelic tests have confirmed its presence in one of their parents, namely, WH 147 (Agrawal, 1986). Likewise the presence of Lr 13 in HI 840 and NI 9056 is suggested from their pedigrees. Ciano 67, known to possess Lr 13, is one of the parents of HI 840 and is involved in the parentage of Saric F 70 which in turn, finds a place in the pedigree of NI 9056. Moreover, Tobari 66, another parental stock of NI 840, also carries Lr 13 (Rajaram et al, 1988). However, it was evident that additional genes for adult plant resistance to leaf rust were involved in the above wheats. Moreover, leaf rust resistance in CPAN 1842 appears to be imparted exclusively by the gene(s) for adult plant resistance. This was observed in an earlier study also (Sharma et al, 1983). Presence of Lr APR either independently or in conjunction with Lr 13, was indicated in a large number of Indian wheats. (Anonymous, 1988a).

From the foregoing discussion, it is clear that additional unidentified genes for adult plant resistance to both stem and leaf rusts were operative in Indian wheats as indicated earlier (Nagarajan *et al*, 1987). Further studies are needed to establish their identity and allelic relationships.

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POSTSCRIPT

In line with our observations in the Indian context, the Canadian experience in regard of the durability of stem rust resistance of the cultivar 'Selkirk' (*Sr 2*+) in contrast to the susceptibility of 'Renown' and 'Redman', the other two wheat cultivars possessing *Sr 2*, also suggested the possibility of other unidentified resistance genes playing a role in the durability of resistance to stem rust (Mundt, 1990).

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Table 1 Particulars of the wheat stocks studied

S.No.	Wheat Accessions	Origin	Year since rust resistant	Parentage*
1	CPAN 1842	Peru (USDAESN 188/75)	1978	LM 50-53
2	CPAN 1887	S.Africa (ISWRN 168/77)	1979	TIMGALEN/RAVEN // SKEMER
3	CPAN 1929	Mexico (BWELN 53/78)	1980	JUP/ZP"S" // COC
4	CPAN 2041	(ESWYT 11/82)	1984	TSM "S"
5	HI 840	Indore	1981	TAN/TOB // CNO "S"
6	HI 1027	Indore	1982	KAL/BB // PERICO "S"
7	HW 888	Wellington	1979	TIMGALEN/P118
8	MP 843	Powarkheda	1986	WH 147/NAC
9	MP 884	Powarkheda	1986	WH 147/NAC
10	NI 9056	Niphad	1986	NI 6989/HW 142 // LR 64/SR
11	Vl 649	Almora	1985	VL 421/CPAN 1966

* For parentage coding, refer Villareal and Rajaram, 1988.

CPAN = Coordinated Project Accession Number (Coordinated wheat project, New Delhi)

Wheat Accession Numbers 5 to 11 are of Indian origin.
Place of origin of "CPAN 2041' not known.

Table 2 Summary showing the effectiveness of 'tester' and 'control' lines when seedling studied with 13 cultures of Indian stem rust races[a].

Genetic stock	Races for which effective
CPAN 1929	All the cultures tested
VL 649	All except 40A
NI 9056	All except 40A
MP 843	All except 40A and 184
MP 844	All except 40A and 184
HI 840	All except 42 and 42B
HW 888	All except 11A and 40
HI 1027	11A,17,21A-2,34,40,117A,117A-1 and 184
CPAN 1842	21A-2,34,42,117A-1,122,184 and 295
CPAN 1887	11A,17,21A-2,34,40 and 42
CPAN 2041	None of the cultures studied
_Sr_ _2_ CS/Hope 3B	None of the cultures studied
_Sr_ _5_ Reliance	17,21A-2,42,42B,117A-1 and 184
_Sr_ _6_ McMurachy[b]	17,42B,117A-1 and 184
_Sr_ _7a_ CS/KF 4B	117A-1
_Sr_ _8a_ Mentana	11A,17,21A-2,40,117A,117A-1,122 and 295
_Sr_ _9b_ CS/KF 2B	17,42B,117A-1 and 184
_Sr_ _11_ Yalta	11A,17,21A-2,34,40 and 42
_Sr_ _30_ Festiguay[c]	(11A),40A,117A-1,(122),184 and (295)
_Sr_ _36_ CI 12632[d]	34,40A,42,42B,117A,122,184 and 295

a. Cultures of races studied:- 11A, 17, 21A-2, 34, 40, 40A, 42, 42B, 117A? (virulent on 'Reliance'), 117A-1, 122, 184 and 295.

b. _Sr_ _6_ - resistance only for races 17, 117A-1 and 184. Additional gene(s) for resistance to race 42B. (Sawhney and Goel, 1981).

c. 'Intermediate' infection types against races in parentheses.

d. Not tested at Indore. Based on Sawhney and Goel, 1981.

