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Adult-plant resistance to yellow rust in wild emmer wheat

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Abstract

Seventy-six entries of wild emmer, susceptible to a culture of yellow rust, race 39E134, in the seedling stage at a low temperature-profile, were tested with the same culture for field resistance at two locations in the Netherlands. While most entries were susceptible also in the adult-plant stage, 15 showed an intermediate or resistant infection-type in Flevoland and 18 at Wageningen. In subsequent seedling tests at low and high temperature-profiles, including 20 entries which at either of the two locations had displayed field resistance, 16 entries were shown to possess temperature-sensitive genes, whereas four appeared to have true host stage-bound adult-plant resistance.

Additional keywords: Triticum dicoccoides, Puccinia striiformis, stripe rust, temperature-sensitive genes.

Introduction

Among 58 accessions of wild emmer wheat (*Triticum dicoccoides* Körn), Gerechter-Amitai and Stubbs (1970) found two accessions to be very resistant when tested with many isolates of yellow rust in both seedling and field tests. In later work it was shown that numerous selections of wild emmer were highly resistant to isolates of yellow rust from many countries (Van Silfhout and Gerechter-Amitai, in preparation). In addition to this 'seedling' or overall resistance conferred by major genes, Gerechter-Amitai et al. (1984) described in wild emmer also another kind of resistance conferred by temperature-sensitive 'minor-effect' genes, which are race-specific (Gerechter-Amitai and Van Silfhout, in press) and, when combined, display additive gene action (Grama et al., 1984). Gerechter-Amitai et al. (1984) concluded that these genes are effective not only in the seedling stage but also in the adult-plant stage, in the field.

In cultivated wheat, breeding to reduce yield losses caused by yellow rust (*Puccinia striiformis* Westend.) is based mainly on three kinds of resistance. One of these, referred to above as overall resistance, operates in all growth stages of the plant and is effective under a wide range of environmental conditions. The other two kinds of resistance are often detected in the field in the adult-plant stage and are therefore called 'field resistance'. One being conferred by genes sensitive to environmental conditions which prevail in summer and coincide with the adult-plant stage, the other by genes which come to expression only in the adult-plant stage. Transitions and intermediate situa-

tions between the latter two kinds of resistance may exist. Pope (1968), Sharp and Fuchs (1982), Qayoum and Line (1985), Milus and Line (1986) and others described a type of field resistance induced by an increase in temperature during the growing season. The induction of resistance by increasing the temperature could also been shown in the seedling stage in growth rooms with the same lines as used in some of these experiments. Slovenčikova (1972) found that the amount of light can also influence the expression of field resistance. Studying the resistance in the wheat cultivar Bellevue, Pochard et al. (1962) showed that the field resistance of this cultivar was not influenced by temperature. With respect to most cultivars which possess field resistance it is not known, however, whether this resistance is related to certain environmental conditions or is due to adult-plant stage proper.

So, overall resistance and temperature-sensitive resistance have been reported both in cultivated wheat as well as in wild emmer wheat. However the type of field resistance caused by genes which come to expression only in the adult-plant stage has not yet been described for wild emmer wheat. The objective of the present study was to investigate whether in wild emmer also true adult-plant resistance occurs.

Materials and methods

The seed of wild emmer used in this study consisted of 79 entries from 62 collection sites in Israel. The sites range from −125 m alt. near Lake Kinneret (Sea of Galilee) to approximately 1500 m alt. on Mt. Hermon. The specimens showed a wide variation for morphological traits and spike color characteristics.

The entries were selected by the second author from his collection of wild emmer on the basis of their susceptibility to Israeli isolates of yellow rust when previously tested in the seedling stage in growth chambers at a constant temperature of 15 °C and a light intensity of 22 000 lux at plant height.

The studies of field resistance were carried out in the Netherlands with the Dutch isolate 68009 of race 39E134. All entries were first tested in the seedling stage, in growth rooms at temperatures of 17/15 °C day/night and a light intensity of 24 000 lux, in order to ascertain the absence of overall resistance genes to this rust isolate.

After vernalization, the seedlings were planted out at two locations. In Flevoland, the nursery was established in an isolated plot in an oil-seed rape field; in Wageningen, at the IPO, the nursery was established in a plastic tunnel. Ten plants of each entry were grown in an one-meter row, spacing between rows 30 cm. To ensure a constant inoculum pressure on all entries during the experiment, a spreader row was planted along the nursery. Field inoculations were made, when the plants were in the tillering stage, with the same isolate previously used in the seedling test. The inoculum was suspended in mineral oil and applied onto the nursery using a low volume sprayer. When the yellow rust had developed optimally and the plants were in the water-ripe to early-milk growth stage, readings were taken on infection-types using the 0-9 scale of McNeal et al. (1971).

