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OBITUARY

DR D J SAMBORSKI

1922-1989

Dr D J Samborski died in June 1989.

Dr Samborski - 'Dan' to his four brothers and three sisters, "Sam" to his legion of friends and colleagues, had a brilliant career as one of the world's leading researchers on the physiology and genetics of wheat rust; his special interest was the leaf rust disease. He started his University studies after returning in 1945 from active service overseas in the army. He took BSA and MSc degrees at the University of Saskatchewan, his native province, and the PhD degree at McGill University in 1954. After two years as a research associate working on physiology of parasitism in the rusts at the University of Saskatchewan, he was appointed to the plant pathology staff of the Agriculture Canada Research Station at Winnipeg.

Sam was a superb team worker. He collaborated in various combinations with physiologists, geneticists, plant breeders, cytologists. He worked on breeding leaf rust resistant varieties; inheritance and effects of specific genes for resistance in the host, and virulence in the pathogen, critical steps in metabolic pathways; histopathology of compatible and incompatible host-pathogen combinations. Although he was deeply involved in basic, and often "high technology" research, he never forgot practical problems, and worked energetically on rust race surveys and epidemiology, and determining rust reactions of plant breeders' lines in field tests and greenhouse studies.

Sam brought to all his work a highly developed ability to recongise what was important and to formulate concepts. He shared his insights with his colleagues and collaborators, and taught his laboratory skills, and his methods of reasoning, to the graduate students, postdoctoral fellows, and visiting scholars from various countries who came to work in his laboratory. He organised and taught advanced graduate courses as an honorary professor at the University of Manitoba. He served as a consultant on research programs in Mexico, Brazil, and in Europe; and participated in and was chairman of various international symposia and working groups.

Sam was outstanding in his ability to finish what he started. He prepared for publication of the results of each project as it was completed, and was able to say that he had no "unfinished business" when he retired. His research productivity was most impressive, and was widely recognised and acclaimed. He was made a Fellow of the American Phytopathological Society, of the Canadian Phytopathological Society, and of the Royal Society of Canada. He was given the DL Bailey Award, and the Award for Outstanding Reserach, by the Canadian Phytopathological Society; the Distinguished Graduate Award by the University of Saskatchewan; and shared with a colleague the Gold Medal of the Professional Institute of the Civil Service of Canada.

Sam's personal qualities outshone even his brilliant scientific, technical, and professional accomplishments. He was a devoted husband to his wife Margaret, and a fond father to their daughters Lynn and Pat. He doted on his grandchildren Melanie, Steven and newly-born Megan. He spent much time with the two older ones, treated them as adults, and imparted to them his love and much of his knowledge of nature. There are not many children five years old who can recognise and call by their scientific names the common fleshy fungi of their region!

People who associated with Sam briefly, as well as his colleagues of many years, became his personal friends. He enlivened serious scientific conferences, working committees, and small meetings with his quick wit and irreverent humor. People congregated around him, and wherever Sam was one of a group, whether working or relaxing, there was always laughter as well as serious discussion.

Sam will be sorely missed by his wife, his children and their families, by his four brothers, three sisters and their families, and many other relatives, and by his numerous professional colleagues and friends in many countries. And he will be especially missed by this old colleague and friend, who for many yaers made a "pilgrimage" of some three thousand kilometers every autumn just to spend a few days walking with Sam on the Prairies, nominally hunting for partridge, but really there just to enjoy his company and good humor to sustain me for another year.

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GENETIC DIVERSITY IN *TRITICUM DURUM* (DESF.) I. STUDIES ON STEM RUST RESISTANCE

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SUMMARY

Monogenic or digenic control of inheritance of stem rust resistance was indicated in three exotic *durum* land races, ED 155 and ED 1096 of Egyptian origin, and ED 404 from Turkey. Genetic diversity was observed among these wheats for adult plant resistance against race mixtures as well as for seedling resistance to four individual Indian stem rust pathotypes, 21A-2, 40, 117A and 117A-1. Two susceptible Indian *durum* land races, EK 69 and ML 4, showed suppressor factors only for the adult plant resistance in all three of the above resistant stocks. The genes conferring adult plant resistance were, therefore, thought to be different from those conditioning seedling resistance.

INTRODUCTION

Rust diseases of wheat, particularly stem and leaf rusts, have been the major constraints in the *durum* improvement programme in India. Eight lines out of around one thousand accessions tested from a world collection of *durum* germplasm showed combined resistance to stem and leaf rusts in field tests conducted during 1973 to 1975 at six different hot-spot locations in India (Bahadur *et al*, 1977). Three of the above genotypes *viz*. ED NOS. 155, 404 and 1096, were observed maintaining their resistance in the multilocation tests during subsequent years of testing. The present paper attempts to study the mode of inheritance and to explore the genetic diversity for stem rust resistance among the above wheat stocks so that their potential can be judiciously exploited in the breeding programmes.

MATERIALS AND METHODS

Three resistant exotic *durum* land races *viz*. ED NOS. 155, 404 and 1096, and two susceptible local *durum* wheats, EK 69 and ML 4, were used in the present study. Their particulars are listed in Table 1. Crosses were attempted between the resistant and susceptible wheats (RxS) as well as among the resistant parents (RxR) without reciprocals. The F_1 and F_2 progenies were subsequently raised. The F_2 populations along with the parents were subjected to artificial rust epiphytotics in the field using mixtures of stem rust races being currently maintained in India. Reactions were recorded combining disease severity (percentage of infection according to modified Cobb scale) with the response (pustule type).

The parental lines were seedling tested with 13 different stem rust pathotypes largely representing the virulence spectrum of Indian stem rust populations. The F_2 progenies were also seedling studied with four of the currently prevalent and virulent Indian stem rust pathotypes including 21A-2, 40, 117A and 117A-1. The test isolate 117A, however, showed virulence on the differential host Reliance. Its virulence spectrum with regard to the other standard as well as additional differential hosts (Charter and Yalta) was otherwise typical of the biotype in question. The seedling tests were conducted in a glasshouse at temperatures ranging between 11°C and 30°C. However, the temperatures remained between 15°C and 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).

The Chi-square method was used for testing the goodness of fit of the observed F_2 ratios. Nucleus inoculum of the test pathotypes was obtained from IARI, Regional Station, Flowerdale, Simla, India. The studies were conducted during 1984 to 1988.

RESULTS AND DISCUSSION

Genetic diversity for stem rust resistance among the three exotic durum land races under study was indicated from their seedling responses to various stem rust pathotypes (Table 2). Although all three of them showed resistance to 11 out of the 13 pathotypes tested, high infection types were observed in ED 155 for races 40A and 122; in ED 404 to the isolates 42B and 117A-1; and in ED 1096 against virulences 40A and 295.

Field studies of the F_2 populations showed that both ED 155 and ED 404 possessed one dominant factor while ED 1096 had a pair of dominant complementary factors for the adult plant resistance to Indian stem rust populations. The F_2 segregations among RxR crosses revealed that the genes for adult plant resistance were diverse in all three of the resistant parents studied. Among the susceptible wheats, EK 69 was observed to have one suppressor factor for the adult plant resistance in the three resistant stocks under study whereas ML 4 showed the presence of one for ED 155 and two suppressors for the gene action in ED 404 and ED 1096 (Table 3). In an earlier study presence of two inhibitors was indicated in the susceptible Indian aestivum wheat PbC 281 and PbC 591 for the adult plant resistance to stem rust in NP 790 (Sikka and Rao, 1958).

Digenic control of the inheritance of seedling resistance to stem rust races 21A-2, 40, 117A and 117A-1 was observed in the resistant stocks. However, ratios were obtained with different kinds of genic interactions such as 15R:1S; 13R:3S; 11R:5S and 9R:7S (Table 4). Inheritance studies involving seven resistant tetraploid wheats showed that Spelmar, Vernal, Gamadi Abdu Tipo, St.464 and Iumillo, each had three genes for resistance to stem rust pathotype 111-SS2; Cl 8155 had either two or three genes for resistance and Kubanka probably had one (Williams and Gough, 1968). The durum wheat cultivar, Ward, was observed to have two to four genes for seedling resistance to eight different cultures of stem rust (Williams et al, 1978). In another recent study on the genetics of stem rust resistance in tetraploid wheats in India, resistance was observed to be dominant over susceptibility with mono-, di- and trigenic control involving duplicate and complementary interactions (Raut et al, 1984).

