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RESISTANCE OF *TRITICUM DICOCCOIDES* TO INFECTION WITH *ERYSIPHE GRAMINIS TRITICI**

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Triticum dicoccoides, wild emmer wheat, *Erysiphe graminis tritici*, powdery mildew, resistance, Israel, germplasm, wheat, collection.

SUMMARY

The reactions of 233 *Triticum dicoccoides* accessions, collected at 10 sites in Israel and elsewhere, to infection with cultures of *Erysiphe graminis tritici*, were determined. The reactions indicated that the number of sources of resistance to *E. graminis tritici* which can be obtained from *T. dicoccoides* plants growing wild in Israel and elsewhere is almost unlimited. One hundred and fourteen or 49% of the accessions were resistant, and 137 or 59% of the accessions were resistant or moderately resistant to infection with four cultures of *E. graminis tritici* which possess the virulence genes corresponding to most of the identified resistance genes in wheat. Accessions collected at sites with marginal habitats where *T. dicoccoides* grows poorly and has lower grain weight, were more susceptible than were accessions collected at sites with an optimal habitat for growth of *T. dicoccoides*. The results agreed with those in a previous study with *Hordeum spontaneum*, and indicate that to obtain *H. spontaneum* or *T. dicoccoides* accessions with the highest level of resistance to the powdery mildew pathogens, plants should be collected at sites in ecological and geographic regions where those two species occupy optimum habitats and are exposed to the powdery mildew pathogens.

INTRODUCTION

The disease powdery mildew of wheat (*Triticum aestivum* L.), incited by the pathogen *Erysiphe graminis* DC. ex MERAT. f. sp. *tritici* (EM. MARCHAL), is one of the most important diseases of wheat on a world wide basis. The disease causes significant losses in wheat production in the United States, UK, New Zealand, and Hungary (HERBERT et al., 1948; LARGE & DOLING, 1962; SMITH & SMITH, 1974; SZUNICS & SZUNICS, 1970).

The most effective and efficient method for reducing losses in production from wheat powdery mildew is the development of resistant cultivars. Wheat cultivars resistant to the pathogenic strains of *E. graminis tritici* have been identified by scientists in Bulgaria, Hungary, German Democratic Republic, UK, Sweden, Australia, Poland, and India (KUNOVSKI et al., 1973; LARGE & DOLING, 1962; LEIJER-STAM, 1965; MCINTOSH, 1978; NOVER & LEHMANN, 1969; RALSKI & WOZNIAK-STRZEMBICKA, 1972; SZUNICS & SZUNICS, 1970; UPADHYAY et al., 1972). However, the genetics diversity among

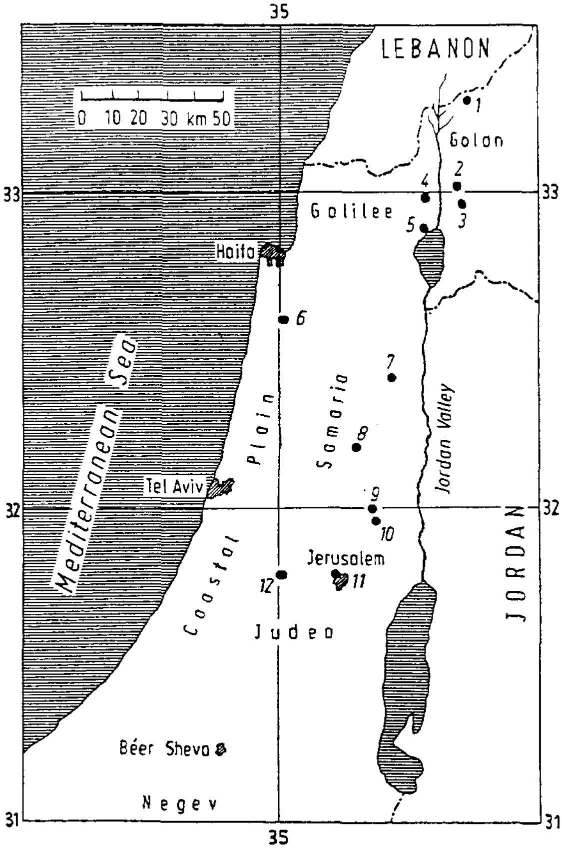

Fig. 1. Geographic distribution of sampling localities of *T. dicoccoides*.

those resistant cultivars is limited, since many of those cultivars have parents with the same resistance genes.

