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Being obligate parasites, the cereal rusts are considered to be among the most specialised of organisms. Not only are they confined to a narrow range of main and alternate hosts but, within their main hosts, a particular isolate will develop only on a selection of cultivars, relating to the respective virulence and resistance factors which are present. The genetic basis of this relationship was first described for flax and its rust *Melampsora lini* by Flor (1942). Since then many such genes for gene relationships have also been described for cereal rusts (Roelfs, 1984). The methods currently used for race identification consider the outcome of infection, in a system of various classes of resistance or susceptibility (Hoerner, 1919; McNeal et al., 1971). Although much work has been done on rust infection in susceptible responses, for example Pole-Evans (1907) and Rowell (1984), little research has been carried out to investigate the development of rusts on non-host cereals. Ogilvie and Brown (1971) describe the growth and development of wheat stem rust *Puccinia graminis tritici* during the first five days after inoculation on susceptible and resistant wheat cultivars, non-host cereals and five species of dicotyledons. Field observations (Abiev et al., 1982) indicate, that wild grasses can be used as hosts by wheat yellow rust and represent a possible source of infection for wheat crops. Some work on the development of incompatible host-parasite combinations has been done using fluorescence techniques (Niks, 1981; 1982). A preliminary experiment was carried out to investigate the possibilities of growth experiments with cereal leaf rust fungi on non-host cereal cultivars. No replication was applied in this preliminary experiment. The results from the preliminary experiment are presented in Table 1. The present investigation aimed to study further the development of cereal rusts on non-host cereals.

#### MATERIALS AND METHODS

Two isolates of barley brown rust (*Puccinia hordei* Oth) and

#### INTRODUCTION

Quantitative aspects of colony growth and development in uredinal infections of the cereal leaf rust fungi were investigated in controlled conditions. The colony growth patterns of the cereal leaf rusts in host and non-host relationships showed strong host preference. However, unexpected colony development including sporulation occurred in some of the pathogen/non-host combinations.

#### SUMMARY

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DEVELOPMENT OF CEREAL RUSTS ON HOST AND NON-HOST PLANTS

The urediniospores of all isolates germinated well on all cereal cultivars, forming appressoria over their stomata (but not *P. striiformis* which does not produce appressoria) but some of the germ tubes of rusts which were specialised on glabrous hosts (barley and oats) grew in a somewhat disorientated manner on the hirsute cultivars (rye, triticale and wheat), thus often missing the nearest stomata. The same could be observed with germ tubes of rusts normally developing on hirsute leaves, when they were inoculated onto glabrous cultivars. Substomatal vesicle (SSV) formation and the development of infection hyphae could be observed after appressorium formation. Only in very rare cases could an abortion of the infection be recorded at

## RESULTS

On day 21, the length and breadth of colonies were measured on unstained leaves. This was possible only where sporulation or distinct chlorosis occurred and some latent infections thus escaped this last assessment. For the qualitative assessment of sporulation, a four class system was adopted: with 0=none, 1=very little, 2=reduced and 3=full sporulation. The quantitative assessment was carried out using a suction method for spore collection (Helfer 1985) and measuring the spore concentration photometrically at 500nm. The experiments were carried out using three replicates of each host-isolate combination. Where unexpected sporulation on non-hosts occurred, spore samples were collected and the identity of the isolate was tested on varieties of the normal host plant.

$$\text{Radial growth} = \frac{\text{length}}{2} * \text{breadth} / 2$$

Fungal colonies were calculated using the formula: the invading fungal mycelium were measured. The radial growth of the fitted with epifluorescence equipment, and the length and breadth of specimens were then examined with a Leitz Ortholux 2 microscope, MZR New, in the procedure after Rohringer et al. (1977). The sections of 10-15mm length were cut off the leaves after 3, 7 and 11 days, fixed and cleared in boiling lactophenol : ethanol (1:2) for 90 seconds and stained for fluorescence microscopy in Calcofluor White As the water agar provides sufficient humidity to keep the air inside the petri dishes saturated, no controlled humidity was required. Inoculation the petri dishes were transferred to controlled environment cabinets and kept at 14°C at 16h light and 8h darkness. presence of at least 10 and not more than 60 spores/cm<sup>2</sup>. After were used and an inoculum density was chosen which ensured the petri dishes. For the inoculation freshly collected urediniospores leaves were kept on 80ppm benzimidazole. Water agar (0.7%) in plastic by heat sterilising the settling tower between every inoculation and immersing the nozzle of the spray gun in 70% ethanol for 40 min. The settling tower. Special care was taken to avoid cross contamination (cv. Bush) respectively. The inoculation was carried out in a spore wheat (cvs. Armada and Michigan Amber) and one cultivar of triticale oats (cvs. Maris Tabard and Bond), rye (cvs. Rheidol and Dominant) and detached leaves of two cultivars of barley (cvs. Berac and CI 1243), and wheat yellow rust (*P. striiformis* Westend) were inoculated onto (*P. recondita* Rob. & Desm.), wheat brown rust (*P. tritici-na* Eriksson) one isolate each of oat crown rust (*P. coronata* Corda), rye brown rust

Gaeumann (1959) mentioned many possible hosts for the five rust species investigated in this paper. For *P. hordei* he listed 12 host species, all of which belong to the genus *Hordeum*. *P. coronata* was described in three groups and 16 formae specialties on 256 host species comprising barley, oats, rye and wheat (all attacked by the forma *specialis avenae* Eriksson). For *P. triticea*, 29 host species, including rye and barley, were described. The host range of *P. recondita* (*P. dispersa*), according to Gaeumann, consists of 12 species, none of them being cereals apart from rye. *Puccinia*

## DISCUSSION

appressorium formation (once with barley brown rust on wheat) or SSV formation (occasionally in wheat yellow rust on oats). In many combinations external formation of SSV without stomatal penetration could be observed: rye brown rust formed external SSV when inoculated on oats and triticale, wheat brown rust on barley and oats, and wheat yellow rust on all examined hosts. This phenomenon had first been noticed in barley yellow rust (*P. striiformis*) on barley and other cereals (Helfer, unpublished results, Kellock, personal communication). Early abortion *sensu* Niks (1982) occurred in most non-host combinations, but not necessarily at all penetration sites. The results 3 days after inoculation include these early abortions. After 7 days, the aborted fungal tissue did not take up the fluorescent stain in any more, possibly because it was dead and decomposing. This explains the disappearance of positive growth values in incompatible reactions after three days.

Table 2 shows the radial growths of the six pathogens on nine cereal cultivars on days 3, 7, 11 and 21. No statistically significant interaction occurred, indicating the susceptibility and resistance of cultivars to rusts. Several inconsistencies could be observed here: oat crown rust was observed growing quite substantially (580 µm) on wheat cultivar Michigan Amber on day 7 but not on any of the other dates; wheat yellow rust developed well in the barley cultivar Berac (679 µm on day 11) and in the rye cultivar Rheidol (1484 µm on day 11) without producing visible infection on day 21; the same was true to a lesser extent for oat crown rust on barley cultivar Berac (239 µm) and the two rye cultivars (458 and 652 µm respectively); wheat yellow rust on the oat cultivar Maris Tabard could be observed only on one date (day 21) when it sporulated. On day 7 sporulation began to occur in the wheat/wheat brown rust combination, with the other combinations following later. On day 21 all compatible combinations were sporulating, including some unexpected ones: *P. triticea* formed spores on the barley cultivar CI 1243, the two rye cultivars and triticale, and *P. striiformis* sporulated abundantly on Maris Tabard oats in one replicate. The identities of the wheat yellow rust and the wheat brown rust isolates was later confirmed on the respective wheat varieties. Table 3 shows the mean values of sporulation and the spore production measured colorimetrically by light absorbance. Wheat yellow rust produced the highest response from single infection sites. The sporulation of the incompatible barley brown rust isolate race A on barley cultivar CI 1243 was very low, as were sporulations from other incompatible combination. A hypersensitive response was evident in the barley brown rust race A/CI 1243 combination.



