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IDENTIFICATION OF POWDERY MILDEW RESISTANCE GENES IN POLISH COMMON OAT (*Avena sativa* L.) CULTIVARS USING HOST-PATHOGEN TESTS

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A b s t r a c t

The aim of the present study was to characterize and identify powdery mildew resistance genes in Polish common oat cultivars using host-pathogen tests. A differential set of six *Blumeria graminis* f.sp. *avenae* isolates virulent or avirulent to four cultivars and one line that has known resistance to powdery mildew were used. Among the investigated cultivars, only four of them (13.3%) had resistance patterns similar to genotypes belonging to the differential set. The resistance of OMR group 1 was found in the cultivar 'Dragon', while that of OMR2 in the cultivar 'Skrzat'. The cultivars 'Deresz' and 'Hetman' showed a resistance pattern that corresponded with OMR group 3. The resistance corresponding to OMR4 was not found, which suggests that until now this gene has not been used in Polish oat breeding programmes. The cultivar 'Canyon' had a different pattern of resistance than the genotypes that have already known OMR genes, which indicates that the resistance of this cultivar is determined by a new gene or a combination of known genes.

Key words: *Blumeria graminis*, *Avena sativa* L. cultivars, genetic resistance, host-pathogen tests

INTRODUCTION

Powdery mildew caused by *Blumeria graminis* DC. f.sp. *avenae* Em. Marchal. is a leaf disease of common oat especially in cold and humid regions (R o d e r i c k et al. 2000). Weather conditions have a significant influence on the development of the pathogen. It has been observed that the disease becomes more intense after mild winters and warm springs (P r i e s t l e y and B a y l e s , 1979). Powdery mildew is very common in northwestern Europe and in North America (A u n g et al. 1997; S c h w a r z b a c h and S m i t h , 1988) and it also occurs in the countries of Eastern Europe, including Poland (S e b e s t a et al. 1991). Oat crop losses caused by powdery mildew are significant and range from 5 to 10%, even up to 30% in Western Europe (C l i f f o r d , 1995; H s a m et al. 1997). Breeding cultivars with a resistance gene to powdery mildew is the most effective and ecological method for controlling this fungal disease. Because of this, the most important is to use resistance genes in oat breeding programmes as well as to identify and introduce new resistance genes that are effective in relation to the existing population of *Blumeria graminis* DC. f.sp. *avenae*. Resistance to powdery mildew in oat determined by major genes has been characterised as Oat Mildew Resistance groups (J o n e s and J o n e s , 1979). To date, six OMR groups have been characterised in oat, but only three of them: OMR1, OMR2 and OMR3, have been commonly used in breeding programmes (H s a m et al. 1997, 1998; K o w a l c z y k et al. 2004). To identify and locate such a gene of resistance, the host-pathogen tests are commonly used (H s a m et al. 1997; K o w a l c z y k et al. 1998; Z e l l e r et al. 1998). Because of this, the aim of the present study was to identify powdery mildew resistance genes which are present in Polish common oat cultivars using host-pathogen tests.

MATERIALS AND METHODS

Thirty Polish common oat (*Avena sativa* L.) cultivars were evaluated. As differential genotypes, 4 cultivars and 1 line of common oat were used: 'Bruno' had the resistance of OMR group 1, 'Jumbo' had the resistance pattern of OMR2, 'Mostyn' of OMR group 3, the line AV1860 of OMR4, while the cultivar 'Fuchs' was used as a susceptible one. The control cultivars and line were kindly supplied by Sai L.K. Hsam

from the Technical University of Munich, Germany. The Polish common oat cultivars were screened for *Blumeria graminis* response using six powdery mildew isolates that can differentiate the various OMR groups. Isolates were collected from different parts of Poland and selected based on the previous study (O k o ń and K o w a l c z y k , 2012).

The host-pathogen tests were carried out on the first leaves of 10 day-old seedlings. Leaf fragments were placed on 12-well culture plates with benzimidazole agar (6 g of agar per 1 l of water and 35 mg × l^{-1} of benzimidazole). The control genotypes were put into the first and last well of each dish in the following order: the susceptible cultivar, the cultivars that had the OMR1, OMR2 and OMR3 genes and the line that possessed the OMR4 gene. Plates with leaf fragments were inoculated, using an inoculation tower, by placing about 500-700 spores of powdery mildew per 1 cm^2. Then, the dishes were incubated in a phytotron chamber at about 17°C and illuminance of about 4 kLx.

Ten days after inoculation with powdery mildew isolates, the resistance levels of the tested genotypes were scored. Three classes of reactions to the isolates used were observed: r – resistant (0-20% infection relative to Fuchs); i – intermediate (20-50% infection); and s – susceptible (> 50% infection).

