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IDENTIFICATION OF RESISTANCE GENES AGAINST *ERYSIPHE GRAMINIS TRITICI* IN INDIAN AND EXOTIC WHEATS

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ABSTRACT

Powdery mildew resistance genes were postulated in 82 Indian and exotic wheat genotypes using infection-type matching technique. The genotypes were subjected to eight pathotypes of *Erysiphe graminis* f. sp. *tritici* with diverse virulence. Based on their reaction to the pathotypes, the genotypes were categorised into 8 groups (I to VIII). Resistance in first VI groups was governed by genes *Pm3a, Pm3c, pm5, Pm8* and some unidentified gene(s) individually or in combination. In majority of the genotypes resistance was attributed to gene *Pm8* individually or in combination with other gene(s). Presence of gene *Pm8* was confirmed by pedigree relationships. Sixteen genotypes in group VII behaved differentially to the pathotypes; however, resistance in these genotypes could not be attributed to any known gene(s). Twenty two genotypes in group VIII showed susceptible reaction to all the pathotypes indicating absence of resistance gene(s).

Key words : Powdery mildew, *Triticum aestivum, Triticum durum,* Infection-type matching technique.

Wheat powdery mildew, *Erysiphe graminis* f sp. *tritici* E. Marchal, can be effectively managed by cultivation of resistant varieties. Identification of resistance donors is a prerequisite for any breeding programme aimed at evolving powdery mildew resistant varieties. Further, the information regarding resistance genes in the donors helps in their proper exploitation, recommendation of newly developed varieties, deployment schemes, constitution of multilines and varietal mixtures. Some preliminary assumptions regarding underlying resistance genes in donors can be drawn from pedigree relationships [1], and infection-type matching technique [2] based on gene-for-gene concept [3] using specific powdery mildew isolates confirms the presence of underlying race-specific resistance genes. Information on powdery mildew resistance genes in wheat genotypes is available from Germany [1, 4, 5], Denmark [6], U.S.A. [7], Czechoslovakia [8] and China [9].

The present investigation reports powdery mildew resistance genes in some Indian and exotic wheats using infection-type matching technique.

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MATERIALS AND METHODS

HOST : Eighty two stocks of *Triticum aestivum* L. and *T. durum* Desf. having field resistance to *E. graminis tritici* and some promising genotypes were selected from various national and international nurseries. The information on the pedigree and origin of the genotypes is given in Table 1.

Table 1. List of genotypes and their origin

Genotype/line	Pedigree	Origin
Agra Local	A local selection from Uttar Pradesh	India
7 ARSN 36	PF 70354/ALD "S"//BOW"S"	CIMMYT
7 ARSN 68	IAS 58/4/KAL/BB//CJ "S"/3/ALS	"
7 ARSN 72	IAS 58/4/KAL/BB//CJ "S"/3/ALD "S"/5/BOW	"
ALDRM 64	CM 79 A.307/BH 1146//BOW "S"	"
BW 10284	PF 79765.LQT 137-81	"
BW 11757	PF 74354/LD/ALD "S"OC 3551	"
BW 11770	China-7	"
BW 12238	Maya "S"/BON	"
BW 12258	Whydah PF 77478	"
BW 12584	MRNG/BUC "S"//BLO "S"/PSN "S"	"
BW 12792	YMI-6	"
BW 12788	BRI/3/KVZ/GV "S"/KA "S"/EMEK/32/4 Pat 70402/ALD "S"	"
BW 14596	F. 371/TRM//3383.20	"
BW 14626	Tob"S"/8156//Y50E/3* KAL/4/MRS//KAL/BB/3/A2	"
DKW 104	Unknown	India
7 DSN 53	CHIL "S"	CIMMYT
DWR 151	Unknown	"
18 EDYT 1	GTA "S"/DUR 69	"
18 EDYT 9	STN "S"	"
18 EDYT 21	VAVAROS 79	"
E 506 P_3-P_1	Unknown	India