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Table 1 - Radial growth (µm) of some leaf rust fungi on host and non-host cereal cultivars and on susceptible and resistant hosts

a) Barley rusts on three barley cultivars		b) Other relationships		
Cultivar Midas	Day 2	Day 4	Day 7	SED (+)
Isolate *)				
BBR race A	20	46	120	
BBR 83-2	23	68	238	
BYR race 1	18	44	260	
Cultivar CI 1242				
Isolate				
BBR race A	22	47	166	
BBR 83-2	26	45	218	
BYR race 1	22	43	55	
Cultivar Berac				
Isolate				
BBR race A	25	38	158	
BBR 83-2	27	91	224	
BYR race 1	24# (+)	42	399	
SED (+)	±2.6	±9.7	±46.4	
Cultivar Armada (wheat)				
Isolate	25 hours	113 hours	209 hours	
BBR 83-2	39	0	0	
BYR race 1	24	0	0	
OCR FR 1	9	12	0	
RBR 70-1	27	0	0	
WBR 77-22	25	141	508	
Cultivar Berac (barley)				
Isolate				
BBR 83-2	22	80	413	
BYR race 1	22	85	163 (+)	
OCR FR 1	37	75	285	
RBR 70-1	24	15	0	
WBR 77-22	19	0	0	
Cultivar Maris Tabard (oats)				
Isolate				
BBR 83-2	25	0	0	
BYR race 1	0	0	0	
OCR FR 1	37	195	309 (+)	
RBR 70-1	22	0	0	
WBR 77-22	17	0	102	
Cultivar Rhaidol (rye)				
BBR 83-2	26	0	0	
BYR race 1	22	84	515	
OCR FR 1	36	21	1056	
RBR 70-1	39	194	239	
WBR 77-22	21	0	0	
SED (+)	±3.9	±18.3	±52.5	

\*) BBR = barley brown rust (*P. hordei*)  
 BYR = barley yellow rust (*P. striiformis*)  
 OCR = oat crown rust (*P. coronata*)  
 RBR = rye brown rust (*P. recondita*)  
 WBR = wheat brown rust (*P. tritici*)  
 (+) estimated values only

Table 2 - Radial growth (um) of leaf rust fungi on host and non-host cereal cultivars

Cultivar	Cultivar Berac (barley)			Cultivar CI 1243 (barley) Isolate			Cultivar Maris Tabard (oats) Isolate			Cultivar Bond (oats)			Cultivar Rhaidol (rye) Isolate		
	Day 3	Day 7	Day 11	Day 3	Day 7	Day 11	Day 3	Day 7	Day 11	Day 3	Day 7	Day 11	Day 3	Day 7	Day 11
BBR race A	44	272	644	4	0	0	4	0	0	15	11	0	15	11	0
BBR 84-1	61	259	633	10	0	0	10	0	0	11	0	0	11	0	0
OCR FR-1	87	73	239	68	476	768	68	476	768	73	73	1482	73	73	1338
RBR 70-1	21	9	0	26	25	0	26	25	0	21	0	0	21	0	0
RBR 80-21	18	5	209	16	0	0	16	0	0	7	80	80	7	80	569
WYR 104E137	26	73	679	25	0	0	25	0	0	23	0	0	23	0	1516
BBR race A	52	98	260	52	98	260	52	98	260	52	98	260	52	98	260
BBR 84-1	74	343	736	74	343	736	74	343	736	74	343	736	74	343	736
OCR FR-1	61	0	0	61	0	0	61	0	0	61	0	0	61	0	0
RBR 70-1	25	0	0	25	0	0	25	0	0	25	0	0	25	0	0
WBR 80-21	22	48	290	22	48	290	22	48	290	22	48	290	22	48	290
WYR 104E137	14	0	0	14	0	0	14	0	0	14	0	0	14	0	0
Cultivar CI 1243 (barley) Isolate															
BBR race A	52	98	260	52	98	260	52	98	260	52	98	260	52	98	260
BBR 84-1	74	343	736	74	343	736	74	343	736	74	343	736	74	343	736
OCR FR-1	61	0	0	61	0	0	61	0	0	61	0	0	61	0	0
RBR 70-1	25	0	0	25	0	0	25	0	0	25	0	0	25	0	0
WBR 80-21	22	48	290	22	48	290	22	48	290	22	48	290	22	48	290
WYR 104E137	14	0	0	14	0	0	14	0	0	14	0	0	14	0	0
Cultivar Bond (oats)															
Isolate															
BBR race A	15	0	0	15	0	0	15	0	0	15	0	0	15	0	0
BBR 84-1	11	0	0	11	0	0	11	0	0	11	0	0	11	0	0
OCR FR 1	73	455	1482	73	455	1482	73	455	1482	73	455	1482	73	455	1482
RBR 70-1	21	0	0	21	0	0	21	0	0	21	0	0	21	0	0
WBR 80-21	7	0	80	7	0	80	7	0	80	7	0	80	7	0	80
WYR 104E137	23	0	0	23	0	0	23	0	0	23	0	0	23	0	0
Cultivar Rhaidol (rye)															
Isolate															
BBR race A	39	0	0	39	0	0	39	0	0	39	0	0	39	0	0
BBR 84-1	27	39	0	27	39	0	27	39	0	27	39	0	27	39	0
OCR FR 1	84	206	458	84	206	458	84	206	458	84	206	458	84	206	458
RBR 70-1	57	572	1338	57	572	1338	57	572	1338	57	572	1338	57	572	1338
WBR 80-21	38	218	569	38	218	569	38	218	569	38	218	569	38	218	569
WYR 104E137	19	0	1516	19	0	1516	19	0	1516	19	0	1516	19	0	1516

/Continued ...



Table 3 - Sporulation of cereal leaf rusts on nine host and non-host cereal cultivars

(a) Qualitative assessment (Scale 0-3)

Isolate (**) (**)	BBR	BBR	OCR	RBR	WBR	WYR
BBR	2.3	2.7	0.0	0.0	0.0	0.0
CI 1243	(B)	0.7	2.3	0.0	0.0	0.0
Maris Tabard	(O)	0.0	0.0	3.0	0.0	1.0
Bond	(O)	0.0	0.0	3.0	0.0	0.0
Rheidol	(R)	0.0	0.0	2.7	1.0	0.0
Dominant	(R)	0.0	0.0	0.3	2.5	0.0
Bush	(T)	0.0	0.0	0.0	2.0	0.0
Armada	(W)	0.0	0.0	0.0	2.3	1.7
Michigan Amber	(W)	0.0	0.0	0.0	3.0	2.0

SED ±0.4127

0 = no sporulation

1 = little sporulation

2 = reduced sporulation

3 = abundant sporulation

values represent means of three replicates

(b) Spore number production of single infections measured by light absorbance at 500 nm (X 10<sup>3</sup> spores)

Isolate (**) (**)	BBR	BBR	OCR	RBR	WBR	WYR
BBR	33	34	0	0	0	0
CI 1243	(B)	<30	33	0	0	0
Maris Tabard	(O)	0	0	46	0	0 (+)
Bond	(O)	0	0	45	0	0
Rheidol	(R)	0	0	0	37	<30
Dominant	(R)	0	0	0	34	30
Bush	(T)	0	0	0	35	0
Armada	(W)	0	0	0	37	48
Michigan Amber	(W)	0	0	0	41	207

SED ±40

(+) = sporulation in one case but not in sample

(\*) B = barley (\*\*) BR = brown rust

O = oats

R = rye

T = triticale

W = wheat

YR = yellow rust

CR = crown rust

BR = brown rust

Productivity of wheat in India is restricted by widespread epidemics of *Puccinia striiformis* West., *P. recondita* Rob. ex Desm. f. sp. *tritici* and *P. graminis* (Pers.) f. sp. *tritici* Erikss. and Henn., causing yellow, brown and stem rust of wheat, respectively, the severity of these diseases varying from year to year and from location to location. Breeding for disease resistance has been the main approach in disease management to reduce the effect of rust diseases. However, there is a lack of knowledge of the *Yr*, *Lr* and *Sr* genes present in the cultivars prior to their identification and release, and there is much dependence on the evaluation of resistance under multilocation testing and artificial epiphytotic. Despite phenotypic heterogeneity, unconscious selection of the same genes or genes giving similar expression has led to genetic vulnerability. Identification of the avirulence/virulence genes present in the pathogen cultures that cause yellow, brown and stem rust was done by Bahadur et al., (1985), and by Nagarajan et al., (1983, 1986). By selection of the appropriate pathotypes able to distinguish various resistance genes a large number of genotypes were evaluated, the results of which are discussed here.

#### MATERIALS AND METHODS

pure pathotypes of *P. striiformis*, *P. recondita* f. sp.

#### INTRODUCTION

By selecting and inoculating appropriate pathotypes differing for their avirulence/virulence genes and by comparison of the host-pathogen interaction (HPI) matrix, probable resistance gene/s in test cultivars were inferred. Reference to the parentage of such lines indicated further evidence for the presence of the postulated genes. Genes *Lr1*, *Lr3*, *Lr10*, *Lr14a* or *Lr22*, *Lr15* and *Lr26* were detected either independently or in combination. The presence of genes *Yr2*, *Yr7* and *Yr9*; and *Sr5*, *Sr7a*, *Sr8*, *Sr11* and *Sr31* in various combinations were also postulated. Only a few resistance genes are in common usage in the Indian wheat material indicated in 53 genotypes examined.