Moreover, differences in the gene action of the resistant lines were also observed between their crosses with the two susceptible parents when the RxS crosses involving ED 404 were tested with the races 21A-2, 40 and 117A; and when those involving ED 155 and ED 1096 were studied with the races 117A-1 and 40 respectively (Table 4). Similarly, differences in the genetic behaviour of Bijaga Red, a resistant Indian durum wheat, were observed between its crosses with the two susceptible varieties, HD 4502 and HI 7747, for seedling resistance to stem rust races 15C and 122 (Kolhe et al, 1977). Such differences may be due either to the background effects or to the innate heterogeneity for rust resistance. Susceptible segregants observed in the F_2 progenies from all of the RxR crosses established that the genes for seedling resistance too were non-allelic. Furthermore, RxR crosses confirmed the presence of duplicate dominant genes each in ED 155 and ED 1096 against race 21A-2 and one dominant plus one recessive factor each for races 117A and 117A-1. Segregation for race 40 showed that one dominant plus one recessive factor and duplicate dominant genes were operative for this pathotype in ED 155 and ED 1096 respectively. In the crosses of ED 404 with the two other resistant parents, duplicate dominant factors and one dominant and one recessive factors in each were observed for the races 21A-2 and 40 respectively. One dominant plus one recessive factors each in ED 155 and ED 1096 and the two genes showing an interaction of 11R:5S were operative in ED 404 for race 117A (Table 4). In an earlier study, genetic diversity for seedling resistance to stem rust was observed in a number of crosses involving 13 lines derived from four tetraploid wheats viz. Mindum, Acme selection, Khapli emmer and Palestine (Williams and Miller, 1982).

From the nature of the gene action, it was apparent that the genes conferring adult plant resistance were different from those conditioning seedling resistance since while the former were suppressed by the inhibitors present in EK 69 and ML 4, the latter ones were not affected.

The three exotic durum land races under report have been shown to possess diverse genes for leaf rust resistance also (Mishra et al, 1989). These wheat genotypes could, therefore, be utilised in the durum breeding programmes as diverse sources of combined resistance to stem and leaf rusts.

ACKNOWLEDGEMENTS

We wish to express our gratitude to the Head, IARI, Regional Station, Flowerdale, Simla, India, for supplying the nucleus inoculum of the stem rust pathotypes used in the study. Our sincere thanks are due to the Director, IARI, New Delhi, and to the Head, IARI, Regional Station, Indore, for the facilities provided. The technical help rendered by Mr A K Mittal, Mr Jagdish, Ms. Lalita Glande and Mr Charansingh is appreciated.

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Table 1. Particulars and phenotypic characteristics of the durum wheats used in the study

Accession No.	Name	PI No. (USDA)	Parentage	Country of origin	Phenotypic characteristics					
					Height (cm)	Earhead size(cm)	Glume colour/ Hairiness	Days to anthesis	Grain colour	1000 grain Wt.(g)
ED 155	Durum H	153774	Not known	Egypt	120	6X1.5	White glabrous	90-95	Amber	40-45
ED 404	-	166997	Not known	Turkey	107	9X0.9	White glabrous	95-100	Red	35-40
ED 1096	-	133457	Not known	Egypt	111	6X1.5	White glabrous	85-90	Amber	40-45
EK 69	Ekdania	-	Not known	India	110	6X1.2	White glabrous	75-80	Amber	40-45
ML 4	Malvi local	-	Not known	India	100	6X1.1	White glabrous	80-85	Amber	55-60

Table 2. Seedling responses of the wheats under study to various Indian stem rust pathotypes

Genetic stock	Pathotypes												
	11A	17	21A-2	34	40	40A	42	42B	117A	117A-1	122	184	295
ED 155	0;	0	0;	0	0;	3-4	0;	0;	0;	0;	3-4	0;	1-2++
ED 404	0;	0;	1-2	0;	0;	0;-1+	0;	2-3	0;	2-3	0;	0;	0;
ED 1096	0;	0	0;	0;	0;	3-4	0;	0;	0;	0;	1-2+	0;	2-3
EK 69	4	3-4	4	3-4	4	4	4	4	4	4	4	4	4
ML 4	4	3-4	4	3-4	4	4	4	4	4	4	4	4	4
Agra local (check)	4	3-4	3-4	3-4	4	4	3-4	4	4	4	4	4	4

Infection types 0 to 2++ indicate resistance; higher infection types indicate susceptibility.

Table 3. Field segregation of F_2 populations from RXS and RXR crosses when studied with mixtures of stem rust races.

Cross	Number of plants		Expected ratio	P value
	resist.	suscept		
RXS Crosses				
ED 155XEK 69	29	151	3R:13S	0.5-0.3
ED 155XML 4	33	113	3R:13S	0.3-0.2
ED 404XEK 69	26	169	3R:13S	0.1-0.05
ED 404XML 4	9	153	3R:61S	0.7-0.5
ED 1096XEK 69	18	183	9R:55S	0.05-0.02
ED 1096XML 4	5	187	9R:247S	0.5-0.3
RXR Crosses				
ED 155XED404	150	15	15R:1S	0.2-0.1
ED 15XED 1096	173	15	57R:7S	0.2-0.1
ED 404XED 1096	135	16	57R:7S	0.9-0.8

Table 4. Segregation of F_2 seedlings from RXS and RXR crosses when tested with individual stem rust races.

Cross	Rust races	Number of seedling resist.	Number of seedling suscept.	Expected ratio	P value
RXS crosses					
ED 155XEK 69	21A-2	155	7	15R:1S	0.5-0.3
	40	91	14	13R:3S	0.2-0.1
	117A	145	31	13R:3S	0.7-0.5
	117A-1	49	10	13R:3S	0.8-0.7
ED 155XML 4	21A-2	314	21	15R:1S	0.99-0.98
	40	194	43	13R:3S	0.9-0.8
	117A	130	27	13R:3S	0.7-0.5
	117A-1	51	32	11R:5S	0.2-0.1
ED 1096XEK 69	21A-2	128	8	15R:1S	0.9-0.8
	40	90	18	13R:3S	0.7-0.5
	117A	48	12	13R:3S	0.9-0.8
	117A-1	64	11	13R:3S	0.5-0.3
ED 1096XML 4	21A-2	52	3	15R:1S	0.9-0.8
	40	92	5	15R:1S	0.7-0.5
	117A	55	12	13R:3S	0.9-0.8
	117A-1	173	25	13R:3S	0.05-0.02
ED 404XEK 69	21A-2	225	13	15R:1S	0.7-0.5
	40	237	64	13R:3S	0.3-0.2
	117A	118	62	11R:5S	0.5-0.3

/Contd

Table 4 (continued)

Cross	Rust races	Number of seedling resist.	Number of seedling suscept.	Expected ratio	P value
ED 404XML 4	21A-2	79	40	11R:5S	0.7-0.5
	40	90	82	9R:7S	0.5-0.3
	117A	91	22	13R:3S	0.9-0.8
RXR Crosses					
ED 155XED 1096	21A-2	395	2	255R:1S	0.8-0.7
	40	312	2	253R:3S	0.5-0.3
	117A	303	5	247R:9S	0.1-0.05
	117A-1	165	3	247R:9S	0.3-0.2
ED 155XED 404	21A-2	351	1	255R:1S	0.8-0.7
	40	139	4	247R:9S	0.7-0.5
	117A	236	15	241R:15S	0.95-0.9
ED 404XED 1096	21A-2	464	2	255R:1S	0.9-0.8
	40	159	8	247R:9S	0.5-0.3
	117A	174	11	241R:15S	0.98-0.95

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GENETIC DIVERSITY IN *TRITICUM DURUM* (DESF.) II. STUDIES ON LEAF RUST RESISTANCE

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SUMMARY

Genetic studies showed monogenic control of adult plant resistance to Indian leaf rust populations in the three exotic *durum* land races, ED 155 and ED 1096 of Egyptian origin, and ED 404 from Turkey. While resistance was dominant over susceptibility in the two Egyptian wheats, the reverse was true in the case of the Turkish wheat. Two genes were observed to govern the inheritance of seedling resistance in each of these wheats against three leaf rust cultures, 12A, 77 and 104B. Tests of allelism showed that the genes for leaf rust resistance too were not common among the above resistant stocks. One suppressor factor was observed to be operative in EK 69, a susceptible local wheat, for the adult plant resistance in ED 155 and ED 1096 whereas ML 4, the other susceptible line used in the study, had one suppressor for adult plant resistance in all the three resistant genotypes studied as well as for seedling resistance in ED 404 against the pathotype 104B. From the nature of the gene action, it was apparent that the genes conferring adult plant resistance were different from those conditioning seedling resistance. Presence of additional unidentified genes and/or gene interactions was suggested from the observed range of effectiveness to various designated *Lr* genes to different Indian Leaf rust pathotypes with particular reference to races 12-1 and 77.

INTRODUCTION

Leaf and stem rust diseases are the most serious maladies of the wheat crop in central and peninsular parts of India which constitute the main *durum* growing belt of the country. Three exotic *durum* land races *viz*. ED NOS, 155, 404 and 1096 were among those eight lines identified possessing combined resistance to leaf and stem rusts of wheat in a study involving around one thousand accessions (Bahadur *et al*, 1977). Consistently low levels of infection observed on the above three genotypes during subsequent tests pointed to the durable nature of their resistance to the two rusts. The mode of inheritance and genetic diversity for stem rust resistance in these wheats has been reported. (Mishra *et al*, 1989). The present communication deals with the above aspects with regard to their leaf rust resistance.