Entries which in the nurseries were more resistant than in the seedling stage were tested once more in the seedling stage, 10-15 plants per entry, for the possible presence of temperature-sensitive genes. One set of the entries was kept at a high temperature-profile with a maximum of 24 °C and a minimum of 15 °C, while a duplicate set was tested at a low temperature profile with a maximum of 18 °C and a minimum of 4 °C.

In both profiles, the maximum temperature was maintained for 10 h and the minimum for 9 h, with a gradual increase and decrease, respectively, for 2.5 h. Light conditions in both growth chambers were 23 000 lux for 6 h, a dark period for 12 h, and a gradual increase and decrease for 3 h in between.

Results

In the seedling trials, out of the 79 entries of wild emmer which had been uniformly susceptible to yellow rust in Israel, 76 proved to be likewise susceptible also to the Dutch test isolate. In the nurseries, 20 of these entries showed in at least one of the two locations a more resistant infection-type in the adult-plant stage than they had displayed in the seedling stage (Table 1). In Flevoland, under field conditions, 15 entries had a resistant or intermediate infection-type; at Wageningen, in a plastic tunnel, 18 entries fell into this category. These include 13 entries which at both locations had either a resistant or intermediate infection-type in the adult-plant stage. Usually, the resistance was higher at Wageningen than in Flevoland, but in three instances (entries 12, 13, 17) the reverse was observed.

In a further study to elucidate whether the field resistance observed in the 20 entries was due to the higher temperatures in summer or to true adult-plant resistance, the entries were tested in the seedling stage, at two temperature-profiles (Table 1). While all entries were susceptible at the low temperature-profile, 16 showed a shift towards resistance at the high temperature-profile (11 displaying an intermediate and five a resistant infection-type), indicating in these entries the presence of temperature-sensitive genes. Four entries (4, 5, 7, 19) were susceptible also at the higher temperature-profile.

Discussion

In our experiments, field resistance in the adult-plant stage showed up in 20 out of 76 entries tested, suggesting that this phenomenon is of rather frequent occurence in wild emmer.

The results of the seedling tests at two temperature-profiles demonstrate that in the majority of these cases, the resistance could be ascribed to temperature-sensitive genes. This conclusion is confirmed by the field test. It was found that at Wageningen, where the nursery was grown in a plastic tunnel, the resistance was often higher than in Flevoland, where the nursery was grown in the open field. Since in the plastic tunnel the temperature was higher than in the open, it may be assumed that the greater resistance was conferred by temperature-sensitive genes in these entries. However, in three instances (entries 12, 13, 17), temperature-sensitive resistance was shown in the seedling tests, but in the field tests the resistance at Wageningen was lower than in Flevoland. This could be the result of other environmental conditions, such as a lower light intensity at Wageningen, due to the plastic tunnel.

In four instances (entries 4, 5, 7, 19) there was no indication of the presence of temperature-sensitive resistance in the seedling stage. The resistance which was observed in the field is thus most probably true adult-plant resistance. The resistance in entries 5 and 7 seems to be most valuable since it is highly effective (infection-types 2-3) and showed up in both nurseries. In two other instances (entries 3, 6), the field resistance is probably a combination of temperature-sensitive resistance and true adult-plant

Table 1. Infection-types on 20 entries of wild emmer in the seedling stage in growth cabinets at two temperature-profiles, and in the adult-plant stage in field nurseries at two locations, scored after inoculation with the same isolate of yellow rust.

Entry number	Wild emmer selection	Seedling reaction		Adult-plant reaction	
		18/4 °C	24/15 °C	Flevoland	Wageningen
1	G 108-5B	9[1]	1	8	5
2	G 110-2M	9	6	8	6
3	G 111-3M	8	6	2	2
4	G 112M	9	8	7	2-3
5	G 123-1M	9	9	3	3
6	G 136-1M	8	5	2	2-3
7	G 150-1M-4M	9	8	2-3	2-3
8	G 153-1M	9	4	7	2-3
9	G 186-1M	9	6	9	5
10	G 224-1B	9	6	6	7
11	G 258-1BM	9	4	6	5
12	G 260-1M	9	2-3	2-3	6
13	G 301-1B	8	6	2-3	6
14	G 322-5-1B	9	4	3	3
15	G 382M	8	4	4	4
16	G 386M	8	2-3	3-6	4-6
17	G 404M	7	1-2	2-3	8
18	G 496M	8	2-3	4-6	2
19	G 570M	8	8	6	6
20	G 697M	9	6	6	5

[1] Infection-types according to the scale of McNeal et al. (1971).

resistance. In these entries, in the seedling tests, the effect of the temperature-sensitive genes appears to be of only minor magnitude (IT 5-6). Therefore it is assumed that the additional resistance (IT 2-3) found in the field tests can also be ascribed to adult-plant resistance.