#### SUMMARY

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EVALUATION OF SOME INDIAN WHEATS FOR *Yr*, *Lr* AND *Sr* GENES,  
 BY MATCHING TECHNIQUE, AND THE GENETIC UNIFORMITY OBSERVED.

triticum and P. graminis f. sp. tritici maintained at the Regional station, Flowerdale, Indian Agricultural Research Institute (IARI) were used to inoculate lines or near isogenic lines possessing known genes (Table 1). Such an evaluation, done at least six times, covered various seasons and indicated the avirulences/virulence genes of the isolates. The host pathogen interaction (HPI) recorded after 15 days following international procedure, was grouped into seven categories i.e. 0, 1, 2, 3, 4 and X. Symbols + or - were used to show degrees of minor variation in reaction. Reactions of the lines with known resistance genes against the pathogen isolates were compared with those of the test cultivars to postulate the possible host resistance genes. As the seedling reaction data generated are extensive, they have been presented in a condensed way (Browder, 1973). It is assumed here that the gene expression recorded as HPI is not influenced by the genetic background in which it occurs. Subsequently, the percentage of the cultivars in which resistance genes were postulated were studied (Villareal and Rajaram, 1984) to identify the possible donors of these genes.

#### RESULTS AND DISCUSSION

The HPI recorded, was grouped into two for purposes of analysis as the High Infection Type (HIT), reaction types 3 and 4, and Low Infection Type (LIT), reaction types 0 to 2<sup>+</sup> reaction types. These reaction types when compared with the tester gene(s) fall into four groups (Johnson et al., 1987). Wherever the control and tester lines had total identity for L:L (LIT : LIT) and H:H (HIT : HIT) it implies that they may possess identical resistance genes. When there are lines in the L:H class, invariably the tester and control have different resistance genes. When the matrix has values in the H:L group apart from L:L and H:H and none in the L:H, it may imply that there may be a gene, additional to the postulated gene. When presence of more than one resistance gene was inferred, reactions of the lines possessing them were compared with that of the test cultivar. From Table 2 it can be observed that in most of the cases the L:L and H:H were uniform, and in no case there were any in the L:H category. This implies that there is a high probability for the presence of the postulated genes. In certain cases, isolates were classified into the H:L category which can be interpreted as indicating that additional genes are present. However, it must be emphasised that all gene designations based solely on such classifications of interactions between cultivars and pathogen isolates can only be tentative, and much depends on the specific virulence of the pathogen isolates, which is often not fully known (Johnson et al., 1987). The pedigrees showed that in many cases certain varieties, known to possess specific resistance genes were involved (Table 3). Though the seedling reaction of N10B against P. striiformis tritici virulences are not available to demonstrate it as the contributing source for Yr2, speculated in a number of lines, repeated involvement of N10B in the parentage makes us believe that Yr2 might have come from N10B. It is widely believed that

Kalyansona, WL711 and a number of others may carry Yr2 (Perwaiz and Johnson, 1986; Johnson et al., 1987), and they have N10B in their pedigree. Sonalika may carry Yr2, plus an additional unidentified gene and is designated as Yr2+. The 1B/1R translocation present in Kawkaz, Aurora and Fundulea contains Yr9, Lr26, Sr31 and Pm that are very tightly linked. In such cases presence of Lr26 was inferred using P. reconducta tritici races, confirmed by testing for Yr9 that accords immunity to yellow rust races occurring in India. Similarly, presence of Sr31 that imparts seedling resistance to black rust races occurring in India, was inferred. Hope is said to contain LR14a and is involved in the parentage of a number of varieties. Gene Lr3 present in Frontana through Mentana (Frontana=Frontera/Mentana) involved in the parentage also occurs in FKN. Yaktana 54, with the pedigree, Vaqu48/Kentana48/Frontana, has both Lr1 and Lr3 in addition to Sr, while Nai 60 is said to contain Lr10. Line FKN also has Sr6, Sr7a, Sr8 and Sr9b, Chris has Sr5, Sr6, Sr7a, Sr9g, and Sr12, Timgalen contains Sr5, Sr6, Sr8 and Sr36 and Thatcher possesses Sr5, Sr9g, Sr12 and Sr16 in addition to Yr7. Gabo 55, Sonora 64 and Timstein have Sr11 and Tumbillo has Yr7 and Sr9g (McIntosh, 1983). With this basic information, when the pedigrees of the postulated material are scanned, there is further evidence for the presence of the resistance genes (Table 4). Although at CIMMYT and in many of the South Asian countries a large number of varied crosses are made, ultimately potential varieties result from relatively few crosses. The 'General Combining Ability' of these top ten lines repeatedly seen in the parentage seems to have contributed the resistance genes present and to genetic uniformity.

In the hills of NW India, local wheats (horizontally susceptible), Kalyansona, (Yr2) and Sonalika (Yr2+) and HS207 (Yr9) have been released. For the plains of NW India, the target area, a number of varieties have been identified, namely, WL711 (Yr2), Arjun (= HD2009), Raj 1482 (both Yr2+), CPAN1992 (Yr9). The genetic basis of the yellow rust resistance in these cultivars indicate an over-dependance on Yr2 and Yr9, and the need for greater gene diversification is essential for yellow rust of wheat. In the case of resistance to brown rust no such conclusion could be drawn. Brown rust occurs all over the country and of the material listed in Table - 4 only 11 are released varieties for six different zones.

The stem rust resistance base also seems to be dependant on Sr5, Sr7a, Sr8, Sr11 and Sr31 in various combinations. This study indicates that a few resistance genes are frequent in Indian wheat cultivars. However, these observations cannot be used to generalise that the resistance base of Indian wheats is narrow, because it is possible that adult plant resistance genes that are not easily identifiable may also be present. It further indicates the over dependance of the Indian wheat programme on CIMMYT/North American sources for rust resistance. To widen the base, embarking on a systematic programme to incorporate specific combination of resistance genes as followed in Australia, is suggested. Use of varieties of Chinese, Australian or European

origin in crosses apart from following diverse approaches in breeding for rust resistance, is likely to broaden the rust resistance base of Indian wheats.

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Table: - 1 Races/virulences of wheat rust pathogens used in identifying the genes.

<u>P. graminis tritici</u>		<u>P. recondita tritici</u>		<u>P. striiformis</u>	
Race	Virulence	Race	Virulence	Race	Virulence
11A	203G15	10	13R19	13	67S8
14	16G2	12-1	5R37	20A	70S64
15	58G15	12-2	1R5	31	67S64
17	73G7	63	OR8-1	38	66S0-1
21	9G5	77	45R31	57	OS0
21A-1	20G21	77-1	109R63	A	70S4
21A-2	75G5	77A	109R31	G	4S0
24	18G3	77A-1	109R23	I	38S102
24A	5G19	104	17R23	K	47S102
34	26G13	104B	29R23		
40	104G13	107	45R3		
40A	62G29	108	13R27		
42	19G35	162	93R7		
42B	7G35				
117	37G3				
117A-1	38G18				
117A	36G2				
122	7G11				
184	53G1				
295	7G43				





Puccinia graminia tritici

Table 2 continued

Sr8; Sr11	:	HP	1518	12	0	4	1	Sr8+Sr11+
Sr31	:	CPAN 1922**	17	17	0	0	0	Sr31
		CPAN 1922**	17	17	0	0	0	Sr31
		HUW 258**	17	17	0	0	0	Sr31
		HS 207**	17	17	0	0	0	Sr31
		ISWYN 9**	17	17	0	0	0	Sr31
		ISWYN 15**	17	17	0	0	0	Sr31
		ISWYN 22**	17	17	0	0	0	Sr31
		ISWYN 41**	17	17	0	0	0	Sr31

\*\* Based on the postulation that Lr26 is tightly linked with Yr9 and Sr31.

Table-3 Resistance genes of eleven common varieties involved in the parentage of Indian wheats and the resistance genes present in them.

S. No.	Variety	Parentage**	Gene(s) present	Reference
1.	Kalyansona (=8156; HD1593)	<u>PJ'S'</u> / <u>GB55</u>	<u>Yr2</u> , ( <u>Lr3</u> ), <u>Sr6</u> , <u>Sr11</u>	Perwaiz and Johnson (1986); Luig (1983)
2.	LR64	<u>Y50/N10B</u> // <u>L52/3/2*LR</u>	( <u>Yr2</u> ), <u>Sr2</u> , <u>Sr6</u> , <u>Sr7b</u> , <u>Sr9a+</u>	Luig (1983)
3.	Penjamo	<u>PKN/N10B</u> 126. IC	( <u>Yr2</u> , <u>Lr1</u> , <u>Lr3</u> ) <u>Sr8</u> , <u>Sr9b</u>	Luig (1983)
4.	Pitic 62	<u>YT54/N10B</u> 126. IC	( <u>Yr2</u> , <u>Lr1</u> , <u>Lr3</u> ) <u>Sr5</u> , <u>Sr6</u> , <u>Sr8</u> , <u>Sr9b</u>	Luig (1983)
5.	Sonalika	<u>II54-388/AN/3/YT54/N10B/Lr64</u>	<u>Yr2+</u>	McIntosh PC
6.	Sonora-64	<u>YT54/N10B</u> // <u>2*Y54</u>	( <u>Yr2</u> , <u>Lr3</u> ) <u>Sr5</u> , <u>Sr11</u>	Luig (1983)
7.	Kavakz		<u>Yr9</u> , <u>Lr26</u> , <u>Sr31</u> , <u>Sr5</u>	Luig (1983) McIntosh (1983)
8.	Yaktana 54	<u>Y48/KT48</u> // <u>FN</u>	( <u>Lr1</u> , <u>Lr3</u> , <u>Sr8</u> )	
9.	HD2160	<u>MASOC*3/YT54/N10B</u>	( <u>Yr2</u> , <u>Lr1</u> , <u>Lr3</u> , <u>Sr5</u> , <u>Sr8</u> )	
10.	Bajio 66	<u>S64A</u> // <u>TAPP/NAI60</u>	( <u>Lr10</u> ) <u>Sr11</u>	McIntosh (1983)
11.	Inia 66	<u>LR64/SON64</u>	<u>Sr8</u> , <u>Sr9a</u> , <u>Sr11+</u>	Luig (1983)

\*\* Parentage coding refer (Villareal and Rajaram 1984).  
'S' Selection

() Denotes genes present, indicated by known and confirmed parental lines that are underlined.  
Conclusive experimental proof for the postulated genes not available.