MATERIALS AND METHODS

Three resistant exotic durum land races, ED 155 and ED 1096 of Egyptian origin and ED 404 from Turkey, and two susceptible Indian durum wheats, EK 69 and ML 4, were used in the present study. Their particulars and phenotypic characteristics have been described earlier (Mishra et al, 1989). Crosses were attempted between the resistant and susceptible wheats (RxS) as well as among the resistant ones (RxR) without reciprocals. The F_1, F_2 and F_3 progenies were subsequently raised. The F_2 populations along with the parents were studied for their adult plant responses under artificially created rust epiphytotics using mixtures of leaf rust races being currently maintained in India. The parental lines were seedling tested with 15 different leaf rust pathotypes representing a cross section of the virulence spectrum of Indian leaf rust populations. The F_2 progenies were also seedling studied with three of the currently prevalent and virulent Indian leaf rust pathotypes including 12A, 77 and 104B. The seedling tests were conducted at temperatures ranging between 11°C and 30°C. However, the temperatures remained between 15°C and 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). The Chi-square method was used for testing the goodness of fit of the observed ratios. Nucleus inoculum of the pathotypes used in the study was obtained from IARI, Regional Station, Flowerdale, Simla, India. The studies were conducted during 1984 to 1988.

RESULTS AND DISCUSSION

Seedling responses of ED 404 were different from those of ED 155 and ED 1096 when tested with 15 different Indian leaf rust pathotypes. While all three of the above wheats produced high infection types against race 12-1, ED 404 showed resistance to race 77A, the most virulent of the Indian leaf rust pathotypes to which both ED 155 and ED 1096 were susceptible (Table 1).

Field evalulation of the F_2 progenies against race mixtures showed that while ED 155 and ED 1096 each had one dominant gene, a single recessive gene was operative in ED 404 for the adult plant resistance to Indian leaf rust populations. It may be seen from the segregating F_2 populations from RxR crosses that the genes for adult plant resistance were non-allelic (Table 2). The gene action in ED 155 and ED 1096 was suppressed by an inhibitor present in both the susceptible parents, EK 69 and ML 4. One suppressor factor in ML 4 was operative for the adult plant resistance in ED 404. In an earlier study the field resistance of Yaqui 53 was found to be suppressed by an inhibitor present in NP 824 (Pokhriyal and Kohli, 1962). In another recent study, a suppressor factor was observed in 'Pissi Local', a susceptible Indian aestivum land race, for the adult plant resistance in the wheat variety HD 2189 (Kaushal et al, 1982). Both EK 69 and ML 4 were also observed to suppress the adult plant resistance in the three exotic durum land races under study to Indian stem rust populations (Mishra, et al, 1989). The observed presence of suppressor factors for field resistance in the wheat land races necessitates that a large F_2 population be evaluated if their desirable agronomic traits are to be combined with the appropriate levels of rust resistance.

Digenic control of the inheritance of seedling resistance was observed in the three resistant parents under study against the leaf rust races, 12A, 77 and 104B. Progenies from RxS crosses produced F_2 ratios with 13R:3S or 11R:5S segregation (Table 3). In earlier studies on the inheritance of leaf rust resistance in _durum_ wheats, two recessive genes were observed to be operative in Leeds and Ramsey, while a single recessive gene conditioned the resistance to leaf rust culture 70-1 (race 1) in D 561 and D 6733 (Stater, 1973; Rashid _et al_, 1976). The gene expression was observed to be identical between RxS crosses involving EK 69 and ML 4 except in their crosses with ED 155 against race 104B, the segregations being 13R:3S (ED 155 x EK 69) and 11R:5S (ED 155 x ML 4). Similarly differential behaviour in gene action was reported between the crosses of Bijaga Red, a resistant Indian _durum_ wheat, with the two susceptible lines, N 59 and N 1264, for resistance to two leaf rust races, 77 and 162A. (Kadam _et al_, 1983).

One suppressor factor was indicated in ML 4 for the seedling resistance in ED 404 to race 104B (Table 3). Presence of inhibitor(s) in Pissi local suppressing the gene action in a number of resistant Indian _aestivum_ wheats including HD 2160, HD 2189, HI 666, HW 142, J 40 and WH 132 for leaf rust race(s) 10/162 has been reported (Lohani, 1983). From the nature of the gene action, it was apparent that the genes conferring adult plant resistance were different from those conditioning seedling resistance since while the former were suppressed in case of ED 155 and ED 1096 by the inhibitors present in EK 69 and ML 4, the latter ones were not affected. Although the seedling resistance to race 104B in ED 404 was suppressed by the inhibitor factor in ML 4, this was observed to be conditioned by one dominant and one recessive gene as against the single recessive gene control of the adult plant resistance in the above wheat genotypes.

Production of susceptible segregants in the F_2 progenies resulting from RxR crosses revealed that the genes for seedling resistance too were not common among the three sources of resistance under study (Table 3). However, modifications of the gene expression were observed in the following crosses. In the cross ED 155 x ED 1096, the two resistance genes in each of the parents were modified to duplicate dominant ones and an all-dominant four genes F_2 segregation was observed when tested with the races 12A and 77. Since there was only one susceptible segregant observed in the F_2 populations studied, the F_3 lines of the above cross were subsequently analysed with the respective races for the confirmation of the F_2 ratios. A good fit to the expected F_3 ratio of 223 homozygous R:32 segregating : 1 homozygous S supported the above assumptions based on F_2 ratios (Table 4). Similar modifications of the gene expression have been reported earlier. Pairs of dominant complementary genes for resistance to stem rust race 295 in the two _aestivum_ wheats, HD 2009 and HD 2177, were modified as duplicate dominant factors in both the varieties. (Kaushal, 1982). One of the two recessive genes for resistance in the wheat variety J 40 behaved as dominant in its crosses with the two other resistance parents, H 2189 and HI 666, when tested with the leaf rust culture 10 (Lohani, 1983). In the cross ED 155 x ED 404, the two genes showing 11R:5S interaction against race

12A were modified to duplicate recessive genes (7R:9S interaction) in one of the parents resulting in 211R:45S F_2 segregation. Cases are on record of such a dominance reversal due to background effects in other studies on wheat rust genetics. It was observed that the dominant gene in the varieties HW 142 and WH 132 behaved as recessive in their crosses with HI 666 against leaf rust race 10. Pairs of dominant genes behaved as recessive for resistance to leaf rust race 162 in a cross of J 40 and HD 2189. Similarly dominant gene(s) of HD 2189 and Tob 66 acted as recessive in their crosses respectively with Ciano's' - Gallo and J 40 when tested with the culture 162 of leaf rust. The aforesaid instances were reported in a study on the genetics of leaf rust resistance in *Triticum aestivum* (Lohani, 1983). Likewise *Lr11* has shown a dominance reversal in the background of wheat cultivar Sonalika (Gupta *et al*, 1984).

Earlier studies revealed that only *Lr9*, *Lr10*, *Lr19*, *Lr24*, *Lr25*, *Lr26*, *Lr27* + *Lr31*, *Lr28* and *Lr29* among the designated *Lr* genes tested against Indian leaf rust cultures, showed resistance to leaf rust race 77 (Sawhney *et al*, 1977; Sawhney and Goel, 1983). Since all the above genes except *Lr26* also showed effectiveness to race 12-1, (Mishra, unpublished data), their probable presence in the wheats under study is ruled out from the latter's susceptibility to the above pathotype. Presence of *Lr26* too is ruled out as it is closely linked with *Sr31* (McIntosh, 1983) showing effectiveness to all Indian stem rust pathotypes whereas the wheats under study were observed to be susceptible to two stem rust races (Mishra *et al*, 1989). Since resistance to race 77 was observed to be conditioned by two different genes in each of the three resistant stocks studied, the presence of additional unidentified genes and/or gene interactions of additive/complementary nature is suggested. These observations support the earlier indications of differences between the genes for leaf rust resistance identified from *Triticum durum* and those from *T.aestivum* (Pande and Rao, 1984; Sharma *et al*, 1986).

Since genetic diversity among the three exotic *durum* land races under report has also been observed for stem rust resistance (Mishra *et al*, 1989) these wheats could be of immense value in achieving the desired levels of combined resistance to stem and leaf rusts in the *durum* improvement programme in the country.