EIGSN 37	Unknown	"
EIGSN 89	TAN"S"//GOF"S"/ALD "S"	"
EIGSN 118	SHANGHAI*3-42 B-OY	"
10 ESWYT 17	AGA/4*YR//4* HER	"
4 HCWSN 4	Unknown	"
4 HCWSN 73	Unknown	"
HD 2402	HD 2267/HD2236	"
HD 2501	HD 2189/HD 2160	"
HD 2580	TTR 'S'/JUN 'S'	"
HD 3456	Unknown	"
2 HEWSN 11	ALDAN "S"/IAS 58	CIMMYT
2 HEWSN 17	BAU "S"	"
2 HEWSN 35	SPB "S"	"
2 HEWSN 90	WRM//KAL/BB/3/BCW "S"	"
2 HEWSN 134	F.12 71/CDC//GEN	"
2 HEWSN 193	VEE 5 "S"/3/BNQ "S"/CNT 8//ALDN"S"/IAS58	"
2 HEWSN 205	CEP 7593/CEP 7887/3/PEL72380/ATR71/BOW "S"	"
2 HEWSN 213	PF 74354//LD/ALD"S"	"
HI 1077	Gallo/Aust # 61-157//CNO/No. 66/3/KAL/BB	India
HS 321	DGA-BJY 'S'/GH 'S'	"
HUW 284	(PAVON 76 × HUW 37) × HUW 202	"
HUW 376	CPAN 1962/HUW 206//HUW 202	"
HW 135	Unknown	"
HW 318	Unknown	"
HW 741	BB/CC//CNO/3/NO/PI	"
HW 961	Unknown	"
HPW 90	Unknown	"
22 IBWSN 86	WRM//KAL/BB/8/BOW "S"	CIMMYT
22 IBWSN 95	BOW "S"/BUS "S"	"
22 IBWSN 290	INIA/*A.distichum*//INIA/3/VEE"S"	"

20 IDSN 153	HUI "S"//CIT 71/CII	"
22 IDSN 192	DACK "S"/KIWI "S"/4/68111/RGB//WARD/3/AMAL 72	"
19 ISEPTON 25	IAS 58/4/KAL/BB/CJ "S"/3/A:D "S"/5/BOW "S'	India
19 ISEPTON 30	IAS 58/4/KAL//CJ "S"/3/ALD ""/BOW"S"	"
ISWRN 193	Unknown	"
K 8806	K 8002/HD 2204	CIMMYT
5 KBSN 56	MRNG/BUG "S"//BLD"S"/PSN "S"	"
N 9464	WH 147/HD 2189	"
PBW 154	HD 2160/HD 2177	"
RL 76	Unknown	"
RL 88	Unknown	"
RL 116	TL 1210/CPAN 1922	"
RL 117	TL 1217/CPAN 1922	"
RL 118	TL 1217/CPAN 1922	"
RL 122	TL 1217/CPAN 1922	"
RL 124	TL 1217/CPAN 1922	"
RL 126	TL 1217/CPAN 1922	"
RL 127	RL 1217/CPAN 1922	"
RL 132	TL 1217/CPAN 1922	"
RRM 61	AGA/4* ZA 75	"
RRM 62	AGA/5* ZZA 75	"
RRM 77	RL 6043/4* YR 70	"
RRM 88	RL 6043/3* GEN 81	"
Shimla Local	A local collection from Himachal Pradesh	India
VL 672	Unknown	"
VL 682	PIA/HD 2160	"
VL 711	HAHN 'S' * 2 /PRE 'S'	"
WOL(LRA) 107	SISSONAI/DEPRES//CAL//HU/3/BUC "S'/Pun 'S'	CIMMYT
WOL (MRA) 64	Unknown	"
WON (HAA) 12	NS 984-1/NE 701136//OVOSADSKA 2699	"

PATHOGEN : Eight pathotypes of *E. graminis tritici* collected during surveys in Himachal Pradesh conducted during 1991-92 [10], were used in the present studies. The avirulence/virulence formulae of the pathotypes are given Table 2. These pathotypes allowed the identification of genes *Pm3a, Pm3c, pm5* and *Pm8.*

Table 2. Avirulence/virulence formulae of the pathotypes of *Erysiphe graminis tritici* used in postulation of resistance gene

Pathotype no.	Avirulence/virulence formula
1	*PPm1, PPm2, PPm3b, PPm4a, PPm6/pPm3a, pPm3c, ppm5, pP7m, pPm8, pPm (Ma)*
2	*PPm1, PPm2, PPm3a, PPm3b, PPm4a, Ppm5, PPm6, PPm8/pPm3c, pPm7, pPm(Ma)*
3	*PPm1, PPm2, PPm3c, PPm4a, PPm6/pPm3a, pPm3b, ppm5, ppm7, pPm8, pPm(Ma)*
4	*PPm1, PPm2, PPm3a, PPm3b, PPm4a, Ppm5, PPm6/pPm3c, pPm7, pPm8, pPm(Ma)*
5	*PPm1, PPm2, PPm3b, PPm4a, Ppm5, PPm6/pPm3a, pPm3c,pPm7, pPm8, pPm(Ma)*
6	*PPm1, PPm2, PPm3a, PPm3b, PPm3c, PPm4a, PPm8/ppm5, pPm6, pPm7, pPm(Ma)*
7	*PPm1, PPm2, PPm3a, PPm3c, PPm6, PPm8/pPm3b, pPm4a, ppm5, pPm7, pPm(Ma)*
8	*PPm1, PPm2, PPm3b, PPm4a, Ppm5, PPm6, PPm8/pPm3a, pPm3c, pPm7, pPm(Ma)*