Table - 4 Details or the parentage of the lines where  $\overline{Yr}$ ,  $\overline{Lr}$  and  $\overline{Sr}$  genes have been postulated.

S. No.	Variety	Cross/pedigree	Postulated gene(s)	Remark/possible source
1.	BAU2191	K7340/HP1209	$\overline{Lr1+Lr3+}$	HP1209=E4871/PJ62 E4871=N10B-E17/Y53/Y50//KT54 RR21=SKA
2.	BR298	TD-RR21	$\overline{Yr2+}$	RR21=SKA
3.	BR322	Supressa/SKA	$\overline{Lr1+Lr3+}$	SKA=I154-388/AN/3/YT54/N10B/LR64
4.	BR326	CNO'S'-8156/Y50E-8156//KAL	$\overline{Sr5+Sr11}$	Y50=NTH/Marroqui NTH=TH/Hope
5.	BR346	HD1982/SA42pt-19-3	$\overline{Sr5+Sr8}$	HD1982=E5557/HD845 E5557=P-61IV-2134 YT54
6.	BR2074	BR2002/SKA	$\overline{Lr1+Lr3}$	
7.	CPAN1869	MD/N-K117/FR KAD	$\overline{Lr14a}$	N=TH/Hope
8.	CPAN1922	Ove-FL158-FDL/MFN'S'/TIB63//Cararazque	$\overline{Yr9, Lr26, S 31}$	has 1B/1R translocation
9.	CPAN1992	BOW'S'=AU/KAL//BB/WOP'S'	$\overline{Lr26+}$ $\overline{Yr9, Sr31}$	" "
10.	DL230-6	K7537/HD2160	$\overline{Lr1+Lr3}$	
11.	DWR-61	KAL-SKA/TOB66-31330	$\overline{Lr1+Lr3}$	
12.	HB618	KAL/HW113//HB208	$\overline{Yr2+}$	
13.	HD2009	LR64A/NA169	$\overline{Yr2+}, \overline{Lr10}$	(Arjun)
14.	HD2307	HD2160/116-1-3	$\overline{Yr2+}$	
15.	HD2329	HD1962-E4870-K65/HD1553//UP262	$\overline{Lr10+}$	UP262=S308/BJ66
16.	HD2428	HD1949/HD2160	$\overline{Lr1+}$	HD1949=YT54-N10B/NP852

Contd...../

Table 4 Continued

17.	HDR17	PI62/WL410	Lr3+, Sr5+Sr8+	WL410=(S63-S326)/KAL
18.	HI977	GLT-Aust-61 157/CNO	Lr10+	
19.	HI1076	GLT Aust II-61- 151-CN066-KAL-BB	Lr3+	
20.	HP1102	8156(B)/NAD63	Lr1+Lr3	NAD63=PJ2* Y54
21.	HP1209	E4871/PJ62	Sr5+Sr11+	N=TH/Hope E4871=N10B/Y53/Y50/KT54
22.	HP1518	UPK1/HP1102	Sr8+Sr11+	HP1102=8156/NAD63 NAD63=PJ/2*Y54
23.	HS86	E6160/S227//S308	Yr2+	
24.	HS159	HS1076/SKA	Yr2+	
25.	HS207	KVZ/BUHO//KAL/3/BB	Yr9, Lr26+, Sr31	has 1B/1R translocation
26.	HUW213	(NOR/MotL)/HD2160	Lr14a+	
27.	HUW243	WL711/CPAN1980// 2*WL711	Sr5+Sr7a Sr11	WL711=S308-CHR/KAL
28.	HUW258	KAL/LFE/KVZ	Yr9, Lr26+, Sr31	has 1B/1R translocation
29.	HUW269	Furry/KAL//BB	Lr3+	
30.	HUW271	HD2160/WH147	Lr3+	
31.	ISWYN 9	Veery's'	Yr9, Lr26+, Sr31	has 1B/1R translocation
32.	ISWYN 15	Veery's'	Yr9, Lr26+, Sr31	" "
33.	ISWYN 22	Veery 4 (Mex20)	Yr9, Lr26+, Sr31	" "
34.	ISWYN 41	Veery 2	Yr9, Lr26+, Sr31	" "

Contd....//

Table 4 Continued

35.	ISWYN 44	Veery's'	Yr9, Lr26+, Sr31	has 1B/1R translocation
36.	Janak (HD1982)	E5557/HD845	Lr1+Lr3	E5557=p-61 IV-213 Yr54
37.	K8020	KAL/HD1982	Yr2+, Lr1+	
38.	K8230	K816/K65/WL410	Sr5+Sr11+	WL410=(S63-S326)/KAL
39.	K8237	HD2160/K68	Sr5+Sr11+	HD2160=MASOC*3/Yr54/ N1OB-Calidad-TOB-CFN HD1949 TOB=BAJ67/S64
40.	Kalyansona	FN-K58-NTH/N1OB// GB55	Yr2	
41.	Lok-1	S-308/S331	Yr2	
42.	N18272	HD2012/P162// HD2012	Yr2+	
43.	N18289	HD2012/P162// HD2012	Yr2+	
44.	N18303	" "	Yr2+	
45.	N18306	" "	Yr2+	
46.	N18668	" "	Lr3+	
47.	Raj 1482	NAPO-TOB'S/ 8156//KAL-13-8	Yr2+	
48.	Raj 1555	Cocorit's'/Raj911	Yr7	Cocorit has Iumillo(?)
49.	Raj 1944	HD2009/Raj 821	Yr2+	HD2009=Lr64A/NA160
50.	Sonalika	I154-388/AN/3/ Yr54/N1OB//Lr64	Yr2+	
51.	VL 421	S64/Y50E GTO	Yr2+, Lr3+Lr15, Sr5+Sr11+	Y50=NTH/Marroqui NTH=TH/Hope
52.	VL 602	VL 404/CPAN1283	Yr2+, Lr14a	VL404=KT/BG/FN/U/ St-404-PJ-74160-II- 15079
53.	WL 711	S308/chris//KAL	Yr2	

Underlined genotype possibly contributed to the resgene in question.

PREVALENCE AND DISTRIBUTION OF PHYSIOLOGIC RACES OF LEAF RUST (*Puccinia recondita* Rob. ex. Desm.) IN PENINSULAR INDIA DURING 1982-83 AND

1983-84

BY

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SUMMARY

Racial analyses indicated that the race complexes 12, 77, 162 and races 10, 104, 108 of leaf rust (*Puccinia recondita* Rob. ex. Desm.) were prevalent during the years 1982-83 and 1983-84. The races 77, 77A 77A1, 77B, 12 and 162 were found predominant in Peninsular India.

INTRODUCTION

Breakdown of resistance of a newly developed rust resistant wheat variety after its wider adaptation on farmers field is a frequent phenomenon. This is due to the vast potential of the genetic variability in the rust pathogen through parasexuality and mutation, particularly in India. The survey and monitoring of the rust race flora pattern of leaf rust pathogen (*Puccinia recondita* Rob. ex. Desm.) is therefore of much importance. The information on the race flora of the pathogen in a particular area is essential for implementing suitable breeding programmes. Hence the occurrence and distribution of the races of wheat leaf rust in nature during 1982-83 and 83-84 crop season in Peninsular India are presented in this paper.

MATERIALS AND METHODS

Leaf rust infected samples were received from different States viz: Tamil Nadu, Karnataka, Gujarat, Andhra Pradesh and also trap nurseries in different locations. These were established on the susceptible variety 'Molta' in a glasshouse. They were analysed on a set of international differentials for leaf rust (Johnston and Mains, 1932) with the addition of some other varieties as supplementary differential hosts.

RESULTS AND DISCUSSION

The prevalence and frequency pattern of different races of leaf rust in the States are presented in Table 1.