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Table 1 **Seedling responses of the wheats under study to various Indian leaf rust pathotypes**

Genetic stock	Pathotypes 10	11	12	12A	12-1	20	77	77A	77-1	104A	104B	106	107	108	162
ED 155	0;-1	0;-1	0;-2	0;	3	0;-1	0;-1	3	0;-2	0;-2	1-2	0;-2	0;-2	0;-2	0;-1
ED 404	0;-1	0;-1	0;	0;-1	3	0;-1	0;	0;-1	0;	0;-2	0;	0;-1	0;	0;-1	0;
ED 1096	0;-1	0;	0;-2	0;	3	0;-2	0;-1	3	1-2	0;-2	1-2	0;-2	0;-1	0;-2	0;-1
EK 69	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4
ML 4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4	3-4
Agra Local (Check)	3-4	4	3-4	3-4	3-4	3-4	4	4	4	3-4	4	3-4	3-4	3-4	4

Infection types 0; to 2 indicate resistance; higher infection types indicate susceptibility

Table 2 **Field segregation of F_2 populations from RXS and RXR crosses when tested with mixtures of leaf rust races**

Cross	Number of plants		Expected ratio	P Value
	Resistant	Susceptible		
RXS Crosses				
ED 155XEK 69	27	152	3R:13S	0.3-0.2
ED 155XML 4	34	113	3R:13S	0.2-0.1
ED 404XEK 69	44	148	1R:3S	0.7-0.5
ED 404XML 4	11	147	1R:15S	0.8-0.7
ED 1096XEK 69	33	168	3R:13S	0.5-0.3
ED 109XML 4	29	96	3R:13S	0.3-0.2
RXR Crosses				
ED 155XED 404	132	25	13R:3S	0.5-0.3
ED 155XED 1096	176	11	15R:1S	0.9-0.8
ED 404XED 1096	131	20	13R:3S	0.1-0.05

Table 3 **Segregation of F_2 seedlings from RXS and RXR crosses when tested with individual leaf rust pathotypes**

Cross	Patho-type	No. of seedlings Resist.	No. of seedlings Suscept.	Expected ratio	P Value
RXS Crosses					
ED 155XEK 69	12A	113	47	11R:5S	0.7-0.5
	77	56	13	13R:3S	0.99-0.98
	104B	86	19	13R:3S	0.9-0.8
ED 155XML 4	12A	116	41	11R:5S	0.2-0.1
	77	284	51	13R:3S	0.1-0.05
	104B	95	35	11R:5S	0.3-0.2
ED 404XEK 69	12A	134	45	11R:5S	0.1-0.05
	77	195	43	13R:3S	0.8-0.7
	104B	72	16	13R:3S	0.9-0.8
ED 404XML 4	12A	80	32	11R:5S	0.7-0.5
	77	96	26	13R:3S	0.5-0.3
	104B	44	136	13R:51S	0.2-0.1
ED 1096XEK 69	12A	50	11	13R:3S	0.9-0.8
	77	118	18	13R:3S	0.1-0.05
	104B	90	17	13R:3S	0.5-0.3
ED 1096XML 4	12A	55	13	13R:3S	0.95-0.9
	77	43	12	13R:3S	0.7-0.5
	104B	72	24	13R:3S	0.2-0.1
RXR Crosses					
ED 155XED 404	12A	206	39	211R:45S	0.5-0.3
	77	345	8	247R:9S	0.3-0.2
	104B	136	5	247R:9S	0.99-0.98
ED 155XED 11096	12A	306	1	255R:1S	0.9-0.8
	77	394	1	255R:1S	0.7-0.5
	104B	301	11	247R:9S	1.0-0.99
ED 404XED 1096	12A	175	10	241R:15S	0.8-0.7
	77	450	16	247R:9S	0.95-0.9
	104B	161	5	247R:9S	0.8-0.7

Table 4 **Behaviour of F_3 lines from the cross ED 155XED 1096 when tested with leaf rust races 12A and 77**

Cross	Patho-type	F_3 Behaviour			Expected ratio*	P Value
		Resist.	Seg.	Suscept.		
ED 155	12A	84	5	-	223:32:1	0.2-0.1
X						
ED 1096	77	95	10	-	223:32:1	0.7-0.5

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

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EVALUATION OF ISRAELI DURUM LAND RACES FOR RUST RESISTANCE IN INDIA

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SUMMARY

One hundred and thirty five durum land races from Israel were field-evaluated during 1984 to 1989 for resistance to rust pathogens with particular reference to stem and leaf rusts of wheat. Seven stocks viz ID Nos 1142, 1169, 1221, 1568, 1805, 2334 and 2498, showed resistance to both stems and leaf rusts. Inadequate levels of seedling resistance observed in these lines suggested the presence of effective adult plant resistance gene(s) for the two rusts. Three of these lines viz ID Nos 1142, 1568 and 1805 tended to possess field resistance to stripe rust as well. Tendencies for resistance to other wheat diseases were also observed.

INTRODUCTION

Rust diseases of wheat, particularly stem rust, have been major constraints in the durum improvement programme in India. Rust resistance donors of proven value are limited and hence there is an immediate need to search for additional sources of resistance. The present study attempts to evaluate 135 durum land races from Israel for the attributes of rust resistance. Special emphasis has been laid on identifying stocks possessing combined resistance to both stem and leaf rusts since these are the most important wheat disease problems of central and peninsular India, the main durum belt in the country.

MATERIALS AND METHODS

Out of 148 durum accessions received from Israel during 1980 and 1981, 135 lines representing five different taxonomic groups of "population groups" (Poiarkova and Blum, 1983) were used in the present study (Table 1). They are all land races and form a part of the germplasm collections made in the northern Negev in Israel during the early seventies and except for the "population group 3", which was evidently introduced to Israel from northern Africa, all the other groups are of Palestinian origin (Myra Manoah, personnal communication). These strains have been regularly evaluated since 1983-84 for adult plant responses to stem and leaf rusts at Indore in Central India, which is one of the 'hot-spot' locations in the country for these two rust diseases. In addition, the above germplasm was subjected to multilocation testing from 1986-87 to 1988-89 at other 'hot-spots' in the country including Mahabaleshwar and Wellington in the south and Gurdaspur in the north.

The lines were grown in the field as one metre rows, 20 to 25 cm apart, with an infector row consisting of highly susceptible wheats, planted after every 20 test rows. Recommended agronomic practices were observed for raising the crop. Artificial rust epiphytotics were created using mixtures of rust/biotypes being currently maintained in India with the help of hypodermic syringe inoculations and spore suspension sprays at all the test locations except at Wellington where natural rust epidemics occur regularly. Reactions were recorded combining disease severity (percentage of infection according to modified Cobb scale) with response (pustule type). These were converted to co-efficients of infection (CI) following Loegering (1959). Average co-efficients of infection (ACI) for respective crop seasons were calculated by averaging the CI values obtained at different locations in the event of multilocation testing. Mean co-efficient of infection (MCI) was derived by calculating the mean of all CI and ACI values. Lines having MCI values up to a maximum of 10.0 were rated as resistant. From Gurdaspur, relevant data were available only for the year 1986-87 and reactions from Wellington for the 1988-89 crop season were not taken into account because of the poor rust development.

Seedling tests of seven lines viz ID Nos 1142, 1169, 1221, 1568, 1805, 2334 and 2498 showing consistent field resistance to both stem and leaf rusts were conducted at Indore in a glasshouse during January/ early February with temperatures ranging between 11°C to 31°C. However, the temperatures remained in the range 15°C to 25°C for 18 to 20 hours a day. Standard procedures for inoculation of seedlings and recording of reactions were followed (Stakman et al, 1962). Tests were carried out twice during 1988 and were repeated during 1989. Thirteen pathotypes of stem rust and eighteen of leaf rust, largely representing the virulence spectrum of Indian stem and leaf rust populations, were used in this study. Nucleus inoculum of the test pathotypes was obtained from IARI, Regional Station, Flowerdale, Simla, India.

RESULTS AND DISCUSSIONS

On the basis of MCI values, seven stocks viz ID Nos 1142, 1169, 1221, 1568, 1805, 2334 and 2498 showed adult plant resistance to both stem and leaf rust (Tables 2 & 3). ID 1169, which showed a range of stem rust infection from 0 to 10S and an MCI value of 3.82, was most resistant of all the lines under study. With the exception of the 1986-87 crop season at Mahabaleshwar, the other lines also exhibited consistently good levels of stem rust resistance, the infection being in the range of 0 to 20S. As regards leaf rust, ID 1568 and ID 1805 showed high levels of resistance, the infection being in the range of

0 to 5S. Other lines also leaf rusted in low intensities, the terminal severity not exceeding 20S except for ID 2498 which recorded 40S during 1986-87 at Mahabaleshwar.

Regarding seedling responses to stem rust, with the exception of ID 1169 which showed highly resistant reaction against two pathotypes viz 21A-2 and 117A-1, the other six lines almost completely lacked seedling resistance. Although low infection types were observed in quite a few mesothetic interactions, there was invariably a preponderance of 3/4 type of pustules and hence such interactions were classified as susceptible (Table 3). Thus it is evident that adult plant resistance gene(s) is/are operative in these lines. The presence of additional gene(s) imparting seedling resistance to stem rust race 117A-1 could probably explain the high level of resistance in ID 1169 since the race in question has been observed to be the most virulent pathotype on durum wheats in India. Moreover, the seedling responses of the gene(s) under discussion are different from those of any of the known Sr genes against stem rust pathotypes (Sawhney and Goel, 1981, Sawhney et al, 1983).