Table 3 Summary showing the effectiveness of 'tester' and 'control' lines when seedling studied with 12 cultures of Indian leaf rust races*.

Genetic Stock	Races for which effective
MP 843	All except 77A and 162
MP 844	All except 77A and 162
NI 9056	10,11,12,20,106,107,108 and 162
HI 840	10,11,20,104,104A,106,107 and 108
HW 888	10,11,(20)**,104,104A,106,107 and 108
VL 649	10,11,12,106,107,108 and 162
CPAN 1929	10,11,20,106,107,108 and 162
CPAN 2041	11,12,106,107,108 and 162
HI 1027	10,11,106 and 107
CPAN 1887	11 and 106
CPAN 1842	None of the cultures studied
TC + _Lr_ _1_	11,12,106,107 and 162
TC + _Lr_ _3_	10,11,20,106,107 and 108
TC + _Lr_ _10_	All except 77A and 162
_Lr_ _13_ Manitou	10,11,106 and 107
TC + _Lr_ _14A_	11 and 106
_Lr_ _15_ KW 1483	11 and 106

* Cultures of races studied:- 10,11,12,20,77-1,77A,104,104A, 106,107,108 and 162

** Segregating responses to race 20

Table 4a Postulation of SR genotypes on the basis of the number of stem rust pathotypes giving low infection types (L) or high infection types (H) on the pairs of host lines.

Control	Tester Line	L:L	L:H	H:L	H:H	Genes postulated Sr 2+
Sr 5+(Sr 6) +Sr 8a+(Sr 9b) +Sr 11+Sr 30	CPAN 1929	13	0	0	0	Sr 5+(Sr 6) +Sr 8a+(Sr 9b) +Sr 30+*
Sr 5+(Sr 6) +Sr 8a+(Sr 9b) +Sr 11	VL 649 NI 9056	12	0	0	1	Sr 5+(Sr 6) +Sr 8a+(Sr 9b) +Sr 11+
Sr 5+(Sr 6) +(Sr 9b)+Sr 36	HW 888	11	0	0	2	Sr 5+(Sr 6) +(Sr 9b)+Sr 36
(Sr 6)+Sr 8a +Sr 30	HI 840	10	0	1	2	(Sr 6)+Sr 8a +Sr 30+
Sr 8a+Sr 11	MP 843 MP 844	10	0	1	2	Sr 8a+Sr 11+
Sr 6	HI 1027	3	0	5	5	Sr 6+
Sr 7a	CPAN 1842	1	0	6	6	Sr 7a+
Sr 11	CPAN 1887	6	0	0	7	Sr 11+
Sr 2	CPAN 2041	0	0	0	13**	Sr 2+

* Presence of Sr 5 + Sr 8a + Sr 30 and absence of Sr 11 in CPAN 1929 confirmed from allelic tests (Mishra et al,)£

** Mesothetic reactions skewed towards susceptibility but characteristed by lower infection types as compared with the control.

Genes in partheneses are ones whose probable presence could not be confirmed due to the overlapping effects of associated gene(s).

+ = Additional gene(s) for seedling/adult plant resistance.

£ = Ref. the other enclosed paper on 'Genetic diversity for stem rust resistance in T.aestivum'.

Table 4b Postulation of LR genotypes on the basis of the number of leaf rust pathotypes giving low infection types (L) or high infection types (H) on the pairs of host lines.