Race complexes 12, 77 and 162 were found to be prevalent during the years 1982-83 and 1983-84. Races 10, 104 and 108 of leaf rust were detected only during 1983-84 with lower frequencies. Rust samples were received for analysis from the States of Maharashtra,

Karnatak and Tamil Nadu during 1982-83 and 1983-84 as there was no rust incidence in the States of Gujarat and Andhra Pradesh. Race 10 was prevalent in the Karnatak and Tamil Nadu states only while race 108 was found only in Maharashtra. In fact Tamil Nadu and Karnatak states are known to be the main foci of infection for Peninsular India (Nagarajan and Joshi, 1980) but the race flora of Maharashtra State and these former two did not remain similar. The prevalence for the years 1978 to 1980 of races 12B and 104B was reported by Bahadur et al. (1982). They also reported the dominance of race complex 104 followed by race 77 and biotype 77A. Race complex 77 was reported to be prevalent during 1981-82 in which biotype 77A predominated in Southern States of India by More et al. (1985).

Biotype 77B was most prevalent followed by 77A, 12A and 162A during the year 1982-83. Biotype 77A predominated during 1983-84 followed by 77 and 77A1. Though races 10, 77B, 104, 108 and 162 were detected their per cent frequencies were very low during the year 1983-84 (Fig. 1).

Cultivation of the wheat variety Sonalika on a large scale favoured rapid development of the race 77 complex. It is also virulent on a number of other cultivars in use viz; Kalyansona, HD 2189, NI 5439, NI 5643, NI 747-1 9, MACS 9, C 306, CPAN 1734, WL 711, DWR 39, WG 777 and VL 401.

The race analysis indicated that the extensive cultivation of a large number of resistant varieties in different states favoured development of new virulences of few race complexes virulent on the varieties under wide cultivation. Therefore there is a need to develop wheat genotypes with a broad genetic base.

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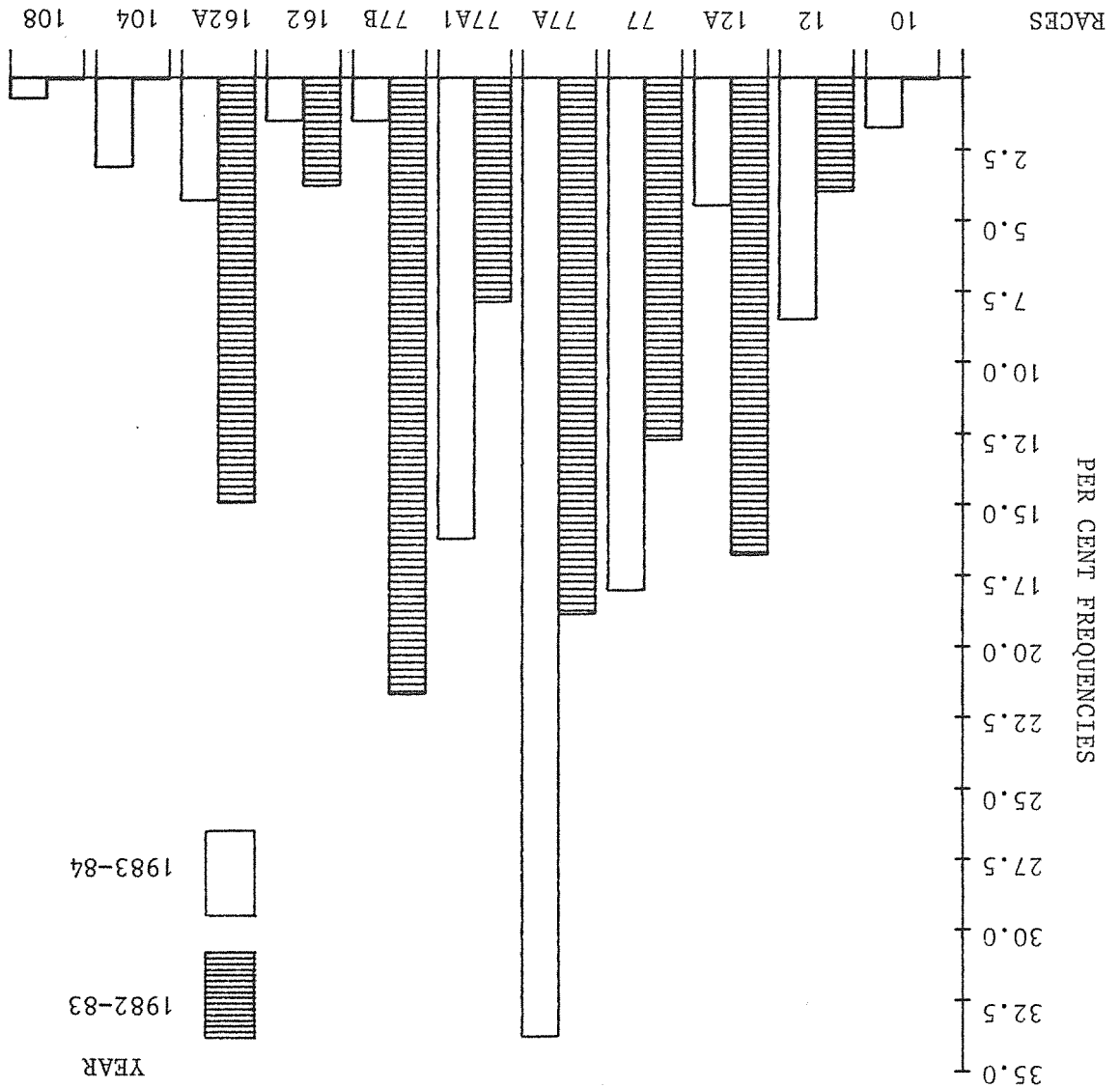
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Table 1. Prevalence and per cent frequencies of races of leaf rust (Puccinia recondita Rob. ex. Desm.) in Peninsular India during 1982-83 and 1983-84.

State	No. of samples	1982-83		1983-84	
		Races detected	No. of samples	Races detected	No. of samples
Tamil Nadu	25	12(1)*, 77(2), 77A(7), 77A1(3), 77B(2), 162(2), 162A(18)	31	10(1), 12(5), 12A1(6), 77(7), 77A(10), 162A(2)	
Karnataka	40	12(2), 12A(1), 77(10), 77A(7), 77A1(4), 77B(13), 162A(3)	63	10(1), 12(14), 12A(2), 12A1(1), 77(7), 77A(23), 77A1(18), 77B(2), 104(2), 162(2), 162A(1)	
Andhra Pradesh	10	77B(3), 77A(2), 77B(4), 162(1)	-	-	
Maharashtra	77	12(5), 12A(3), 77(7), 77A(13), 77A1(3), 77B(14), 162(5), 162A(17)	19	12(1), 12A(3), 77(5), 77A(4), 77A1(2), 104(1), 108(1), 162A(2)	67
Gujarat	18	12A(5), 77(1), 77A(4), 77A1(1), 77B(4), 162A(3)	-	-	
Madhya Pradesh	11	12A(5), 77A1(3), 77B(2), 162A(1)	1	77A1(1)	
Consolidated % Frequencies	181	12(3.85)**, 12A(17.15), 77(12.70), 77A(18.25), 77A1(7.70), 77B(21.59), 162(3.85), 162A(14.95)	114	10(1.75), 12(8.50), 12A(4.30), 12A1(5.95), 77(17.7), 77A(33.7), 77A1(16.9), 77B(1.75), 104(2.55), 108(0.85), 162(1.75), 162A(4.30)	

\* , \*\* Figures showing frequency and per cent frequencies of respective races over total samples.

Fig 1. Per cent frequencies of leaf rust races during 1982-83 and 1983-84.



PREVALENCE AND DISTRIBUTION OF PHYSIOLOGIC RACES OF WHEAT RUSTS IN  
PENINSULAR INDIA DURING 1984-86

BY

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Monitoring the new virulence in rust pathogen is an endless process. Surveys of wheat crops for collection of rust samples are also useful to intercept new and virulent races or biotypes as soon as they appear in nature.

Surveys were under taken of the wheat growing areas of the

states of Tamil Nadu, Karnataka, Andhra Pradesh, Maharashtra, Gujarat and Madhya Pradesh during 1984-85 and 1985-86. Samples of stem rust (*Puccinia graminis* f. sp. tritici Erik and Henn) and leaf rust (*Puccinia recondita* Rob. ex. Desm.) were collected. The inoculum of the samples were multiplied on susceptible wheat varieties and were analysed on a set of standard international differential hosts for stem rust (Stakman and Levine, 1922) and leaf rust (Johnston and Mains, 1932) with the addition of some other varieties of wheat as supplementary differential hosts.

The prevalence and frequency pattern of different races of stem and leaf rust in the States are presented in Table 1.

The year 1984-85 was a rust free year. Only two samples each

of stem and leaf rust from Karnataka state could be collected. On

analysis these samples yielded races 40 of stem rust and 106 of leaf

rust.

Races 77, 77A and 77B of leaf rust were encountered during the

year 1985-86 in Tamil Nadu, Karnataka and Maharashtra states. Race

162 of leaf rust was detected only in Maharashtra during this year.