Genes for resistance to *E. graminis tritici* have been identified in wheat at 8 distinct loci, Pm1 through Pm8, with three genes at the Pm3 locus. Genes at 6 of the 8 loci were transferred to wheat from other *Triticum* species or rye, *Secale cereale* L. Genes were derived at loci Pm2 and Pm6 from *T. timopheevi* ZHUK., at loci Pm4 and Pm5 from *T. diccocum* SCHUEBL., and at loci Pm7 and Pm8 from rye (BRIGGLE, 1966; MCINTOSH, 1978; MOSEMAN et al., 1980). A resistance gene identical to gene Pme, which is closely linked with gene Pm4, has been identified in line TP 229 which was derived from *T. carthlicum* NEDSKI. (JORGENSEN & JENSEN, 1971).

Many sources of resistance to *E. graminis tritici* have been identified in *T. diccocum* and *T. dicoccoides* KOERN. ex ASCHERS. and GRAEBN. AARONSOHN (1910) and GRAS (1979) found that 49% of the 309 *T. dicoccum* accessions, obtained from the USDA Wheat Collection at Beltsville, Maryland, were resistant to a population of *E. graminis tritici* in Italy that was virulent on variety Khapli, which has resistance gene Pm4 and 3 additional genes for resistance to *E. graminis tritici* (MOSEMAN et al., 1980). KRIVCHENKO et al. (1979) determined the reactions of 129 samples of *T. dicoccum* to pathogenic strains of *E. graminis tritici* and found 65% of the samples were resistant in the field, and 62% of the samples were resistant in the seedling stage. In the same tests, they found 28 of 29 *T. dicoccoides* samples were resistant in the field and 11 of 15 samples were resistant in the seedling stage.

T. dicoccoides, the wild tetraploid species from which *T. dicoccum* was derived, was discovered in northern Israel by AARONSOHN in 1910 (AARONSONN, 1910). The natural distribution of *T. dicoccoides* is centered in the upper Jordan Valley from below sea level in the basin of the Sea of Galilee to the cooler slopes of Mt. Hermon at 1300 meters HARLAN & ZOHARY, (1976).

Many accessions of *T. dicoccoides*, obtained from seed collected from plants growing at many sites in Isreal, have been studied. ESHED & WAHL (1975) found that *T. dicoccoides* plants were abundant in eastern Galilee and less common in other regions, and that *E. graminis tritici* isolated from *T. dicoccoides* infected both barley and bread wheat and remained stable following more than 100 reinoculations. GERECHTER-AMITAI & STUBBS (1970) studied *T. dicoccoides* accessions collected from 32 sites, and found seedlings from 17 of the 55 accessions were resistant to *Puccinia striiformis* WEST. in the first leaf stage. GERECHTER-AMITAI & GRAMA (1974) showed that the resistance of selection G-25 of *T. dicoccoides*, collected from near Rosh Pinna, had one dominant gene conditioning its resistance to *P. striiformis*.

NEVO et al. (1982) studied the genetic diversity of *T. dicoccoides* populations collected at 12 sites in Israel by analyzing the electrophoretically discernible allozymic variations in protein. They found a statistically significant variation among localities for 6 spikelet characters and that allozymic variation was correlated with spikelet variation. They also found allozymic and spikelet variations were significantly correlated with, and partly predictable by, the water factors precipitation, evaporation and relative humidity, as well as soil type.

The objectives of this study were to identify new sources of resistance to *E. graminis tritici* and to determine the relative frequency of resistant plants at different sites in Israel among *T. dicoccoides* accessions collected and studied by NEVO et al. (1982).

MATERIALS AND METHODS

The 233 *T. dicoccoides* accessions used in this study were previosly studied for genetic diversity and environmental associations by NEVO et al. (1982). The accessions were collected from plants growing at 10 sites (see Figure 1 and Table 2). The sites extend from Mt. Hermon (site 1) in the north to sites 11 and 12 near Jerusalem in the south to Bat Shelomo (site 6) near the coastal plains. The sites represent the range of geographical and ecological conditions where *T. dicoccoides* grows in Israel. The accessions within each site were collected at random.