INOCULATION AND INCUBATION : The seedlings of test genotypes alongwith susceptible check Agra Local were raised in aluminium trays (30 cm × 20 cm × 9cm), filled with a mixture of field soil and Farm Yard Manure (10:1), under spore proof conditions. Eight days old seedlings (1-leaf stage) of the test material were inoculated with each pathotype by dusting heavily mildewed seedlings of susceptible cultivar Agra Local. The trays with inoculated seedlings were placed in wooden cages, covered on all sides with two layers of muslin cloth and the top with polythene sheet which allowed natural light to the seedlings. The maximum and minimum temperatures during the incubation period were 25 ± 7°C and 10 ± 5°C, respectively.

DATA RECORDING : The data were recorded 10 days after inoculations using a slightly modified '0-4' scale [11]. Seedlings with infection types 0, 1 and 2 were classified as resistant, and those showing infection types 3 and 4 as susceptible. Any tray in which susceptible variety Agra Local did not develop infection type 4 was discarded. All the genotypes alongwith a set of differential lines with known genes for resistance were evaluated twice to confirm the results.

RESULTS AND DISCUSSION

Infection types of the genotypes to eight pathotypes of *E. graminis tritici* are given in Table 3. On the basis of the differential reactions to the pathotypes, the genotypes were grouped into 8 categories designated as I to VIII. The probable genes for powdery mildew resistance are also given.

Table 3. Reaction of wheat genotypes to eight pathotypes of *Erysiphe graminis tritici*, their groupings and probable gene(s)

Group/Genotype	Pathotype no.								Probable gene(s)
	1	2	3	4	5	6	7	8	
I/ 7 ARSN 68	;	;	4	;	4	-	;	;	*Pm3a, Pm8+*
II/ HUW 284,HW 135, RRM 61, Shimla Local,VL 672	4	4	-	4	4	;	;	4	*Pm3c+*
HD 2501	4	3	-	4	4	2	;	4	*Pm3c+*
III/10 ESWYT 17	4	-	-	4	4	;	;	2	*Pm3c, Pm8*
RL 116	3	2	-	4	4	;	;	-	*Pm3c, Pm8+*
IV/BW 12238	3	;	3	4	;	4	3	;	*pm5+*
PBW 154	4	;	-	4	-	;	3	-	*pm5+*
V/BW 12584, BW 14596	3	;	3	4	;	;	1	-	*pm5, Pm8+*
VI/7 ARSN 36, 7ARSN 72, 2 HEWSN 35, 2 HEWSN 193	-	;	4	3	4	;	;	;	*Pm8+*
4 HCWSN 4, HS 321, RRM 77	4	;	3	4	4	2	;	;	*Pm8+*

BW 10284, BW 11757, BW 1770, BW 12792,7 DSN 53, 2 HEWSN 213, HW 318, 19 ISEPTON 25, 19 ISEPTON 30, ISWRN 193, K 8806, RL 117, RL 118, RL 122, RL 124, RL 127, RL 132, RRM 88, VL 711, WON(HAA) 12	3	;	4	4	4	;	;	-	*Pm8+*
2 HEWSN 134, RL 126	3	;	3	4	4	;	-	2	*Pm8+*
BW 12788	3	;	4	4	3	;	;	-	*Pm8+*
EIGSN 89	;	;	3	4	4	;	;	3	*Pm8+*
VII/ALDRM 64, DKW 103, EIGSN 37	3	4	4	4	3	;	3;	3	-
EIGSN 118, HD 2402, 22 IBWSN 86	4	3	4	4	4	4	;	4	-
E 506 P3-P1, HD 2580, 2 HEWSN 90, 20 IDSN 153, 5 KBSN 56, N 9464, VL 682	3	3	4	4	4	;	3	4	-
2 HEWSN 205, 22 IBWSN 290, WOL (LRS) 107	3	3	4	4	4	;	3	2	-
VIII/BW 12258, BW 14626, DWR 151, 18 EDYT 1, 18 EDYT 9, 18 EDYT 21, 4 HCWN 73, HD 3456, 2 HEWSN 11, 2 HEWSN 17, HI 1077, HPW 90, HUW 376, HW 741, HW 961, 22 IDSN 192, 22 IBWSN 95, RL 76, RL 88, RRM 62, WOL(MRA) 64, Agra Local	4	4	3	3	4	4	4	4	-
Isogenic lines									
Asosan × Cc^8	3	;	4	;	-2	3	;-1	;-2	3	*Pm3a*
Sonora × Cc^8	4	4	1-2	4	4	;-2	1-2	4	*Pm3c*
CS/Hope	3	;-2	3	4	;	3	3	2	*pm5*
Kavkaz	3	;	4	4	4	;	;-2	;	*Pm8*