Since temperature-sensitive genes will mask adult-plant resistance under summer conditions in the field and also under simulated summer conditions in growth chambers, it may well be that the frequency of adult-plant resistance is greater than could be shown in our experiments. Only when temperature-sensitive genes give intermediate resistance and adult-plant genes give complete resistance, can the presence of adult-plant resistance be detected. In our experiments in at least two of the entries, the presence of both temperature-sensitive genes and true adult-plant resistance genes is indicated (entries 3, 6).

In conclusion, it can be stated that wild emmer may serve as a useful source not only for major genes and temperature-sensitive genes of minor or major effect, but also for true adult-plant genes for yellow rust resistance.

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Samenvatting

Volwassenplantresistentie tegen gele roest in wilde emmer tarwe

Voor dit onderzoek werden 76 herkomsten van wilde emmer tarwe (*Triticum dicoccoides* Körn.) geselecteerd op basis van vatbaarheid voor gele roest (*Puccinia striiformis* Westend. f.sp. *tritici*) in het kiemplantstadium. In een veldtoets met hetzelfde gele roest isolaat (fysio 39E134) werd de reaktie in het volwassenplantstadium bepaald. Deze toets werd in Wageningen in een plastic kas uitgevoerd en in Flevoland in een geïsoleerd veld.

In Flevoland vertoonden 15 herkomsten een intermediaire of resistente reaktie, in Wageningen werd dit bij 18 herkomsten waargenomen. Om na te gaan of de waargenomen veldresistentie mogelijk berust op temperatuurgevoelige genen, werd de resistentie vergeleken bij hoge en lage temperatuur. Van de 20 herkomsten, die resistentie vertoonden in de veldtoets in Wageningen of in Flevoland, bleken er 16 temperatuurgevoelige resistentiegenen te hebben. Vier herkomsten lijken echte, stadium afhankelijke, volwassenplantresistentie te vertonen.

References

Gerechter-Amitai, Z.K., Sharp, E.L. & Reinhold, M., 1984. Temperature-sensitive genes for resistance to *Puccinia striiformis* in *Triticum dicoccoides*. Euphytica 33: 665-672.

Gerechter-Amitai, Z.K. & Silfhout, C.H. van, 1988. Race-specificity of temperature-sensitive genes for resistance to *Puccinia striiformis* in *Triticum dicoccoides*. Euphytica 37 (in press).

Gerechter-Amitai, Z.K. & Stubbs, R.W., 1970. A valuable source of resistance to yellow rust in Israeli populations of wild emmer, *Triticum dicoccoides* Körn. Euphytica 19: 12-21.

Grama, A., Gerechter-Amitai, Z.K. & Silfhout, C.H. van, 1984. Additive gene action for resistance to *Puccinia striiformis* in *Triticum dicoccoides*. Euphytica 33: 281-287.

McNeal, F.H., Konzak, C.S., Smith, E.P., Tate, W.S. & Russel, T.S., 1971. A uniform system for recording and processing cereal data. USDA, Agricultural Research Service, ARS: 34-121.

Milus, E.A. & Line, R.F., 1986. Gene action for inheritance of durable high-temperature, adult-plant resistance to stripe rust in wheat. Genetics 76: 435-441.

Pochard, E., Goujon, C. & Vergara, S., 1962. Influence de la temperature, de l'éclairement et

du stade de la plante sur l'expression de la sensibilité à une biotype de rouille jaune de quelques variétés françaises de blé. Annales de l'Amélioration des Plantes 12: 45-58.
Pope, W.K., 1968. Interaction of minor genes for resistance to stripe rust in wheat. Proceedings of the 3rd International Wheat Genetics Symposium, Australian Academy of Science, Canberra, Australia, pp. 251-257.
Qayoum, A. & Line, R.F., 1985. High-temperature, adult-plant resistance to stripe rust of wheat. Phytopathology 75: 1121-1125.
Sharp, E.L. & Fuchs, E., 1982. Additive genes in wheat for resistance to stripe (yellow) rust (*Puccinia striiformis* Westend.) Crop protection 1: 181-189.
Slovenčikova, V., 1972. Adult-plant resistance of the spring wheat Zlatka to yellow rust. Proceedings of the European and Mediterranean Cereal Rusts Conference, Prague, pp. 243-247.