Control	Tester Line	L:L	L:H	H:L	H:H	Genes postulated
Lr 10+(*Lr 13*)	MP 843 MP 844	10	0	0	2	*Lr 10*+(*Lr 13*)+
Lr 1+*Lr 3* +(*Lr 13*)	NI 9056	8	0	0	4	*Lr 1*+*Lr 3* +(*Lr 13*)+
Lr 3+(*Lr 13*)	HI 840	6	0	2	4	*Lr 3*+(*Lr 13*)+
Lr 13	HW 888	4	0	3	4*	*Lr 13*?**+
Lr 1+*Lr 13*	VL 649	6	0	1	5	*Lr 1*+*Lr 13*+
Lr 3+(*Lr 13*)	CPAN 1929	6	0	1	5	*Lr 3*+*Lr 13****
Lr 1	CPAN 2041	5	0	1	6	*Lr 1*+
Lr 13	HI 1027	4	0	0	8	*Lr 13*+
Lr 14/*Lr 15*	CPAN 1887	2	0	0	10	*Lr 14a*/*Lr 15*+
Lr APR	CPAN 1842	0	0	0	12	*Lr* APR

* Segregating for race 20

** Presence of only *Lr* APR reported in earlier studies (Anonymous, 1988a)

*** Presence of *Lr 13* based on Ne2 tests (Agrawal, 1986). *Lr 13* in parentheses indicates that its probable presence could not be confirmed due to the overlapping effects of associated gene(s)

\+ = Additional gene(s) for seedling/adult plant resistance

Cereal Rusts and Powdery Mildews Bulletin

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A PATHOTYPE OF *PUCCINIA GRAMINIS* F.SP. *TRITICI* ON *Sr24* IN INDIA

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SUMMARY

Occurrence of a pathotype carrying virulence for *Sr24*, an alien gene known for its resistance to all pathotypes of *Puccinia graminis* f.sp. *tritici* in many countries, is reported from India. It appears to be a single mutation change in the existing pathotype 40A(62G29). The new pathotype 40-1(62G29-1) in relation to 40A(62G29) on the lines having *Sr24* is described.

INTRODUCTION

A dominant gene *Sr24*, located on the 3DL chromosome transferred to wheat (*Triticum aestivum* L.) from *Agropyron elongatum* (Host) Beauv., conferred resistance to *Puccinia graminis* f.sp. *tritici* in India and many other countries. In 1984 however, it was rendered susceptible by a race 2SA100, in South Africa (Le Roux, 1985). Since then the number of phentotypes has increased in that country (Le Roux and Rijkenberg, 1987). In order to have resistance against P. *graminis* f.sp. *tritici* and P. *recondita* f.sp. *tritici*, *Sr24* was incorporated into Indian wheats also. As a result of 6-7 backcrosses, *Sr24* was incorporated into Sonalika, Kalyansona, NI 5439 and C306 and lines Unnath Sonalika (HW2001), Unnath Kalyansona (HW2002), Unnath NI 5439 (HW2003) and Unnath C306 (HW2004), respectively were developed (Anonymous, 1988).

MATERIALS AND METHODS

Black rust samples collected from different regions of the country were multiplied on the susceptible cultivar Agra local. The fresh crop of urediospores from Agra local was used to inoculate the sets of differentials (Bahadur *et al*, 1985). Host response was described as per Stakman *et al* (1962). All the lines having *Sr24* and the Australian line Torres (also having *Sr24*) were evaluated.

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RESULTS AND DISCUSSION

Analysis of a sample of black rust from the summer nursery at Wellington (Tamil Nadu) in 1989, revealed a pathotype identical to 40A(62G29) but with additional virulence for Sr24 (3D/Ag) isogenic line. The isolations from Sr24 were repeatedly tested on differential sets and found consistent under different environments. Infection on Sr24, however, appeared 2-4 days later than on Agra local. The new pathotype was designated as 40-1(62G29-1). The avirulence/virulence formula for this pathotype is Sr12, Sr13, Sr14, Sr22, Sr25, Sr26, Sr27, Sr30, Sr31, Sr32, Sr33, Sr35, Sr36, Sr37/Sr2, Sr5, Sr6, Sr7a, Sr7b, Sr8, Sr9a, Sr9b, Sr9c, Sr9d, Sr9e, Sr9f, Sr9g, Sr10, Sr11, Sr15, Sr16, Sr17, Sr19, Sr21, Sr23, Sr24, Sr28, Sr29 and Sr34. While it was detected in 2 per cent of the samples analysed in 1989, its frequency increased to 27 per cent in 1990.

The response of different lines to 40-1(62G29-1) and its comparison to 40A(62G29) is given in Table 1. While Sonalika, Kalyansona, NI 5439 and C306 were susceptible, to both the races, Sr24, HW2001, HW2001A, HW2002, HW2002A, HW2003, HW2004 and Torres were susceptible to the former and resistant to the latter. Preliminary studies on adult plant resistance show that most of the entries were susceptible to 40-1 and resistant to 40A.