Group I : Resistance of genotype 7ARSN 68, the only genotype in group I, was attributed to genes *Pm3a, Pm8* and some other gene(s) which could not be

postulated with the present pathotypes. Pedigree of 7ARSN 68 involved Aurora and Alondra, which are known to possess gene *Pm8* [12]. However, origin of gene *Pm3a* and unidentified gene(s) could not be ascertained.

Group II : Based on the differential reaction of the genotypes against the powdery mildew pathotypes, resistance in genotypes HUW 284, HW 135, RRM 61, Shimla Local and VL 672 was attributed to gene *Pm3c* and some other unidentified gene(s).

Group III : Resistance in two genotypes, 10 ESWYT 17 and RL 116, was attributed to the genes *Pm3c, Pm8* and some other unidentified gene(s). Genotype RL 116, a stable wheat-like triticale-wheat derivative was selected from the cross CPAN 1922 × TL 1210. CPAN 1922 has Orelando in its pedigree, having gene *Lr26* and *Yr9* for leaf rust and yellow resistance, respectively [12] and TL 1210 is a triticale line involving rye genome. Gene *Pm8* has also been transferred from rye by 1B/1R translocation [12, 13]. Moreover, leaf rust resistance in RL 116 was found to be due to gene *Lr26* and some other unidentified genes (Plaha, personal communication). Genes *Lr26* and *Yr9* are reported to be closely linked with gene *Pm8* [12]. Hence, origin of gene *Pm8* in RL 116 may have been derived from genotype orelando or TL 1210.

Group IV : Resistance of genotypes BW 12238, and PBW 154 was postulated to be due to gene *pm5* and some other unidentified gene(s). Pedigree records show the involvement of genotypes Hope and Siete Cerros in the stocks, both of which are known to possess gene *pm5* [6, 8].

Group V : Resistance genes *pm5, Pm8* and some other unidentified gene(s) individually or in combination were postulated in BW 12584 and BW 14596. Pedigree analysis of these genotypes reveals involvement of Hope and Siete Cerros through the involvement of Kalyansona and Hope, which are known to have gene *pm5*.

Group VI : Resistance in 31 genotypes in group VI was attributed to the powdery mildew resistance gene *Pm8* and some other unidentified gene(s). Pedigree relationships of genotypes 7 ARSN 36, 7 ARSN 72, BW 11757, BW 11770, BW 12792, 7 DSN 53, 2 HEWSN 35, 2 HEWSN 134, 2 HEWSN 193, 2 HEWSN 213, 19 ISEPTON 25, 19 ISEPTON 30, K 8806, VL 711 and WON(HAA) 12 reveal the involvement of Alondra, Bobwhite, Aurora, Kavkaz, Veery, Ures or Orelando possessing powdery mildew resistance gene *Pm8* [12, 13], thereby confirming the postulation of gene *Pm8*. The pedigree of genotypes 4 HCWSN 4 and ISWRN 193 is not known. Genotypes RL 117, RL 118, RL 122, RL 124, RL 127 and RL 132 are wheat like hexaploid

triticale bread wheat derivatives selected from the cross CPAN 1922 × TL 1210. CPAN 1922 has orelando in its pedigree, having genes *Lr26* and *Yr9* for leaf rust and yellow rust resistance, respectively. Seedling resistance to leaf rust in these genotypes was found to be due to gene *LR26* (Plaha, personal communication), confirming the presence of gene *Pm8*, as leaf rust resistance gene *Lr26* and powdery mildew resistance gene *Pm8* are closely linked [13]. Powdery mildew resistance gene *Pm8* and some other unidentified gene(s) which could not be identified with the available pathotypes were postulated in genotypes BW 12788 and EIGSN 89. Presence of gene *Pm8* was evident from the involvement of Kavkaz and Alondra in these genotypes, which are known to possess gene *Pm8* [9, 13].