RESULTS

The cultivars 'Fuchs', 'Bruno', 'Jumbo', 'Mostyn' and the line AV1860 with already documented oat mildew resistance groups effectively differentiated using six powdery mildew isolates derived from the population of *Blumeria graminis* DC. f.sp. *avenae* collected in Poland. The cultivar 'Fuchs' showed a susceptible response to all isolates. The cultivars 'Bruno' (OMR1), 'Jumbo' (OMR2), 'Mostyn' (OMR3) and the line AV1860 (OMR4) were characterised by isolate-specific resistance, intermediate or susceptible response (Table 1).

Table 1
Reaction of 5 differential cultivars and line after inoculation with 6 differential isolates of powdery mildew.

Cultivar/line	*Blumeria graminis* DC. f.sp. *avenae* Em. Marchal. isolate						Oat Mildew Resistance (OMR)
	M1	M3	M10	M16	M17	M24	
Fuchs	s[1]	s	s	s	s	s	OMR0
Bruno	i[2]	s	r[3]	s	s	r	OMR1
Jumbo	r	i	s	r	s	i	OMR2
Mostyn	s	i	s	s	i	r	OMR3
AV1860	r	r	r	r	s	s	OMR4

Among the 30 tested common oat cultivars, 26 of them showed susceptible or intermediate responses to all six powdery mildew isolates. Only four cultivars had already known resistance genes. The cultivar 'Dragon' was resistant to three isolates: M10, M16 and M24, and showed the same disease response pattern as the differential cultivar 'Bruno' which had the resistance of OMR group 1. OMR1 was previously identified in the cultivar 'Monod', which was derived from the *A. sativa* line 01747/10/7 (H a y e s and C a t l i n g , 1963). The cultivar 'Manod' is in the pedigree of cv. 'Dragon' and it is possible that 'Dragon' inherited the OMR1 gene from this cultivar. The cultivar 'Skrzat' had the same response pattern as the differential cultivar 'Jumbo'. This indicates the presence of OMR group 2 in this genotype. Analysis of the pedigree of the cultivar 'Skrzat' showed that the line Cc4146, which had the documented resistance of OMR group 2, was an ancestor of this cultivar and 'Skrzat' could have inherited the resistance of OMR group 2 from this line. Two cultivars, 'Deresz' and 'Hetman' were resistant to isolates M3, M17 and M24. Based on this, it is possible to conclude that they exhibited the disease response pattern of OMR3, similar to that of the standard differential cultivar 'Mostyn'. Analysis of the available pedigrees of 'Deresz' and 'Hetman' does not allow for identification of accession from which these cultivars could have inherited the resistance pattern of OMR group 3. Resistance corresponding to OMR4 was not found in the Polish common oat cultivars tested. The cultivar 'Canyon' was resistant to all isolates used in the host-pathogen tests; this pattern of resistance was different than that obtained for the standard differential cultivars and lines (Table 2).

Table 2
Reaction of 30 oat cultivars grown in Poland after inoculation with 6 differential isolates of powdery mildew.

Cultivar/line	*Blumeriagraminis* DC. f.sp. *avenae* Em. Marchal. isolate						Postulated Oat Mildew Resistance (OMR) group
	M1	M3	M10	M16	M17	M24	
Akt	s	s	s	s	i	i	-
Arab	s	s	s	s	s	i	-
Bachmat	s	r	i	s	s	s	-
Bajka	s	s	s	s	s	s	-
Borowiak	s	i	s	s	s	s	-
Boryna	s	s	s	s	s	s	-
Borys	s	s	s	s	s	s	-
Cacko	s	i	i	i	s	s	-
Cekin	s	s	s	s	s	s	-
Chwat	i	i	i	s	s	i	-
Deresz	s	i	s	s	i	r	OMR3
Dragon	i	s	r	s	s	r	OMR1
Dukat	s	s	s	s	s	s	-
Farys	s	s	s	s	s	i	-
German	s	s	s	s	s	s	-
Góral	s	i	i	i	i	i	-
Grajcar	s	s	s	i	i	s	-
Hetman	s	i	s	s	i	r	OMR3
Jawor	s	s	s	s	s	s	-
Karol	s	s	s	s	s	s	-
Kasztan	i	i	i	s	i	s	-
Komes	s	s	s	s	s	s	-
Kwant	s	s	s	s	s	s	-
Santor	s	s	s	s	s	s	-
Sławko	s	s	s	s	s	s	-
Sam	s	s	s	s	s	s	-
Skrzat	r	i	s	r	s	i	OMR2
Canyon	r	r	r	r	r	r	U[4]
Sprinter	s	s	s	s	s	s	-
Polar	s	s	s	s	s	s	-