Race 40(104G13), of P. graminis f.sp. tritici was isolated in 1932 from a cultivar Pusa-4 in a sample from Pune (Mehta, 1940). After a lapse of some 43 years a variant 40A(62G29) was isolated from Wellington, Nilgiris (Tamil Nadu), in 1975 (Sharma et al, 1975). No further variation could be detected in this group until 1989. Pathotype 40-1(62G29-1) differed from 40A(62G29) only in respect of virulence on Sr24. Since Sonalika, Kalyansona, NI5439, C306 were susceptible to 40A(62G29), it is likely that 40-1(62G29-1) might have evolved by a single mutational change.

The Nilgiris and Palney hills in the South are known to serve as one of the foci for stem rust infections in Central India (Nagarajan and Joshi, 1985). Wheat is cultivated all year round in the Nilgiris and the chances of building up this pathotype over a large area are very high. Increase in per cent of this pathotype over two years supports this contention. A similar pattern was observed in South Africa (Le Roux and Rijkenberg, 1987).

Although this gene (Sr24) is closely linked with Lr24 which confers resistance against P. recondita f.sp. tritici, it should be used in combination with other effective resistance genfes in the future.

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Table 1: Seedling reactions of different lines/Cvs. to two races.

S.No.	Lines/Cvs.	Pathotypes 40A (62G29)	40-1 (62G29-1)
1	HW 2001	1-2 (R)	3⁻-4(S)
2	HW 2001A	1-2 (R)	3⁻-4(S)
3	HW 2002	1-2 (R)	3⁻-4(S)
4	HW 2002A	1-2 (R)	3-4 (S)
5	HW 2003	;-1 (R)	3-4 (S)
6	HW 2004	2⁻-2(R)	3-4 (S)
7	Torres	;-1 (R)	3-4 (S)
8	Sr24	2⁻-2(R)	3-4 (S)
9	Sonalika	4 (S)	4 (S)10
10	Kalyansona	4 (S)	4 (S)
11	NI 5439	4 (S)	4 (S)
12	C 306	4 (S)	4 (S)

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MONOSOMIC ANALYSIS OF RESISTANCE TO POWDERY MILDEW IN WINTER WHEAT CULTIVAR GALAHAD

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INTRODUCTION

Powdery mildew is a serious pathogen of cereals. Therefore knowledge on genetic bases of resistance to powdery mildew is useful for the breeding of resistant wheat cultivars. This contribution presents results of the monosomic analysis of powdery mildew resistance in the English winter wheat cultivar Galahad.

MATERIAL AND METHODS

The cultivar Galahad is a semi-dwarf mid-season winter wheat of high yield potential, very suitable for biscuit manufacture. It originates from the cross (Joss Cambier x Durin) x Hobbit 'sib' and was released in 1982. Its resistance to yellow rust, powdery mildew and septoria is good, to brown rust moderate (Bingham et al).

For the location of powdery mildew resistance standard monosomic analysis using monosomic series of the cultivar Zlatka was applied. Single progenies of the F_2 generation of Zlatka monosomics x Galahad were tested in the greenhouse at the seedling stage. Inoculation was carried out by dusting the plants with spores of a powdery mildew race. This race was virulent to the genes Pm 8, 2b, 4b, 3a, 7, as well as to the genes Pm 1 and Pm 5 (lower infection rate) and avirulent to the genes Pm 2, 3b, 2+6. Inoculated plants were kept under glass cylinders in the growth-chamber where the temperature varied between 12-15°C; illumination by fluorescent tubes for 14 hours per day was used. After 14 days infection types on single plants were classified (0, 1, 2 = resistant; 3, 4 = susceptible).

RESULTS AND DISCUSSION

The F_2 generation of the crosses of Zlatka monosomics x Galahad segregated into two categories: resistant, infection type 0 (;1) and susceptible, infection type 3-4. When data of all progenies were summarised, the frequency of resistant plants was 75.7%, susceptible plants 24.3%. In the progeny of a disomic F_1 plant there were 77.6% resistant and 22.4% susceptible.