Race 15C, 40, 40A 42B2, 117, 117A and 122 of stem rust were detected

during the same period from the above mentioned states of Southern

India.

Races 15C and 122 were confined to Tamil Nadu while 42B2 to

Maharashtra state.

It is noteworthy that race 106 of leaf rust was detected after

a very long time during 1984-85 in Karnataka. This race had a very

low frequency as already reported (Singh et al., 1978). The frequency

of race 77A (73.0) was the highest followed by race 77B (25.75) during

the 1985-86. Though race 77 (0.6) and 162 (0.6) were detected their

frequencies were too low.

Race 40A (43.0) of black rust was found to be predominant with

high frequency followed by 117A (20.43) and 40 (15.0). The races 15C

(8.6), 42B2 (2.15), 117 (6.45) and 122 (4.30) were detected with low

frequencies.

This study revealed that race complex 40 and 117 of stem rust

and 77 of leaf rust occurred at the highest frequencies, and suggest

the need for deploying the genes for developing rust resistant

varieties to overcome their menace.

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Table 1. Prevalence and distribution of races of leaf rust (*Puccinia recondita* Rob. ex. Desm.) and stem rust (*Puccinia graminis* f. sp. *tritici* Erik and Henn) in Peninsular India during 1984-86

State	Leaf rust				Stem rust			
	No. of samples	Races	No. of samples	Races	No. of samples	Races	No. of samples	Races
Tamil Nadu	-	-	9	77A(4)*, 77B(5)	-	-	52	15C(8), 40A(36) 117A(4), 122(4)
Karnataka	2	106(2)	61	77A(61)	2	40(2)	10	40A(4), 117(6)
Andhra Pradesh	-	-	-	-	-	-	-	-
Maharashtra	-	-	89	77(2)77A(51) 77B(36)162(1)	-	-	31	40(14), 42B2(2) 117A(15)
Gujarat	-	-	-	-	-	-	-	-
Madhya Pradesh	-	-	-	-	-	-	-	-
Consolidated % Frequencies	2	106(10)	159	77(0.6)**, 77A(73.0), 77B(25.75) 162(0.6)	2	40(100)	93	15C(8.6), 40(15), 40A(43.0) 42B2(2.15), 117(6.45), 117A((20.43), 122(4.3)

\*, \*\* Figures in parenthesis indicates frequencies and % frequencies of the races.

BROWN RUST ON WHEAT IN NORTH BULGARIA  
FOR THE PERIOD 1979-1985

by

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Development of resistant winter soft wheat varieties preserving the resistance to brown rust for a long period, is possible only with a very good knowledge of the virulence and the genetic nature of the pathogen population variability. Therefore, attention must be given to the genes for virulence. With knowledge of the gene pool and the genetic pattern of the brown rust virulence it is possible to study patterns of their dynamics in nature.

The genetic pattern of the population virulence of the brown rust pathogen was investigated on wheat in North Bulgaria for the period 1979-1985. Studies were conducted of 14 monogenic lines carrying the following genes for resistance:

- Lr 1 (Thatcher<sup>6</sup> x Centenario)
- Lr 2a (Thatcher<sup>6</sup> x Webster)
- Lr 2d (Prelude<sup>6</sup> x Loros)
- Lr 3 (Thatcher<sup>6</sup> x Demokrat)
- Lr 9 (Thatcher<sup>6</sup> x RL 6010)
- Lr 10 (Thatcher<sup>6</sup> x Exchange CLR 1-3)
- Lr 12 (Thatcher<sup>6</sup> x Exchange)
- Lr 13 (Thatcher<sup>6</sup> x Frontana)
- Lr 16 (Thatcher<sup>6</sup> x Exchange CLR 11-12)
- Lr 17 (Klein Lucero x Thatcher<sup>6</sup>)
- Lr 18 (Thatcher<sup>7</sup> x Africa 43)
- Lr 19 (Thatcher RL 6040)
- Lr 23 (Lee 130 x Thatcher<sup>6</sup> RL 6012)
- Lr 24 (Agent)

The infection types of the monogenic lines to the fungus are determined according to the scale of Mains and Jackson (1926). The gene pool of the population virulence of the pathogen was studied in 932 monosolates.

From the researches (Dodov, D and Gospodnova, 1973; Donchev, 1964; Donchev, 1967) made for the period 1959-1962 it was established that the most widely spread races were 13, 20, 77, 122. Investigations made later showed a significant increase of race 77 reaching 87.96% frequency in 1977 (Gospodnova, 1980).

The studies (Casulli et al. 1984) showed that race 77 prevailed in South Italy. The investigation for a longer period (Pasquini and Ziteilli, 1984), showed that some of the races that were widely distributed in Italy, such as 12, 61, 77 occurred also in Bulgaria.

In the investigation of Rizvi et al. (1984) it was indicated that race 77 prevailed in the racial diversity of Pakistan, followed by races 117, 144, 149. Race 77 prevailed also in some Near East countries as Lybia, Egypt, Turkey, Iran, Afghanistan and also in some neighbours of India.

The studies carried out for the period 1979 - 1985 in North Bulgaria showed that race 77 had the highest incidence (Table 1). A significant incidence in single years was established also in races 58, 61, 167, 176. In 1982 race 58 reached 26.37% while in 1983 race 61 reached 44.51%. Race 167 was most widely distributed in 1984 and race 176 in 1980. Race 122 was of less importance in the years of investigation. The other races established in that period were of little importance.

The studies conducted on the genetic virulence of the pathogen (Table 2) showed that many isolates were virulent on the majority of Lr genes tested. From the frequency of occurrence of virulence for the single Lr genes in the course of 7 years of investigations, a wide diversity of the pathogen population was established. A high frequency was recorded (up to 100%) of genes of virulence p12, p13, p24. No isolates were recorded in the fungus population with virulence for the isogenic lines with genes Lr9 and Lr19. These results for the Lr9 and Lr19 genes providing a high resistance are in agreement with the data of many workers in other countries, however the gene Lr9 was not completely effective in Pakistan.

In the years of investigation, the most frequently occurring avirulence/virulence formula was: 9,10,19,23/1,2a,2d,3,12,13,16,17,18,24 (26.39%), followed by the formula: 9,19,23/1,2a,2d,3,10,12,13,16,17,18,24 (17.70%). The formulae 1,2a,9,19,23/2d,3,10,12,13,16,17,18,24; 1,2a,9,19,23/2d,3,12,13,16,17,18,24 and 1,9,16,19,23/2a,2d,3,10,12,13,17,18,24 were 7.35%, 6.72%, 4.47% respectively. These were followed by the formula 9,19,16,19,23/2a,2d,3,12,13,17,18,24 with 4.40%. Other formulae were recorded but were an insignificant percentage of the pathogen population.

As a result of the tests, 35 different virulence combinations were detected in the population of the brown rust pathogen on wheat. (Table 3). Till now the isogenic lines Lr 9 and Lr 19 had not lost their effectiveness. Line Lr 23 was highly effective. A very high effectiveness was shown by the lines Lr1 (40.67%) and Lr10 (39.91%). A lower effectiveness the lines Lr 2a (12.98%) and Lr16 (12.23%). The other isogenic lines were rarely effective: Lr 2d (0.21%), Lr 3 (1.07%), Lr 17 (5.68%), Lr 18 (3.33%). Non-effective in juvenile stage were lines Lr12, Lr13, Lr24.

### CONCLUSIONS

Of the studies made for the period 1979 - 1985 it was established:

1. Race 77 was of highest incidence.
2. The resistance of isogenic lines Lr 9 and Lr 19 was not overcome. A very high resistance was observed in line Lr23. Lines Lr1 and Lr10 expressed a good effectiveness. Lr 2a and Lr 16 were partly effective. Lines Lr 17, Lr 18, Lr 3 and Lr 2d were with insignificant and low effectiveness. Non-effective were the isogenic lines Lr 12, Lr 13, Lr 24.