Likewise, with the exception of ID 1568 which showed a pattern of effectiveness somewhat resembling that of Lr 10, the seedling responses of the above stocks (Table 4) do not match with those of the described Lr genes against Indian leaf rust pathotypes (Sawhney et al, 1977; Sawhney and Goel, 1983). These observations are in accordance with the earlier indications of differences between the Lr genes identified from Triticum durum and those from T aestivum (Panda and Rao, 1984; Sharma et al, 1986). However, excepting ID 1568 and ID 1805, the levels of seedling resistance are quite inadequate and the presence of adult plant resistance gene(s) to leaf rust as well is indicated. Gene(s) for adult plant resistance to stem and leaf rusts have been indicated in a number of exotic durum wheats earlier (Bahadur et al, 1977).

Having assessed their value as resistance donors, the next step would logically be to explore the genetic diversity for rust resistance among the above wheat stocks so that their potential can be judiciously exploited in any breeding programme. Although it is not possible to probe into the genetic architecture of these lines on the basis of their parentage, as nothing is known about their parental forms, it is quite likely that they might possess diverse factors for rust resistance associated with the distinct spike and kernel characteristics which formed the basis of their classification into three populations groups (Poiarcova and Blum, 1983), ID Nos 1142, 1169 and 1221 in population group 1; ID 1568 and ID 1805 in population group 2; and ID 2334 and ID 2498 in group 4 as shown in Table 1 (Myra Manoah, pers comm). The above assumption is corroborated by the observed differences among the seedling reactions of the above wheats to the various leaf rust pathotypes (Table 5). However, but for the indication of additional gene(s) for seedling resistance in ID 1169, no information regarding the diversity for stem rust resistance could be deduced on the basis of their seedling reactions to stem rust races (Table 4). The presence of Sr2, a time tested adult plant resistance gene, originally derived from a tetraploid wheat, is not indicated as Sr2 - associated head and stem melanism or pseudo-black chaff (McIntosh, 1988) is not observed in these lines. It would be worthwhile demonstrating the extent of diversity and allelic relationships among these wheats particularly with regard to stem rust resistance through conventional genetic analysis.

Moreover, tendencies for resistance to other wheat diseases also were observed during the multi-locational testing of the above lines of promise for stem and leaf rusts (Table 6). Three lines viz ID Nos 1142,, 1568 and 1805 manifested resistance to stripe rust as well. Further, with the exception of ID 1221 and ID 2334 which showed an MS response to powdery mildew, all the lines exhibited good to moderate levels of resistance to leaf blight and powdery mildew. As regards Kernel bunt, a dreaded wheat disease of north India, the lines were observed to be free from infection as compared with more than one percent infection in the check variety WL 711 under natural incidence at Gurdaspur. However, the data under discussion are available for only one to two seasons/locations and hence further testing is required for confirmation of the above observations.

From the foregoing discussion, it is, therefore, quite clear that the reported material could serve as a potential source of multiple disease resistance in the durum improvement programme.

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Table 1. Classified list of Israeli <u>durum</u> land races (ID Nos) used in the present study*[1]

Population Groups*[2]									
Group 1			Group 2		Group 3	Group 4			Group 5
1119	1210	1304	1153	1968	1361	1354	1789	2527	1406
1120	1213	1314	1165	1976	1566	1360	1821	2567	15155-162
1125	1221	1371	1190	1998	1636	1369	2064	2576	15164
1128	1222	1506	1281	2019	1648	1386	2077	2595	15165
1134	1225	2536	1323	2132	1779	1446	2103	2597	15171-177
1142	1245	2605	1568	2176	1781	1491	2116	2601	15179
1161	1247	2640	1586	2198	1816	1501	2153	2620	15181
1164	1256		1719	2201	2209	1534	2202	2632	15182
1167	1259		1805	2272	2273	1541	2267	2644	15184
1169	1271		1898	2375	2455	1549	2334	2645	15186
1184	1278		1931	2701	2537	1551	2427	2690	15199
1192	1287		1948	2712	2647	1578	2498	2701	
1209	1298		1960		2680	1608	2526	2733	
								2750	

*[1] Classification is based on the information supplied by Myra Manoah, 1988. (personnal communication)

*[2] According to Poiarcova and Blum, 1983.

Table 2. Adult Plant Responses of resistant Israeli durum land races to stem rust.

Genetic Stocks (ID Nos)	83-84	84-85	85-86	1986 - 87				1987 - 88				1988-89			1984-89
	1	1	1	1	2	3	ACI	1	2	3	ACI	1	2	ACI	MCI
1142	10S (10)	tS (1)	20S (20)	F (0)	45MS (36)	F (0)	12.0	ts (1)	ts (1)	10MS (8)	3.33	tMR (0.4)	F (0)	0.2	7.75
1169	10MS (8)	tS (1)	10S (10)	5S (5)	10MR (4)	F (0)	3.0	F (0)	tMS (0.8)	tMR (0.4)	0.4	ts (1)	F (0)	0.5	3.82
1221	5S (5)	tS (1)	5S (5)	5S (5)	50S (50)	F (0)	18.33	tS (1)	tS (1)	5MS (4)	2.0	tS (1)	F (0)	0.5	5.3
1568	20S (20)	tS (1)	10S (10)	tS (1)	50S (50)	F (0)	17.0	F (0)	F (0)	tMR (0.4)	0.13	5MR-tS (1.5)	F (0)	0.75	8.15
1805	10S (10)	5S (5)	10S (10)	tS (1)	40S (40)	5MS (4)	15.0	F (0)	F (0)	tMR (0.4)	0.13	ts (1)	ts (1)	1.0	6.85
2334	10S (10)	F (0)	10S (10)	10MS (8)	45S (45)	F (0)	17.67	10S (10)	5S (5)	5S (5)	6.67	5MR-tS (1.5)	F (0)	0.75	7.51
2498	10S (10)	tS (1)	5S (5)	tMS (0.8)	45S (45)	tMS (0.8)	15.53	ts (1)	5MS (4)	20MR (8)	4.33	5MR-tS (1.5)	F (0)	0.75	6.1
Agra Local (Check)	60S (60)	40S (40)	70S (70)	60S (60)	50S (50)		55.0	50S (50)	50S (50)	40S (40)	46.67	60S (60)	40S (40)	50.0	53.61

Co-efficient of infection (CI) values given in parentheses.

Test Locations: 1=Indore, 2=Mahabaleshwar, 3=Wellington

- = Reaction not available

Table 3. Adult Plant Responses of resistant Israeli *durum* land races to leaf rust

Genetic Stocks (ID Nos)	1983-84	84-85	85-86	1986-87					1987-88				1988-89			1984-89
	1	1	1	1	2	3	4	ACI	1	2	3	ACI	1	2	ACI	MCI
1142	tMR (0.4)	tS (1)	tS (1)	5S (5)	20S (20)	tS (1)	tS (1)	6.75	F (0)	5S (5)	tMS (0.8)	1.9	5S (5)	tS (1)	3.0	2.35
1169	tMR (0.4)	tS (1)	5MS (4)	10MR-tS (2.5)	F (0)	tS (1)	F (0)	0.88	tS (1)	10S (10)	5MS (4)	5.0	10S (10)	tS (1)	5.5	2.8
1221	5S (5)	tS (1)	tS (1)	5S (5)	20S (20)	tS (1)	tS (1)	6.75	F (0)	tMS (0.8)	10MS (8)	2.9	10S (10)	F (0)	5.0	3.61
1568	ts (1)	tS (1)	5S (5)	F (0)	5S (5)	tS (1)	F (0)	1.5	tS (1)	F (0)	10MR (4)	1.7	5S (5)	tS (1)	3.0	2.19
1805	tMS (0.8)	tS (1)	5S (5)	tS (1)	tS (1)	5S (5)	tS (1)	2.0	F (0)	tS (1)	tMR (0.4)	0.5	tS (1)	tS (1)	1.0	1.71
2334	10S (10)	F (0)	5S (5)	10R (2)	20S (20)	5S (5)	tS (1)	7.0	5S (5)	5S (5)	20S (20)	10.0	10S (10)	20S (20)	15.0	7.83
2498	10S (10)	tS (1)	F (0)	tS (1)	40S (40)	10S (10)	tS (1)	13.0	F (0)	20S (20)	20S (20)	13.3	20S (20)	10S (10)	15.0	8.72
Agra Local (check)	70S (70)	50S (50)	80S (80)	60S (60)	20MS (16)	-	-	38.0	60S (60)	40S (40)	40S (40)	46.7	80S (80)	60S (60)	70.0	59.11

Co-efficient of infection (CI) values are given in parentheses.

Test locations: 1 = Indore, 2 = Mahabeleshwar, 3 = Wellington, 4 = Gurdaspur, - = Reaction not available

Table 4. Seedling reactions of field resistant Israeli *durum* land races to Indian stem rust pathotypes.