This indicates segregation for one dominant gene, 3:1. Segregation of single progenies in the F_2 generation and the corresponding X^2-values are summarised in Table 1. These data confirmed the segregation ratio 3:1 except in the progeny from the monosomic 5D which had 92.9% of resistant plants ($X^2 = 7.143$) and from the monosomic 3B with 51.7% resistant plants ($X^2 = 8.379$), and from monosomic 5A with 88.1% resistant plants ($X^2 = 3.841$) and 6B with 60.5% resistant plants ($X^2 = 4.246$). This leads to the conclusion that powdery mildew resistance to race 1 in the cultivar Galahad is governed by one dominant gene on chromosome 5D. The three susceptible plants of this critical progeny were assumed to be nullisomic. The progeny of 5A shows an excess of resistant plants, however X^2 is just at the critical value for significance. In the progenies of monosomic 3B and 6B increased numbers of susceptible plants were observed. Presence of suppressors of resistance can be presumed on the above mentioned chromosomes. Possibility of complete inhibition of a gene for powdery mildew resistance is discussed, e.g. by Friebe et al (1989) in the cultivars Florida, Heinrich, Olymp.

Our conclusions were also supported by a X^2-test of homogeneity. When all lines were tested the value of this test was 36.368 (F=21). When 5D, 3B, 5A and 6B progenies were excluded, the value of X^2-test of homogeneity decreased to 12.319 (F=17). Location of the resistance gene on chromosome 5D contributes to the assumption that the resistant reaction to powdery mildew in the cultivar Galahad is controlled by the gene Pm 2 (McIntosh, 1988).

In the UK where the cultivar Galahad and the other Pm 2 cultivars are commonly cultivated, the matching pathogenicity was selected, however frequencies of this pathogenicity decrease from west to east in Europe (Felsenstein, 1986). In Germany, the combination Pm 2 + Pm 6 is effective throughout the whole country (Heun, 1987). Also in Denmark the gene combination Pm 2 + Pm 8 belongs to the most successful ones (Houmoller, 1987). In Czechoslovakia (Mraz, 1989) virulence to the gene Pm 2 was identified; however, race survey was limited to the experimental field in Kromeriz. Data on the distribution of powdery mildew races in the whole territory of Czechoslovakia are not available.

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Table 1 - Segregation of F_2 generation progenies of monosomics from the crosses sof Zlatka monosomics x Galahad after inoculation with a powdery mildew race.

Progeny from monosomic	Total number of plants	Susceptible IT 3-4 Number of plants	%	Resistant IT 0 (;1) Number of plants	%	X^2 3:1
1A	43	12	27.9	31	72.1	0.194
1B	41	6	14.6	35	85.4	2.350
1D	46	13	28.3	33	71.7	0.261
2A	41	8	19.5	33	80.5	0.659
2B	42	10	23.8	32	76.2	0.032
2D	44	11	25.0	33	75.0	0.000
3A	38	10	26.3	28	73.7	0.035
3B	29	14	48.3	15	51.7	8.379++
3D	42	8	19.0	34	81.0	0.794
4A	40	13	32.5	27	67.5	1.200
4B	47	7	14.9	40	85.1	2.560
4D	45	11	24.4	34	75.6	0.007
5A	42	5	11.9	37	88.1	3.841+
5B	42	13	31.0	29	69.0	0.794
5D	42	3	7.1	39	92.9	7.143++
6A	45	13	28.9	32	71.1	0.363
6B	38	15	39.5	23	60.5	4.246+
6D	44	8	18.2	36	81.8	1.091
7A	45	15	33.3	30	66.7	1.667
7B	47	11	23.4	36	76.6	0.064
7D	43	10	23.3	33	76.7	0.070
Disomic	49	11	22.4	38	77.6	0.170
$\sum$	935	227	24.3	708	75.7	0.260

+ P = 0.05 - 0.01
++P <0.01

X^2 - test of homogeneity: 36.368 (P<0.05)
12.319 (P>0.05)

PREPARATION OF PAPERS FOR PUBLICATION IN THE CEREAL RUSTS AND POWDERY MILDEWS BULLETIN

1) All types of papers on cereal rusts and powdery mildews are acceptable, including variability of the pathogens, genetical and physiological studies and breeding for resistance. Papers may be of standard form or as letters and short notes on any relevant subject including the occurrence of epidemics and evolution of new races.

2) Papers should be typed double-spaced on A4 (the same size as the Bulletin) or similar sized sheets and have a 3 cm margin at the top, bottom and both sides.

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4) Figures must be presented in photo-ready condition.

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6) In future the length of papers must not exceed 12 pages including all tables, figures and references, but should preferably be shorter. The 12 pages will be measured at single spaced typing.

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