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TABLE 1 : Races of leaf rust in 1979 - 1985 in Bulgaria

Race	Detected races													
	1979		1980		1981		1982		1983		1984		1985	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
12	3	2.86	-	-	-	-	-	-	-	-	-	-	-	-
20	-	-	-	-	3	3.03	2	2.20	1	0.58	-	-	2	1.21
21	22	20.96	42	22.83	-	-	-	-	-	-	9	6.08	15	9.09
54	2	1.90	2	1.09	-	-	-	-	-	-	-	-	-	-
57	2	1.90	-	-	-	-	-	-	-	-	-	-	-	-
58	9	8.57	6	3.27	1	1.01	24	26.37	24	13.87	8	5.40	17	10.30
61	3	2.86	1	0.54	41	41.41	10	10.99	77	44.51	2	1.35	-	-
62	-	-	-	-	4	4.04	-	-	-	-	-	-	-	-
77	41	39.05	50	27.17	42	42.42	38	41.76	41	23.70	48	32.43	114	69.09
84	4	3.81	1	0.54	-	-	-	-	-	-	-	-	-	-
122	4	3.81	14	7.61	2	2.02	6	6.59	2	1.16	8	5.40	4	2.42
130	1	0.95	1	0.59	-	-	-	-	-	-	-	-	-	-
143	1	0.95	-	-	-	-	-	-	-	-	-	-	-	-
144	-	-	-	-	1	1.01	-	-	-	-	-	-	3	1.82
147	-	-	-	-	-	-	1	1.10	3	1.74	-	-	-	-
149	1	0.95	1	0.54	-	-	7	7.69	8	4.62	1	0.67	9	5.45
167	-	-	14	7.61	5	5.05	1	1.10	8	4.62	46	31.08	-	-
176	4	3.81	31	16.85	-	-	1	1.10	9	5.20	25	16.89	1	0.61

TABLE 2 : Gene races of leaf rust in 1979 - 1985 in Bulgaria

Virulence Group	Avirulence/Virulence formula	Frequency in %								Average 1979-1985
		1979	1980	1981	1982	1983	1984	1985	10	
1	2	3	4	5	6	7	8	9	10	
1	1,2a,9,16,19,23/2	2.86	0.54	15.15	2.19	9.83	13.51	0.47		
2	1,2a,9,19,23/2,3,10,12,13,16,17,18,24	2.86								
3	1,2a,9,10,19,23/2,3,12,13,16,17,18,24			11.11	17.58	10.98	0.67			
4	1,2a,9,10,16,17,18,19,23/2,3,12,13,24			1.01						
5	1,2a,9,17,19,23/2,3,10,12,13,16,18,24				1.09	1.16				
6	1,2a,9,10,16,19,23/2,3,12,13,17,18,24				1.09	1.73				
7	1,2a,9,10,17,19,23/2,3,12,13,16,18,24					1.73				
8	1,2a,2,3,9,10,17,19,23/12,13,16,18,24			1.01						
9	1,2,9,10,16,19,23/2a,3,12,13,17,18,24					0.58				
10	2a,9,19,23/1,2,3,10,12,13,16,17,18,24			1.01		2.02				
11	1,9,19,23/2a,2,3,10,12,13,16,17,18,24	20.00	29.73	18.18	9.89	13.87	29.05	6.67	17.70	
12	1,9,10,19,23/2a,2,3,12,13,16,17,18,24		1.62	6.06	4.40	12.72	0.67	3.03	4.07	
13	1,9,10,18,19,23/2a,2,3,12,13,16,17,24		0.54		1.09				0.27	
14	1,9,18,19,23/2a,2,3,10,12,13,16,17,24		1.08						0.18	
15	1,9,17,19,23/2a,2,3,10,12,13,16,18,24					9.78	2.02	0.60	1.72	
16	1,9,10,16,19,23/2a,2,3,12,13,17,18,24					4.05			0.67	
17	1,9,16,19,23/2a,2,3,10,12,13,17,18,24					1.16	25.67		4.47	
18	1,9,10,16,17,19,23/2a,2,3,12,13,18,24					0.58			0.10	
19	1,9,16,17,19,23/2a,2,3,10,12,13,18,24					0.58			0.10	
20	9,19/1,2a,2,3,10,12,13,16,17,18,23,24	5.71							0.95	
21	9,10,19/1,2a,2,3,12,13,16,17,18,23,24		0.54						0.09	
22	9,10,19,23/1,2a,2,3,12,13,16,17,18,24	8.57	24.86	24.24	32.97	18.42	14.19	26.39	53.33	
23	9,10,16,18,19,23/1,2a,2,3,12,13,17,24	2.86	1.08					0.65	1.21	

TABLE 2 (Contd.): Gene races of leaf rust in 1979 - 1985 in Bulgaria

Virulence Group	Avirulence/Virulence Formula	Frequency in %									
		1979	1980	1981	1982	1983	1984	1985	Average 1979-1985		
1	2	3	4	5	6	7	8	9	10		
24	9,10,16,17,19,23/1,2a,2,3,12,13,18,24	2.86								0.47	
25	9,10,16,17,18,19,23/1,2a,2,3,12,13,24	5.71								0.95	
26	9,10,16,19,23/1,2a,2,3,12,13,17,18,24	20.00	1.62							3.63	
27	9,19,23/1,2a,2,3,10,12,13,16,17,18,24	28.57	26.48	17.17	13.19	13.87	6.76	18.99	24.84	24.84	
28	9,18,19,23/1,2a,2,3,10,12,13,16,17,24		0.54	1.01	2.19	0.58			0.72	0.72	
29	9,10,18,19,23/1,2a,2,3,12,13,16,17,24		1.62					0.30	4.84	4.84	
30	9,17,18,19,23/1,2a,2,3,10,12,13,16,24			1.01					0.17	0.17	
31	9,16,18,19,23/1,2a,2,3,10,12,13,17,24				3.29				0.55	0.55	
32	9,10,17,19,23/1,2a,2,3,12,13,16,18,24				2.19				0.36	0.36	
33	9,17,19,23/1,2a,2,3,10,12,13,16,18,24				4.73			0.86	1.21	1.21	
34	3,9,19,23/1,2a,2,10,12,13,16,17,18,24			3.03					0.51	0.51	
35	3,9,10,19,23/1,2a,2,12,13,16,17,18,24				3.29	1.16		0.85	1.21	1.21	

TABLE 3 : Effectiveness in % of isogenic lines of brown rust for the period 1979-1985 in Bulgaria.

No.	Effectiveness (%)	Isogenic lines	
		No.	%
1	40.67	379	
2	12.98	121	
3	0.21	2	
4	1.07	8	
5	39.91	372	
6	-	-	
7	-	-	
8	12.23	114	
9	5.68	53	
10	3.33	31	
11	-	-	
12	100	932	
13	100	932	
14	99.36	926	

POSTULATED GENES FOR RESISTANCE TO YELLOW RUST IN CZECHOSLOVAKIAN  
WHEAT CULTIVARS

BY<sup>1</sup>

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INTRODUCTION

In Czechoslovakia resistance to the occurring races of the yellow rust pathogen *Puccinia striiformis* West. is required for registration of new cultivars. This requirement has been in force for twenty years and has practically eliminated losses due to yellow rust. Breeding for resistance is based on selection in the field in rust nurseries. However, little is known so far about the genes governing their yellow rust resistance. Many Czechoslovakian cultivars are derived from crosses between West- and East-European cultivars. In this paper results of tests on seedlings in the glasshouse at the Plant Breeding Institute, Cambridge (PBI) and tests in race nurseries in the field performed by the Research Institute for Plant Protection, Wageningen (IPO) are reported. Based on Flor's gene-for-gene hypothesis and by comparison between reactions of the tested cultivars and those of cultivars with known genes for resistance, the presence of certain identified resistance genes is postulated in the cultivars. The pedigrees of cultivars were also considered in these postulations.

MATERIALS AND METHODS

Tests of seedlings were conducted at the PBI using methods similar to those described by Perwalz and Johnson (1986). Seedlings of wheat cultivars were grown in a glass house with filtered air and inoculated with urediospores of single isolates of *P. striiformis* dispersed in talc when the first leaves were fully expanded and the second leaf starting to emerge. They were then placed in a dark, humid chamber at 10°C for at least 24 h before being returned to the glasshouse. Tests were carried out in spring 1986 (March-June) when temperatures in the glasshouse usually ranged between about 10°C at night up to a maximum of 30°C on sunny days but usually about 20°C. The seedlings (first leaf and occasionally also the tip of the second leaf) were scored for infection type between two and three weeks after inoculation, using a Fleck, resistant) to 4 scale. Susceptible infection types (3-4) are designated in Table 1 by S, resistant; -2+ by R or blank and

variable intermediate reactions by M. Eighteen races of P. striliforms were used in the glasshouse tests, listed in Table 1 according to the nomenclature system proposed by Johnson et al (1972). In the Netherlands the cultivars were tested in race nurseries (Zadoks, 1961) inoculated with 13 races, in 1986. Single nurseries were grown at a satisfactory distance isolated by rape to minimize the risk of cross-contamination. Disease severity as % leaf area infected was assessed on three dates at 10 day intervals of which the last assessment is given in Table 2.

Seventeen Czechoslovakian and two Russian cultivars licensed in Czechoslovakia, all winter wheats, were tested in the glasshouse trials. In the field trials nine Czechoslovakian cultivars were included.

The Catalogue of gene symbols for wheat (McIntosh, 1983) was the source of information on Yr genes in the cultivars under discussion.

Table 1 shows glasshouse reactions of the standard differentials and those of the tested cultivars. Results obtained in the race nurseries in the Netherlands are summarized in Table 2.

Cv. Hana, pedigree/NS 984-1 x Mironovskaya 808 x Molsson//, parents of Hana, Mironovskaya 808 does not possess Yr2 and the resistance of Molsson has not been studied. However, Yr2 may be derived from NS 984-1 because one of its parents is Bezostaya 1, some stocks of which may possess Yr2 (Negulescu and Johnson, 1974).