[1]s = susceptible, [2]i – intermediate, [3]r – resistant, [4]u – unknown

DISCUSSION

The host-pathogen tests are very useful tool for identifying resistance to powdery mildew in oat (Hsam et al. 1997, 1998; Hsam and Zeller, 1998). Using host-pathogen tests, Kowalczyk et al. (2004) analysed the response of Polish cultivars of common oat to powdery mildew isolates characterised by avirulence to OMR group 2. The performed experiments showed that only 17.4% of analysed cultivars had a specific resistance pattern. They identified only one cultivar with the resistance of OMR2. They also showed that the cultivars 'Deresz', 'Dragon' and 'Hetman' had different resistance patterns than the cultivar 'Jumbo'. In the present study, the cultivars 'Skrzat', 'Dragon', 'Deresz' and 'Hetman' were also analysed. The experiment confirmed that the cultivar 'Skrzat' had the resistance of OMR group 2. The cultivars 'Deresz' and 'Hetman' are characterised by resistance patterns similar to that of the cultivar 'Mostyn', which has oat mildew resistance of group 3. The cultivar 'Dragon' was shown to have the resistance pattern of OMR1. Using host-pathogen tests, Hsam et al. (1998) studied the response of 207 lines and cultivars of common oat to the infection of 11 selected

powdery mildew isolates. Among the investigated forms from Northern and Eastern Europe, 194 were sensitive to all isolates. Only 5% of the analysed genotypes showed resistance to selected isolates of powdery mildew. They identified five cultivars and lines which possessed OMR1 and three genotypes with OMR3. OMR groups 2 and 4 were not identified in the studied lines and cultivars. The authors analysed common oat cultivars from different European countries, including Poland. They identified OMR group 1 in two cultivars, 'Boruta' and 'Dragon'. The present study confirms that the cultivar 'Dragon' has OMR1. Hsam et al. (1997) identified resistance to powdery mildew in 259 lines and cultivars of common oat from Western Europe and North America. One hundred seventy three of them were susceptible to powdery mildew. The response of nine genotypes showed that they possessed OMR1. Seven analysed forms showed a similar reaction to that of the Cc4146 line with the resistance of OMR group 2. Eleven of the tested genotypes had OMR3. The authors did not identify forms with the resistance of OMR group 4. This may result from the fact that this gene is not used in oat breeding programmes (Sebesta et al. 1991). In the present study, OMR4 was not identified, either. This result suggests that this gene is not used in Polish breeding programmes.

The results obtained in the present research and in many previous studies have shown that powdery mildew resistance is not deliberately selected in oat breeding programmes in many European countries, including Poland. Breeding cultivars with genes of powdery mildew resistance is the most ecological and economical friendly method for reducing the negative effect of powdery mildew. Because of this, looking for new sources of resistance in oat cultivars which will have an effective resistance gene or a combination of resistance genes should be one of the priorities in oat breeding programmes.

CONCLUSIONS

1. In Polish common oat cultivars, powdery mildew resistance genes are not very common. The OMR1 gene was identified in the cultivar 'Dragon', OMR 2 was present in the cultivar 'Skrzat', while OMR3 in the cultivars 'Deresz' and 'Hetman'.
2. OMR group 4 was not identified in any genotype, which suggests that such a gene is not used in common oat breeding programmes in Poland.
3. The cultivar 'Canyon' has an unknown pattern of resistance to powdery mildew and can be used as a donor of new resistance to powdery mildew in common oat.

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Identyfikacja genów odporności na mączniaka prawdziwego w owsie zwyczajnym (*Avena sativa* L.) za pomocą testów żywiciel-patogen

Streszczenie

Celem prezentowanych badań była identyfikacja genów odporności na mączniaka prawdziwego w polskich odmianach owsa zwyczajnego. Testy żywiciel-patogen przeprowadzono wykorzystując 6 izolatów mączniaka prawdziwego różnicujących odmiany i linie owsa z udokumentowaną wcześniej odpornością na mączniaka prawdziwego. W grupie 30 badanych odmian zidentyfikowano jedynie cztery, których odporność na zakażenie izolatami mączniaka prawdziwego pokrywała się z odpornością genotypów posiadających znane geny odporności. Odporność grupy 1 (OMR1) stwierdzono w odmianie 'Dragon', zaś OMR2 w odmianie 'Skrzat'. Odmiany 'Deresz' i 'Hetman' charakteryzowały się odpornością grupy 3 (OMR3). Wśród analizowanych odmian nie zidentyfikowano genotypów posiadających odporność charakterystyczną dla grupy 4 (OMR4), co może wskazywać na to, iż nie jest on wykorzystywany w polskich programach owsa zwyczajnego. Odmiana Canyon była odporna na wszystkie użyte izolaty mączniaka prawdziwego, co wskazuje, że zwiera ona dotychczas nieopisany gen odporności na tego patogena lub kombinację znanych genów, które nadają jej specyficzną odporność.