The 4 cultures of *E. graminis tritici* (Quincy, M010, 127, and ABK) were selected because of their origin and virulence on known genes for resistance in wheat. Culture Quincy was collected and isolated by R. A. Kilpatrick in 1980 from a plant growing in Quincy, Florida. Culture M010 was collected and isolated by J. L. Clayton from a plant growing in Moore County, Michigan. The other two cultures, 127 and ABK, were cultures 21 and 38, respectively, in the study by BRIGGLE (1966).

The method of inoculation and procedure for reading reactions to infection were as follows: Plants were inoculated in the second leaf stage by gently shaking heavily infected plants over the seedlings so that conidiospores were uniformly distributed on the leaves. Reactions to infection were read 7 days after inoculation and verified after 9 days. The infection types (IT) produced by the reactions were read on a 0 to 9 scale from immune to susceptible:

0 = immune, no visible sign of infection,
1 to 3 = resistant, increasing from no necrosis to large necrotic areas, increasing from no mycelium to little mycelium,
4 to 6 = moderately resistant, necrotic areas changing to chlorotic areas, increasing in amount to mycelium and conidiospore production,
7 to 9 = susceptible, decreasing from chlorotic areas to no chlorosis, increasing in amount of mycelium and conidiospore production to a completely compatible relationship with the pathogen.

Plants of each acession were infected with composites of conidiospores of cultures Quincy and M010 (composite no. 1) and of cultures 127 and ABK (composite no. 2). The highest IT was recorded for plants infected with each composite of cultures. The test were conducted in a growth room in which the temperature was maintained at 16–19 C with a 12 hour photoperiod of 175 UEsec^{-1}m^{-2} of cool, white fluorescent light. The reactions to infection were summarized by combining the IT into 3 groups with resistant (R) = 0–3, moderately resistant (M) = 4–6, and susceptible (S) = 7–9. The average IT for accessions from a location was the sum of the IT on each accession divided by the number of accessions from that location.

RESULTS

The IT produced on 11 wheat isogenic lines and varieties, with known genes conditioning resistance to infection with culture 6, to infection with cultures Quincy, M010, 127, and ABK of *E. graminis tritici* are shown in Table 1. The cultures produced different resistant IT on some of the lines and varieties. This suggests that those lines and varieties have more than one gene conditioning their resistance to those cultures. How-

Table 1. Infection types produced by reactions of eleven wheat isogenic lines and varieties to infection with 5 cultures of *Erysiphe graminis tritici*.

Isogenic lines or varieties	CI No.	Genes^{+}	Infection type with cultures				
			6	Quincy	M010	127	ABK
Axminister × CC8	14114	Pm1	0	2	2	1	8
Ulka × CC8	14118	Pm2	2	7	8	2	8
Asosan × CC8	14120	Pm3a	1	8	8	1	1
Khapli × CC8	14123	Pm4 + q	0	6	8	0	0
Yuma × CC8	14124	Pm4 + 1	0	8	8	1	0
Chul × CC8	14121	Pm3b	1	3	4	8	0
Mich. Amber × CC	81588		2	8	8	4	2
Sonora × CC8	14122	Pm3c	0	8	8	8	3
Khapli	4013	Pm4 + 3	0	0	1	0	0
Yuma	13245	Pm4 + 2	0	4	2	0	0
Sonora	3036	Pm3c +	1	6	6	0	3

$^{+}$ Genes conditioning resistance of hosts to culture 6.

Table 2. Reactions of *Triticum dicoccoides* accessions collected in Israel to infection with two composites of cultures of *Erysiphe graminis tritici*.

Location	Site No.	Number of accessions	Composite No. 1[a] reactions[b]			Average infection types	Composite No. 2[a] reactions[b]			Average types
			R1	M1	S1		R2	M2	S2	
Mt. Hermon	1	14	6	2	6	5.0	3	3	8	6.1
Qazrin	2	35	33	2		2.1	35			1.7
Yehudiyya	3	13	6		7	5.6	5		8	5.7
Rosh Pinna	4	28	21	5	2	2.5	27		1	1.8
Tabigha	5	32	15	6	11	4.6	18	4	10	4.5
Bat Shelomo	6	32	5	5	22	6.8	10	4	18	5.8
Kokhav Hashahar	9	34	24	4	6	3.4	26	2	6	3.1
Taiyiba	10	9	2	5	2	4.2	5		4	4.9
Sanhedriyya	11	18	2	1	15	7.2	3	1	14	6.7
Bet Meir	12	18	7		11	5.5	5	1	12	5.9
Total		233	121	30	82		137	15	81	
%			51.9	12.9	35.2		58.8	6.4	34.8	

[a] Composite No. 1 was Quincy and Molo, and Composite No. 2 was 127 and ABK.
[b] Reactions: R = Infection types 0–3; M = Infection types 4–6; and S = Infection types 7–9.

ever, most of those lines and varieties were susceptible to at least one of the four cultures. The susceptibility of those hosts indicates that none of the resistance genes in those hosts are effective in conditioning resistance to those cultures to which they are susceptible. Therefore, plants resistant to infection with all four cultures must have other genes conditioning their resistant reactions or a combination of two or more resistance genes.