Cv. Slavia has the same reaction pattern as Hana and Helnes VII suggesting the presence of Yr2. Its official pedigree indicating cvs Mironovskaya 808 and Bezostaya 1 as parents is not correct. Its reactions to leaf and stem rust are incompatible with this pedigree. However, the correct pedigree is not known and the origin of Yr2 cannot be deduced for Slavia.

Cv. Vignita //Norin 75 x Alba/ x Ilyitchovka/ reacts similarly to cultivars with Yr2 but, in addition it is resistant to races 37E132 and 39E134 like e.g. Vilmorin 23 which may possess the genes Yr3a + Yr4a. Vignita may therefore possess Yr2 + Yr3a + Yr4a. In the race nurseries (Table 2) Vignita displayed a relatively low severity (0 - 5%) with races having avirulence for Yr2 or Yr3a + Yr4a and a relatively high severity (15 - 25%) with races having virulence for those genes. This supports the postulation of these genes in Vignita. The maximum level of infection observed on this cultivar was only 25% and it may therefore be considered to possess some adult plant resistance in addition to the postulated genes.

Cv. Regina/Mironovskaya Yubileyaya 50 x Zora/ x Tadorna/ has a reaction pattern that corresponds to the combined effects of Yr1 + Yr2. The presence of Yr1 + Yr2 in Tadorna supports the postulation of these genes in Regina. In the race nurseries susceptibility of Regina to race 39E134 and resistance to other races indicates the presence of Yr1 + Yr2 + resistance derived from Helnes IV (H4) as in Tadorna (Stubbs, 1985).

Cv. Odra/Manella x Mironovskaya Yubileyaya 50/ probably possesses Yr2 reported in Manella (Stubbs, 1985) but also other gene(s) for resistance to yellow rust.

## RESULTS

Table 1 shows glasshouse reactions of the standard differentials and those of the tested cultivars. Results obtained in the race nurseries in the Netherlands are summarized in Table 2.

Cv. Hana, pedigree/NS 984-1 x Mironovskaya 808 x Molsson//, parents of Hana, Mironovskaya 808 does not possess Yr2 and the resistance of Molsson has not been studied. However, Yr2 may be derived from NS 984-1 because one of its parents is Bezostaya 1, some stocks of which may possess Yr2 (Negulescu and Johnson, 1974).

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Cv. Odra/Manella x Mironovskaya Yubileyaya 50/ probably possesses Yr2 reported in Manella (Stubbs, 1985) but also other gene(s) for resistance to yellow rust.

Cv. Zdar/Caribo x Derenburg St. 6290/ may have Yr3a + Yr4a and other gene(s). In the race nurseries susceptibility of Zdar to races 41E136 and 108E141 and resistance to other races corresponds with the reaction of Carstens V (CV) and may be derived from Caribo as reported by Stubbs (1985).

Cv. Kosutka ///Nebojska x Kosutka/ x Fleuron/ x Yaktana/ may have several genes for seedling resistance. However, the reaction pattern in Table 1 is difficult to interpret and no named genes can be postulated.

Cv. Agra/Purdue 66278 x SO 71-28/Aurora x S 985//  
Cv. Danubia//Aurora x S 985/ x Purdue 5517/  
Cv. Iris/Siete Cerros x Kavkas/  
Cv. Selektta/Slavia x Weihenstephan 378-57/  
Cv. Solaris/S985 x Kavkas/  
All these cultivars were resistant to races avirulent to Clement and susceptible to races with virulence for Clement. Clement carries the wheat-rye translocation chromosome 1B/1R which carries the gene Yr9. The same 1B/1R chromosome is present also in Aurora, Kavkas and Weihenstephan 378-57 which are the sources of Yr9 in these cultivars. Also, in the race nurseries, susceptibility of Danubia, Iris and Solaris only to races virulent to Yr9 supported the postulation of the presence of Yr9.

Cv. Roxana/Solo x Kavkas/  
Cv. Sabina/Weihenstephan 378-57-132b x Caribo/  
Both these cultivars were resistant to all the races used, including those with virulence for Yr9, except for a few susceptible plants. As shown in infection tests with selected leaf rust races, they have Lr26 which is linked with Yr9 (Bartos and Stuchlikova, 1986). In addition to Yr9 they must have other gene(s) effective to the races with virulence for this gene. Because of the different pedigrees of Roxana and Sabina, it is not likely that the additional genes are the same in both cultivars. In the race nurseries, Sabina was susceptible only to race 234E171 with virulence for both Yr9 and CV. The present of CV, resistance derived from Caribo (Stubbs, 1985) is therefore probable.

Cv. Mara/Moïsson x Mironovskaya Yubileyayna 50/ was susceptible to all races, except for a small number of plants that displayed resistant or intermediate reactions to some races in the glasshouse. There was a trend towards a lower infection type on the second leaf to some races but no known genes could be identified. In the race nurseries Mara was resistant to all races indicating that it possesses adult plant resistance.

Cv. Vala/Mironovskaya 808 x Moïsson/  
Cv. Heia/Mironovskaya 808 x Moïsson/  
Both these cultivars were susceptible to all the races except 108E25 to which some but not all plants showed seedling resistance due to unknown gene(s). In the race nursery with race 234E171 the severity in Vala and Heia was 1% and 0% respectively which indicates adult plant resistance of these cultivars.

Cv. Mironovskaya 808 and Mironovskaya Yubileyayna 50, both of Russian origin, were susceptible to all races on the first leaf but displayed a slight trend to a lower infection type on the second leaf. On the other hand some cultivars possessing Yr9 (Agra, Danubia, Iris, Roxana, Selektta, Solaris) showed a trend to a higher infection type on the second leaf, most marked in Iris which was classed as susceptible.

## DISCUSSION AND CONCLUSIONS

The most common gene for yellow rust resistance in the tested cultivars was Yr9 derived either from the Russian cultivars Aurora and Kavkaz or from the line Weihenstephan 378-57 from the Federal Republic of Germany in which the gene Yr9 was postulated earlier because of its linkage with Sr31 and Lr26 (Bartos and Stuchliková, 1986). In addition to this gene the cv. Sabina appeared to carry CV resistance. The cultivar Roxana also carries adult plant resistance in addition to Yr9. The gene Yr2 is the second most common gene in these cultivars and occurs either alone or in combinations with Yr1 + H4 or with Yr3a + Yr4a. Two of the cultivars possess CV resistance in combination either with Yr3a + Yr4a (Zdar) or with Yr9 (Sabina). It is possible that other genes than those carried by the standard differentials are also involved in the resistance of some of the cultivars. Several cultivars have adult plant resistance either alone or in addition to seedling resistance genes.

Finally, it should again be noted that, although the genes proposed to be present are considered to be very probable, it is only possible with this method alone to postulate but not to prove the presence of particular genes.

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TABLE 2 - Severity of yellow rust infection (scale 0-100%) in the race nurseries (last evaluation on 15 July)

Race	Differential Cultivars										Czechoslovakian Cultivars						
	Yr1	Yr2	Yr3a	Yr4a	CV	H4	Yr2	Yr3a	Yr4a	H4	Yr1	Yr2	Yr3a	Yr4a	CV	Yr9	
Chinese 166																	
Heine's VII																	
Bon Fermier																	
Clement																	
Tomboia																	
Heine's IV																	
Viginta																	
Regina																	
Zdar																	
Kosutka																	
Danubia																	
Iris																	
Solaris																	
Sabina																	
Mara																	

<sup>1</sup> Dippes Triumph variant  
<sup>2</sup> Leda variant

32E 0 <sup>1</sup>	1	0	25	1	0	70	0	0	5	5	1	10	5	5	0	0	10
32E 128 <sup>2</sup>	0	70	5	5	0	50	5	5	5	5	5	5	5	5	0	0	5
39E 134	100	70	70	1	0	50	5	50	5	5	5	5	5	5	0	0	15
41E 168	100	70	70	1	70	0	15	5	5	5	5	5	5	5	5	5	5
43E 138	100	70	70	1	0	35	25	35	15	0	0	0	0	0	0	0	5
105E 137	100	70	70	5	0	25	25	5	15	10	10	15	15	15	1	1	1
106E 139	1	70	70	5	0	25	25	0	10	0	10	10	15	15	1	1	0
108E 41	1	1	70	0	70	1	0	0	50	0	10	10	10	10	10	10	5
108E 141	0	70	70	5	1	25	25	0	10	0	10	10	15	15	-	-	5
169E 136	100	50	70	70	0	25	25	5	15	1	1	100	70	70	40	40	5
232E 137	0	50	70	70	0	15	15	0	5	1	1	70	70	70	50	50	5
234E 139	1	50	70	70	0	15	15	0	10	1	1	90	70	70	50	50	1
234E 171	0	50	70	70	50	10	50	5	5	1	1	70	70	70	50	50	1