Group VII : Sixteen genotypes in group VII showed resistant reaction to one or two pathotypes. However, resistance in these genotypes could not be attributed to any of the known powdery mildew resistance gene(s).

Group VIII : Twenty two genotypes in group VIII were susceptible to all the available pathotypes of powdery mildew. Therefore, presence of genes confirming resistance could not be postulated with the available pathotypes.

Of the eleven powdery mildew resistance genes used in this study, only four known genes and some unidentified gene(s) could be postulated in 82 genotypes. In more than 40% genotypes, resistance was attributed to gene *Pm8*. Virulence against this gene has been reported in India [14-16] and abroad [13]. Therefore, it is essential to evaluate new and diverse sources of resistance against powdery mildew. This would enable wheat breeders to plan their breeding programme to obtain desirable levels of resistance against the disease.

REFERENCES

1. M. Heun and G. Fischbeck. 1987(a). Identification of wheat powdery mildew resistance genes by analysing host pathogen interaction. Plant Breeding., **98**: 124-129.
2. L. E. Browder. 1973. Specificity of *Puccinia recondita* f.sp. *tritici: Triticum aestivum* 'Bulgaria 88' relationship. Phytopathology., **63**: 524-528.
3. H. H. Flor. 1955. Host-parasite interaction in flax-rust: its genetics and other implications. Phytopathology., **45**: 680-685.
4. M. Heun and G. FIschbeck. 1987(b). Genes for powdery mildew resistance in cultivars of spring wheat. Plant Breeding., **99**: 282-288.
5. J. Lutz, M. Katzhammer, V. Stephan, F.G. Felsenstein, K. Oppitz and F. J. Zeller. 1995. Identification of powdery-mildew resistance genes in common wheat (*Triticum aestivum* L. em Thell). V. Old German cultivars and cultivars released in the former GDR. Plant Breeding., **114**: 29-33.

6. M. S. Hovmoller. 1989. Race specific powdery mildew resistance in 31 North West European Wheat cultivars. Plant Breeding., **103**: 228-234.

7. S. Leath and M. Heun. 1990. Identification of powdery mildew resistance genes in cultivars of soft red winter wheat. Plant Diseas., **74**: 747-752.

8. J. Lutz, E. Limopert, P. Bartos and F. J. Zeller. 1992. Identification of powdery mildew resistance genes in common wheat (*Triticum aestivum* L.) in Czechoslovakian cultivars. Plant Breeding., **108**: 33-39.

9. X. C. Xia, S. L. K. Hsam, U. Stephan, T. M. Yang and F. J. Zeller. 1995. Identification of powdery-mildew-resistance genes in common wheat (*Triticum aestivum* L.) VI. Wheat cultivars grown in China. Plant breeding., **114**: 174-175.

10. Rax Paul. 1993. Characterisation of resistance to powdery mildew (*Erysiphe graminis* f. sp. *tritici* E. Marchal) in some Indian and exotic wheats., Unpubl. M.Sc. Thesis, Himachal Pradesh Krishi Vishvavidyalaya Palampur, India pp. 97.

11. H. C. Smith and I. D. Blair. 1950. Wheat powdery mildew investigations. Ann. Appl. biol. **37**: 570-583.

12. R. A. McIntosh. 1988. Catalogue of gene symbols for wheat. Proceedings of Seventh International Wheat Genetic Symposium, 1423 pp. Inst. Plant Sci. Res. Cambridge, UK.

13. F. G. A. Bennett. 1984. Resistance to powdery mildew in wheat : A review of its use in Agriculture and Breeding programme. Plant Pathology., **33**: 279-300.

14. S. C. Sharma, A. K. Basandrai and K. S. Aulakh. 1990. Virulence in *Erysiphe graminis* f. sp. *tritici* causing powdery mildew in wheat Pl. Dis. Res., **5**: 115-117.

15. T. R. Sharma and B. M. Singh. 1990. Virulence structure of *Erysiphe graminis* f. sp. *tritici* in Himachal Pradesh. Indian Phytopath., **43**: 165-169.

16. N. Pathania, P. D. Tyagi and A. K. Basandrai. 1994. Pathogenic specialization in *Erysiphe graminis tritici* (powdery mildew of wheat) J. Mycol. Pl. Pathol., **27**: 35-39.