Genetic Stocks (ID Nos)	Pathotypes 11A	14	17	21A-2	40	40A	42	42B	117A	117A-1	122	184	295
1142	3-4	2-4	3-4	3+	2-4	4	4	2-3	2-4	2-4	2-4	2-4	3-4
1169	3-4	1-3+	3-4	0;	2-3	3-4	4	3-4	2-3	0;	3-4	2-4	2-3
1221	3-4	3	3-4	2-3	2-3	3-4	-	2-3	2-4	3-4	2-3	2-4	3-4
1568	2-4	3	3-4	2-3	2-4	2-4	3-4	3-4	3-4	3-4	2-3	2-4	3-4
1805	1-4	1-3	3-4	1-3	2-4	3-4	4	2-3	2-4	3-4	2-3	3-4	2-3
2334	2-3	1-3	3-4	2-3	2-4	3-4	4	3-4	2-3	3-4	2-3	3-4	2-3
2498	3-4	1-3	3-4	2-3+	2-4	3-4	2-3	3-4	2-3+	3-4	2-3	2-4	2-4
Agra Local (Check)	4	3-4	3-4	4	4	3-4	4	4	4	4	4	4	4

IT 0;, 1 and 2 indicate avirulence. Higher infection types indicates virulence. - = Reaction not available

Table 5. Seedling reactions of field resistant Israeli <u>durum</u> land races to India leaf rust pathotypes.

Genetic Stocks (ID Nos)	Pathotypes																	
	10	11	12	12A	12-1	20	77	77A	77-1	104	104A	104-1	104B	106	107	108	162	162A
1142	1-3	3-4	2-3	0;-2	3-4	2-4	3-4	3-4	1-3	3-4	2-3	3-4	2-4	2-3	2-3	2-3	2-3	2-3
1169	1-3	3-4	2-3	0;-2	2-4	2-4	3-4	3-4	2-3	3-4	1-3	2-3	2-4	1-2	2-3	3-4	2-3	3-4
1221	0;-2	1-2	2-3	0;	3-4	3-4	2-3	3-4	1-2	2-3	1-2	1-3	1-3	0;-2	-	1-3	2-3	3-4
1568	1-2	0;-3	1-2	0;	0;-3	0;-3	0;-2	0;-3	0;-2	0;-3	0;-2	1-3	0;-3	1-2	0;-2	0;-2	2-3	0;-3
1805	0;-1	1-3	3-4	3-4	0;-3	0;-3	0;-2	0;-2	0;-2	0;-3	0;-2	1-3	1-3	1-3	0;-2	1-2	1-3	0;-3
2334	1-3	2-3	2-4	2-3	3-4	1-3	0;-3	1-3	2-3	1-3	1-3	2-3	2-3	1-3	0;-3	2-3	2-4	1-3
2498	1-3	1-3	2-4	3-4	3-4	1-3	1-3	2-4	2-3	1-3	1-3	3-4	3-4	1-3	0;-3	2-4	2-4	3-4
Agra Local (check)	3-4	4	3-4	3-4	3-4	3-4	4	4	4	3-4	3-4	3-4	4	3-4	3-4	3-4	4	4

IT 0;, 1 and 2 indicates avirulence. Higher infection types indicate virulence. - = Reaction not available

Table - 6 Adult Plant Responses of stem and leaf rust resistant stocks to other wheat diseases

Genetic Stocks (ID Nos)	YELLOW RUST					Powdery Mildew	Leaf Blight	Kernel Bunt (Percentage)
	1986-87			1987-88	1986-88	1986-87	1986-87	1986-87
	W	G	ACI	W	MCI	W	G	G
1142	F (0)	20S (20)	10.0	tS (1)	5.5	3	3	0
1169	40S (40)	10S (10)	25.0	tS (1)	13.0	3	3	0
1221	40S (40)	50S (50)	45.0	5S (5)	25.5	5	3	0
1568	5S (5)	F (0)	2.5	tS (1)	1.75	4	3	-
1805	tS (1)	tS (1)	1.0	tS (1)	1.0	3	4	-
2334	20S (20)	tS (1)	10.5	20S (20)	15.25	5	3	0
2498	40S (40)	30S (30)	35.0	10S (10)	22.5	2	3	0
<u>Checks</u>								
Agra Local	60S (60)	-	60.0	-	60.0	3	-	-
WL 711	-	100S (100)	100.0	-	100.0	-	7	>1

Co-efficient of infection given in parentheses.
Locations: W = Wellington, G = Gurdaspur. - = Reaction not available

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OBSERVATIONS ON VIRULENCE/AVIRULENCE PATTERNS OF *PUCCINIA RECONDITA* IN WHEAT CULTIVAR MIXTURES AND THEIR COMPONENT PURELINES

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SUMMARY

Three different experiments involving winter wheat cultivar mixtures were conducted at McGregor, Texas in the 1986-87 and 1987-88 growing years. The same experiments were also conducted during 1987-88 at Dallas, Prosper, Stephenville, and Uvalde, Texas. The objectives of the experiments were to determine the virulence structure of *Puccinia recondita* in mixtures and component purelines and to compare the virulence pattern of the pathogen isolates collected at different times from various locations.

Experiments on the population structure of *P. recondita* in mixtures yielded variable results. In some instances there was an increase in virulence genes in the pathogen population from mixtures, and in others there was a decrease. There appears to be a density-dependent effect on *P. recondita* in mixtures ie. fewer virulence genes in the population at low population levels.

INTRODUCTION

Researchers at the USDA Cereal Rust Laboratory in St. Paul, Minnesota (7,8) and Marshall (9,10) in Texas have unequivocally shown a high degree of variability for virulence in populations of the wheat leaf rust pathogen. *Puccinia recondita* Rob. ex Desm. This variability allows the pathogen to adapt rapidly to resistance genes introduced in new cultivars. As a new cultivar gains in popularity with producers, its acreage increases, thus giving the pathogen more opportunities to combine increased virulence with overall fitness traits. Such cultivar-directed selection often results in leaf rust epidemics (3,10). A deployment strategy that could extend the useful life of wheat cultivars in severe leaf rust areas is the use of cultivar mixtures. A cultivar mixture is a heterogeneous crop of a single species. Cultivar mixtures have been effective in controlling several small grain diseases (1,12). A major criticism of cultivar mixtures has been their potential to generate complex, well-adapted races of pathogens. Much of the work in this regard has been theoretical (1,4,5). However, as Wolfe (12) indicated, there has been no field evidence for a consistent increase in a complex race on a cultivar mixture.

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The objective of this study was to determine the virulence structure of P. recondita in several pureline cultivars and their mixed plantings.

MATERIALS AND METHODS

Field plots

Seed of winter wheat cultivars possessing susceptibility of moderate resistance to leaf rust (caused by Puccinia recondita Rob. ex Desm.) were mixed and sown at the Texas Agricultural Experiment Station Research farms located at McGregor in 1986 and 1987, and at Dallas, Prosper, Stephenville, and Uvalde in 1987. Seeding rate was 84 kg/ha, and plot size was 1.2m wide and 9.4m long. Row spacing at McGregor and Uvalde was 30.5cm and 17.3cm at Dallas, Prosper and Stephenville. Plots were bordered on all sides by an oat (cv. H-833) in addition to a 1.2m alley of bare soil at the ends of plots. Each experiment was sown as a randomised complete block design with four replications.

The criteria for cultivar selection within an experiment were leaf rust reaction, similarity of heading dates and maturity, and height. Thus, the moderately resistant (R) wheats, Collin, Sioxland, Thunderbird and TX71C8130R, and the susceptible (S) wheats Hawk, Mustang, TAM 107, and Vona were used in mixtures. In experiment I, Tam 107 (S), Collin (R) and TX71lC8130R (R) were mixed in ratios of 1/3S:1/3R:1/3R and 2/3S:1/3R+R. Experiment II used Mustang (S), Vona (S), and Thunderbird (R) mixed in ratios of 1/3S+S:2/3R and 1/3S:1/3S:1/3R. In experiment III, Hawk (S) and Siouxland (R) were mixed in proportions of 9:1, 3:1, 2:1, 1:1, 1:2, 1:3 and 1:9. The cultivars in each experiment were also grown as pure stands.

Virulence/avirulence analysis

In each experiment, 12 uredinial-bearing leaves were collected from every pure line and mixture (3 leaves per plot with 4 replications). The P. recondita collections were made at Feekes' growth stages (GS) 9 (pre-boot) and GS 11 (early milk) at McGregor in 1987 and Dallas, McGregor, Prosper, Stephenville, and Uvalde in 1988. All collections were transported back to the laboratory in Dallas, where the urediniospores were used to inoculate seedlings of the cultivar Thatcher (CI 10003) or TAM 107 (PI 495594). After 12 days, urediniospores from a single uredinium were inoculated onto a set of Thatcher near-isogenic lines and placed in a dew chamber for a 14 hr dark period at 18°C. The set of Thatcher near-isogenic lines used were Lr 1,2a,2b,2c,3,3ka,9,10,11,14a,14b,15,16,17,18,19,21,23,24,25, 26,28,29,30,32,33, and 33+34. The inoculated plants were placed on greenhouse benches at 26-30°C after the dew chamber treatment. Infection types were recorded 10-12 days following inoculation and were classified as types; (fleck), 0,1, and 2, indicating avirulent reactions, and types 3 and 4 indicating virulent reactions (6).