The reactions of 233 *T. dicoccoides* accessions collected at 10 sites in Israel to infection with the composites no. 1 and no. 2 of *E. graminis tritici* are shown in Table 2. There were 121 or 52% of the accessions resistant to composite no. 1, and 137 or 59% of the accessions resistant to composite no. 2. There were 151 or 65% of the accessions either resistant or moderately resistant to composite no. 1, and 152 or 65% of the accessions either resistant or moderately resistant to composite no. 2.

The reactions of each accessions within the 10 sites to infection with the two composites are show in Table 3. The order of the sites is arranged to show the variations in reactions of accessions to infection between sites. The average IT at the sites for both composites ranged from 1.9 for site 2 to 6.9 for site 11. Accessions resistant to both composites of cultures were obtained from all 10 sites. There were 114 or 49% of the accessions resistant and 137 or 59% of the accessions resistant or moderately resistant to all four cultures. Only 67 or 29% of the accessions were susceptible to both composites.

DISCUSSION

The number of sources of resistance to *E. graminis tritici*, which can be obtained from *T. dicoccoides* plants growing wild in Israel, is almost unlimited. We found 114 or 49% of the accessions resistant and 137 or 50% of the accessions resistant or moderately

Table 3. Reactions of *Triticum dicoccoides* accessions from different sites in Israel to infection with two composites of *Erysiphe graminis tritici*.

Locations	Site No.	Number of accessions	Reactions to composites 1 and 2[a]									Average infection types
			RR	RM	MR	MM	RS	SR	MS	SM	SS	
Qazrin	2	35	33		2							1.9
Rosh Pina	4	28	21		5			1			1	2.1
Kokhav Hashahar	9	34	23		3	1	1			1	5	3.2
Tabigha	5	32	15		2	3		1	1	1	9	4.5
Taiyiba	10	9	2		3				2		2	4.6
Mt. Hermon	1	14	3	3					2		6	5.5
Yehudiyya	3	13	5				1				7	5.6
Bet Meir	12	18	5				2			1	10	5.7
Bat Shelomo	6	32	5					5	5	4	13	6.3
Sanhedriyya	11	18	2		1					1	14	6.9
Total		233	114	3	16	4	4	7	10	8	67	
%			48.9	1.3	6.9	1.7	1.7	3.0	4.3	3.4	28.8	

[a] First letter indicates reactions to composite No. 1 (Quincy and Molo) and second letter indicates reactions to composite No. 2 (127 and ABK). For example: RM = Resistant to composite No. 1 and moderately resistant to composite No. 2.

resistant to the four cultures which possess the virulence genes corresponding to most of the identified resistance genes in wheat. At least one accession resistant to the four cultures was obtained from each of the 10 sites even though the average infection types at two sites were more than 6. In another study of 217 *T. dicoccoides* accessions, collected in Israel by Gerechter-Amitai, 133 or 61% were resistant to composite no. 1 and 135 or 62% were resistant to composite no. 2(unpublished data).

The accessions collected at the three sites 6, 11, and 12 had the highest average infection types indicating that they were less resistant than were accessions collected at the other 7 sites. Those 3 sites are marginal habitats for *T. dicoccoides* where *E. graminis tritici* has seldom been observed. Nevo et al. (1982) found that the grain weight from the accessions collected at those 3 sites was lower than the grain weight at the other 7 sites. In a previous study, (Moseman et al., 1983) we found that *Hordeum spontaneum* L. accessions collected in marginal habitats for *H. spontaneum* were less resistant to the powdery mildew pathogen than were accessions collected in habitats well adapted for growing that species. The results from these two studies indicate that *H. spontaneum* or *T. dicoccoides* accessions with the lowest average infection types or the highest level of resistance to the powdery mildew pathogens, are obtained in habitats where those two species are well adapted.

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