In addition to determining the virulence and avirulence of each collection, the avirulence index (AI) was expressed as a percentage and calculated as:

$$AI = \frac{\text{Number of } \underline{Lr} \text{ lines with avirulent reactions}}{\text{Total number of } \underline{Lr} \text{ lines tested}} \times 100$$

Within an experiment and collection time, the mean AI of the mixtures was compared to that of the purelines in order to estimate the overall virulence in mixtures and purelines.

RESULTS AND DISCUSSION

Because of high temperatures (26-30°C) in the greenhouse following the dew chamber treatment, it was possible that several avirulent infection types were assessed as virulent types. This was evident in the observation that all isolates appeared virulent to Lr 1,2a,2b and 3. This virulence pattern would place all the isolates into unified Numeration (UN) race 13. The UN 13 race was prevalent in the southern plains in 1986 and 1987 (7,8), and comprised 14% of the isolates collected in Texas from 1985-87 (11). However, it would be highly unusual to find only a single race of *P. recondita* over the six location years of this study. Nevertheless, the avirulent reactions should have been accurate because in those cases, uredinia were either absent (fleck reaction) or very small.

The avirulence index could not be calculated for all isolates due to either the lack of infections in the field or in the greenhouse (Table 1). The three-way mixtures in experiment one had consistently smaller AI percentages than their component purelines of TAM 107 (susceptible), Collin (resistant), and TX71C8130R (resistant) at GS 11 (Table 1). This indicates that the *P. recondita* population in the mixtures carries more virulence genes than populations from the component cultivars. The other experiments had variable AI percentages across location years. At Dallas, there was an apparent trend for the *P. recondita* populations in the mixtures to carry fewer virulence genes than the populations in the purelines (Table 1). It was observed that leaf rust intensity was very low at Dallas in 1988. This could indicate that *P. recondita* tends to be less diverse at lower population densities in mixtures as compared to purelines.

Because the data collected during this study may be questionable, any conclusions reached are speculative. As pointed out by Barrett (2), a cultivar mixture presents the pathogen with an evolutionary dilemma whose outcome depends on the population genetics and the dynamics of the pathogen within the mixture. If the pathogen is able to adapt to the mixture, the adaptation rate will depend on the selection coefficients of the phenotypes with different combinations of virulence genes and on the distribution of spores between plants (1,2). The direction of selection in the pathogen population is probably impossible to predict because of the interacting factors of host and pathogen genotypes and environment (1). The present study showed that the *P. recondita* population was variable between mixtures and over locations.

Table 1 The mean avirulence index of *Puccinia recondita* isolates collected from mixtures (M) and purelines (P) at Feekes' GS 9 and GS 11 over six location-years

Experiment and growth stage	Location and avirulence index[1]											
	McG89		McG88		Dal		Pro		Ste		Uva	
	M	P	M	P	M	P	M	P	M	P	M	P
Expt #1												
GS 9	--	--	--	--	58	38	--	--	--	--	--	--
GS 11	40	44	34	40	--	--	27	36	--	--	32	40
Expt #2												
GS 9	--	--	48	56	42	37	33	42	--	--	46	56
GS 11	37	41	36	46	--	--	38	36	33	49	50	38
Expt #3												
GS 9	57	68	49	43	43	32	50	44	36	46	46	59
GS 11	37	30	36	25	40	30	36	31	41	36	46	50

[1]Locations were McG = McGregor, Dal = Dallas, Pro = Prosper, Ste = Stephenville, and Uva = Uvalde. Avirulence indices are expressed as percentages (see text for explanation). Blanks (--) indicate insufficient data to calculate avirulence index.

The results from Dallas, which indicated a density-dependent effect on P. recondita virulence structure in mixtures, agrees with the theoretical arguments of Barrett (2). He surmised that mixed plant populations would have a negative effect on pathogen virulence genes at low, but not at high pathogen population levels.

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WHEAT SOURCES WITH A COMPLEX RESISTANCE TO RUSTS

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SUMMARY

Results are presented regarding the resistance of 47 wheat samples to the three rust species, brown, stem and yellow. On the basis of their response at the adult stage the entries are divided in four groups: 1) resistant to the three rust species; 2) resistant to brown and stem rust, but susceptible to yellow rust; 3) resistant to brown and yellow rusts, but susceptible to stem rust; and 4) resistant to stem and yellow rusts, but susceptible to brown rust.

Within the ranges of the separate groups the entry's response is compared at seedling and adult stages, and entries with typical adult plant resistance are shown. This character is especially typical and common with brown rust.

One of the basic tasks of wheat breeding today is to develop cultivars with a complex resistance to economically important diseases and in the first place to the rusts. All three rust species have economic importance in Bulgaria, but brown rust (*Puccinia recondita* f. sp. *tritici*) occurs most often. Stem rust (*P. graminis* f. sp. *tritici*) and yellow rust (*P.striiformis* f. sp. *tritici*) appear more rarely, but these are more harmful and represent a potential risk for wheat production. That is why a directed immunoselection is conducted against the three rust species. In order to find rust resistant sources thousands of entries are tested for resistance at different Bulgarian Institutes and chiefly at the Plant Protection Institute, Kostinbrod; the Wheat and Sunflower Institute, General Toshevo and the Institute of Introduction and Plant Resources, Sadovo. The results are published in a series of papers (2,5,6,8).

In recent years work on the search for sources with a complex resistance to the three rust species continued and some of the most interesting results are given in this paper.

MATERIALS AND METHODS

The studies were carried out at the Plant Protection Institute in Kostinbrod during the period of 1985-1988 (brown and stem rusts) and at the Wheat and Sunflower Institute, General Toshevo (yellow rust). Several hundreds of samples at the seedling stage were tested to single physiological races of the pathogens and to a population of races at the adult stage (about and after heading). The races used at the seedling stage are showed in Table 1. In addition to these, races 122, 168, and 176 of P.recondita tritici; 14, 56, 186, 191, III-33, of P. graminis tritici; and 38 E 16, 41 E 168, 104 E 41, 108 E 173 and 232 E 137 of P. striiformis were also included in the populations at the adult stage.

The inoculation of the samples studied was done according to the standard methods described in the literature (1,4,8,9,12). The infection type was recorded at the seedling stage after the standard scales (4,8,9,12) and combined scales for the type and severity at the adult stage (7,9,11).

RESULTS & DISCUSSION

The results regarding 47 entries expressing a complex resistance to at least two rust species are indicated in Table 1. Their response to the single races at the seedling stage is designated by the symbols R, MR, MS and S. The average assessments are given at the adult stage. The entries are divided in four groups:

I. Samples with a complex resistance to the three rust species at the adult stage. Their number is 20. Five of them (CIMMYT 2/81, CIMMYT 72/81, CIMMYT 253/81, ECM 403, Triticum fungicidum) are also resistant to the races of the pathogens used at the seedling stage. The rest responded as susceptible at this stage to single races of one or more pathogens. Susceptible entries to single brown rust races are CIMMYT 81/81, CIMMYT 468/81, CIMMYT 547/81, Kenya Zabadi, Zg. 3452/80; to single races of stem rust - T. timopheevi; and to single yellow rust races CIMMYT 30/81, CIMMYT 316/81 and KS 56-R-386 X Ang./Kaw.5-Ag. CIMMYT 278/81 and Sakha are susceptible to single races of brown and yellow rust, and Enkoy to single races of stem and brown rusts. The entries Tp 114/65A and CIMMYT 16/81 are described as susceptible to single races of the three rust species at the seedling leaf stage.

II. Samples with a complex resistance to brown and stem rusts at the adult stage, but susceptible to yellow rust. 19 entries are in this group. Most of them are resistant also at the seedling stage (Angus, CIMMYT 31/81, Gussenka, Kenya Farmer Hope Fulltz 5229 B-41-4, Purdue Abe, Torum F 63, Tp 229). The entries C.I. 12632, CIMMYT 6/81, KOC 11/81 and Minn 69124 are susceptible to single races of the two rust species at the seedling stage. Edmore Era, Khapli x Supreza 59 C 239, Minn 7011, Tolusa and Transek are susceptible only to single brown rust races, while Sonora 64 and Tifton are susceptible to individual stem rust races.

III. Samples with a complex resitance at the adult stage to brown and yellow rusts, but susceptible to stem rust. Two of the four entries included in this group (CIMMYT 3/81 and Eureka) are also resistant to the two rust species at the seedling stage, and the others CIMMYT 102/81 and Frankenmut are susceptible to single races of brown rust.

IV. Entries with a complex resistance at the adult stage to stem and yellow rusts, but susceptible to brown rust. Four samples are included here. Three of them, Kenya Bongo, P-4821-80 Zagreb and TAW 6505/74 are also resistant to these rusts at the seedling stage, and one, SC 792197 is susceptible to one race of stem rust.

It seems that most of the wheat entries studied express the adult plant resistance character to a lesser or higher degree, being susceptible to single races of the pathogens at the seedling stage, while adult plants are resistant to populations including such races. This character is especially typical and common in athe case of brown rust in 17 entries. Adult plant resistance to this rust species is the most highly marked in the samples Bu 17, C.I. 12632, CIMMYT 6/81, CIMMYT 81/81, CIMMYT 468/81, CIMMYT 547/81, Kenya Zabadi, Sakha, Tolusa and Tp 114/65A, which are attacked at the seedling stage by all or by the majority of the races used. With respect to stem rust, adult plant resistance on the whole, is very weakly expressed. Samples with good adult resistance are Minn 69124 and Tifton, Tp 114/65A. Regarding yellow rust the case is similar. Entries with good adult plant resistance expressed to yellow rust are CIMMYT 278/61, CIMMYT 316/81, KS-56-R-386 x Ang./Kaw.5-Ag.

Samples showing adult plant resistance are of great interest, as it is suggested that this resistance is race non-specific (3). As a result of the study, valuable breeding sources are selected possessing complex resistance to rusts on wheat. The most valuable ones are the entries showing complex resistance to the three rust species at the seedling stage and also at the adult stage, i.e. CIMMYT 2/81, CIMMYT 72/81, CIMMYT 253/81, ECM 403, <u>T. fungicidum</u>.

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Table 1. RESISTANCE OF WHEAT CULTIVARS TO RUSTS IN THE 1985-1988 PERIOD

No.	Cultivars	*P. recondita tritici* Seedling resistance to races						*P. graminis tritici* Seedling resistance to races						*P. striiformis tritici* Seedling resistance to races				
		77	77C	157	167	172	Adult plant resistance	11	34	44	II-8	III44	Adult plant resistance	6E 16	41E 136	104E 137	104E 169	Adult plant resistance
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
I.	Resistant to the three rusts																	
1.	Bu 17	S	-	R	MR	S	0	MR	S	R	R	R	0	R	S	R	R	10 M
2.	CIMMYT 2/81*	R	R	R	R	R	t R	MR	R	R	R	R	20 R	R	R	R	R	0
3.	CIMMYT 16/81	S	S	S	S	S	5 R	S	R	R	R	R	t R	R	S	R	R	0
4.	CIMMYT 30/81	R	R	R	R	R	2 R	R	R	R	R	R	5 R	R	R	R	S	10 M
5.	CIMMYT 72/81	R	R	R	R	R	0	R	R	R	R	R	5 R	R	R	R	R	0
6.	CIMMYT 81/81	S	S	R	R	S	t R	R	R	R	R	R	5 MR	R	R	R	R	2 MR
7.	CIMMYT 253/81	R	R	R	R	R	0	-	R	R	R	R	5 R	-	R	R	R	2 MR
8.	CIMMYT 278/81	R	S	R	S	R	t R	MR	R	R	R	R	25 R	R	M	S	R	2 MR
9.	CIMMYT 316/81	R	R	MR	R	R	0	R	R	R	R	R	2 R	R	M	S	R	10 M
10.	CIMMYT 468/81	S	S	R	S	R	10 R	R	R	R	R	R	30 R	R	R	R	R	0
11.	CIMMYT 547/81	S	S	S	S	S	10 R	R	R	R	R	R	15 R	R	R	R	R	5 MR
12.	ECM 403	R	R	R	R	R	0	R	R	R	R	R	2 R	R	R	R	R	2 MR
13.	Enkoy	R	R	R	MR	R	2 MR	R	S	R	R	R	0	-	S	-	-	2 MR
14.	Kenya Zabadi	S	S	S	S	R	5 R	R	R	R	R	R	0	R	R	R	R	2 MR
15.	KS 56-R-386 X Ang./Kaw.5Ag.	R	-	R	R	R	0	MR	S	R	R	R	0	R	S	R	R	2 MR
16.	Sakha	S	S	S	S	R	10 MR	R	R	R	R	R	10 R	R	MS	-	-	0
17.	Tp 114/65A	S	MR	S	MR	S	2 R	S	S	R	R	R	10 MR	R	R	S	R	2 MR
18.	Triticum fungicidum	R	R	R	R	R	0	R	R	R	R	R	0	M	R	R	R	0
19.	Triticum timopheevi	R	R	R	R	R	0	S	R	R	R	R	t M	R	R	R	R	0
20.	Zg 3452/80	R	S	R	R	R	2 R	R	R	R	R	R	0	R	R	R	R	0

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
II.	Resistant to brown and stem rust																	
1.	Agent/Asosan/2/Arthur-Tifton 2848	R	R	R	R	R	0	R	R	R	R	R	t R	R	R	S	S	80 S
2.	Angus	R	R	R	R	R	5 R	R	R	R	R	R	30 MR	R	R	S	R	50 MS
3.	C.I. 12632	S	MR	S	S	S	10 R	S	MR	R	R	R	2 MR	S	S	R	S	50 S
4.	CIMMYT 6/8	-	S	S	R	S	0	S	R	R	R	R	0	R	S	S	R	50 MS
5.	CIMMYT 31/81	R	R	R	R	R	0	R	R	R	R	R	10 R	S	R	R	S	30 MS
6.	Edmorem Era	R	S	R	R	R	0	R	R	R	R	R	15 MR	R	MS	S	R	25 M
7.	Gussenka	R	R	R	R	R	0	MR	R	R	R	R	t R	R	S	S	R	70 S
8.	Kenya Farmer Hope Fulltz 5229 B-41-4	R	R	R	R	R	t R	MR	R	R	R	R	15 MR	S	S	S	R	70 MS
9.	Khapli X Supreza 59 C 239	-	S	MR	MR	MS	t R	R	R	R	R	R	15 MR	S	R	M	MR	30 M
10.	KOC 11/81	R	R	R	S	R	0	S	R	R	R	R	t R	S	R	R	S	10S
11.	Minn 7011	R	S	R,S	S	R	2 R	MR	R	R	R	R	15 R	S	S	S	R	60 MS
12.	Minn 69124	S	S	R,S	R	R	2 R	S	S	R	R	R	5 MR	R	S	R	R	60 MS
13.	Purdue Abe	R	R	R	R	R	2 R	MR	R	R	R	R	0	S	S	S	S	70 S
14.	Sonora 64	R	R	R	R	R	5 R	S	R	R	R	R	10 R	S	MS	S	R	70 S
15.	Tifton	-	R	R	R	R	0	S	S	R	R	R	0	S	MS	S	R	80 S
16.	Tolusa	S	R	R	S	S	15 MR	R	R	R	R	R	10 R	R	S	R	S	40 M
17.	Torum F 63	R	R	R	R	R	5 R	MR	R	R	R	R	5 R	R	R	R	M	10 MS
18.	Tp 229	R	R	R	R	R	t R	MR	R	R	R	R	20 R	S	S	S	R	60 MS
19.	Transek	R	S	R	R	R	0	R	R	R	R	R	10 R	R	S	R	-	70 S

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
III.	<u>Resistant to brown and yellow rust</u>																	
1.	CIMMYT 3/81	R	R	R	MR	R	0	S	R	R	R	R	30 M	R	R	R	R	10 MR
2.	CIMMYT 102/81	S	R	R	MS	R	t R	MS	R	R	R	R	20 M	R	R	R	R	0
3.	Eureca	R	R	R	R	R	2 R	S	R	R	R	R	30 MS	R	R	R	R	20 MR
4.	Frankenmut	S	S	-	MR	-	2 R	S	-	-	-	-	20 S	R	R	R	R	2 R
IV.	<u>Resistant to stem and yellow rust</u>																	
1.	Kenya Bongo	S	MR	R	R	R	30 S	R	R	R	R	R	20 R	R	R	R	R	2 R
2.	P 4821-80 Zagreb	S	-	R	S	R	10 MS	R	R	R	R	R	30 R	R	R	R	R	2 R
3.	SC 792197	MR	S	S	S	S	20 MS	S	R	R	R	R	0	R	R	R	R	0
4.	TAW 6505/74	S	S	S	S	S	30 S	R	R	R	R	R	20 R	R	R	R	R	0
	Michigan Amber /sd/	S	S	S	S	S	50 S	S	S	S	S	S	80 S	S	S	S	S	80 S

* - See lit. No. 10

PREPARATION OF PAPERS FOR PUBLICATION IN THE CEREAL RUST 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 3cm margin at the top, bottom and both sides.

3) It is especially important for Tables to be presented so that they can easily be fitted to an A4 sheet. They must have a 3cm margin all round, and not have so much on that they cannot be copied into the format for the journal.

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

5) Photographs cannot be published.

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.

7) Most papers are accepted for publication, but the editor retains the right to reject papers that are of poor quality or too long.

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