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Genetic control of oat rust diseases

P. Sooväli and M. Koppel

Jõgeva Plant Breeding Institute, 48309 Jõgeva, Estonia

Abstract. Oat grain is indicated to be of great value, especially for its favourable effects on the health of humans and animals. Food and feed industries can utilise only fully developed and faultless oat grain that can be harvested from healthy, unattacked plants. Cultivating disease-resistant varieties seems to be an optimum alternative to chemical control. Growing of the resistant varieties is the most effective biological control of diseases. It is highly economic and ideal from the ecological point of view. Disease resistant varieties are the basic precondition for successful sustainable (organic) agriculture. Stem rust (*Puccinia graminis* Pers. f. sp. *avenae* Erikss. et Henn) and crown rust (*Puccinia coronata* Cda. f. sp. *avenae* Erikss.) are the potentially destructive diseases of oat crop in Estonian conditions. The effectiveness of resistance sources to *Puccinia coronata* and *Puccinia graminis* was tested in the framework of the European and Mediterranean Oat Disease Nursery (EMODN) at Jõgeva Plant Breeding Institute in 1996–2002. Highly resistant to crown rust were Pc-gene lines Pc 39, Pc 54-2, Pc 59, Pc 60, Pc 68 and Pen2xCAV1376. The greatest change in crown rust incidence was recorded for Pc 58 and Pc 61. These lines were completely free from disease infection at the beginning of the trial cycle, but, in 2001, were attacked at a moderate level (5–6 points in 9-point scale). The differential 'Pirol' and the varieties 'Alo', 'Jaak' and 'Edit' of the Estonian Variety List lost resistance to crown rust in 1998. Effective stem rust resistance against *Puccinia graminis* f. sp. *avenae* were conferring Pg-gene lines Pg 15, Pg a and Rodney ABDH. The first report of virulence on Pg 13 in Europe was detected in the framework of EMODN trials in Estonia in 1993.

Key words: Disease resistance, disease incidence, oat crown rust, *Puccinia coronata* f. sp. *avenae*, oat stem rust, *Puccinia graminis* f. sp. *avenae*

INTRODUCTION

Rust diseases are mostly the greatest harmful diseases of cereals. All above-ground parts of a plant can be infected from seedling to mature stadium. Fungi of *Puccinia* species are obligatory parasites with a high level of life cycle complex (alternate host). Symptoms of disease occur on stem and petiole, blade and spike may also be infected. Host plants give three spore forms. On oats two spore stages of rust can occur: the uredial and the telial. Urediospores are mainly responsible for epidemics of rust diseases. Urediospore formation is maintained as long as green plants are available. At cereal ripening rusts cease to produce urediospores and begin to produce teliospores (Sebesta et al., 1997). Uredial pustules develop tear epidermis and bare red-brown spores. Pustules are oval or oblong, open or chark epidermic tissues on the

edges. Development of dark brown teliospores begins when plant is almost ripe. Teliospores remain on straw debrises. *Berberis vulgaris* and *Mahonia* species are alternate hosts to *Puccinia graminis*. Urediospores of stem rust are supposed to be realised by wind from a long distance. During plant growing period, new generation of uredia can be released in every 14 to 21 days (Zillinsky, 1983).

Crown rust (*Puccinia coronata* Cda. f. sp. *avenae* Erikss.) belongs to the most widespread and damaging diseases of oat. It affects leaves, cheaths and panicles. The uredial pustules (uredinia) are oblong and yellow-orange. The telia of *Puccinia coronata* are dark and form rings around uredinia. The inoculum, responsible for epidemics of crown rust in Europe, comes either from wild oat species, other host grasses and volunteer oat plants, or from an alternate host, *Rhamnus catharticus*. The transport of urediospores like in other cereal rusts is supposed to be realised by wind from a long distance, from southeastern Europe (Sebesta et al., 1999).

Stem rust (*Puccinia graminis* Pers. sp. *avenae* Erikss. et Henn) is a potentially damaging oat disease. Stem rust is a more destructive pathogen than crown rust. The reduction of grain yield on a susceptible cultivar, resulting from the effect of stem rust, can vary between 27–29%. The 1000-grain weight can be decreased by 25–29%. Percentage of hulls can be increased by 30–39% as a result of stem rust infection (Sebesta et al., 1999). Stem rust affects all above-ground parts of an oat plant: leaves, sheaths, stems and panicles. The uredial pustules of stem rust are dark red-brown in colour and elongated. The urediospores of stem rust are elliptical. Epidermics of stem rust are incited by *Puccinia graminis* f. sp. *avenae* inoculum that comes either from wild oat species, other host grasses and volunteers, especially from *Berberis vulgaris* bushes. Like in other cereal rusts, urediospores are supposed to be transported from a long distance, from southeastern areas of the European Continent (Sebesta, 1998).

MATERIALS AND METHODS

The European and Mediterranean Oat Disease Nursery (EMODN) trials for testing the incidence of fungal diseases on oat differential cultivars were carried out at Jõgeva Plant Breeding Institute, where 32 oat lines with resistance or tolerance to either crown rust or stem rust were grown in provocative conditions during 1996–2002. Oat lines were sown on hill plots consisting of 10–15 plants in two replications. Late sowing time (beginning of June) was used to maintain green foliage at the time of a spread of urediospores from naturally infected plants. During the same time, oat varieties included in the Estonian Variety List were assessed for the incidence of rust infection under the conditions of natural infection and compared with the results of the EMODN trial. Field trials were carried out on 10-m^2 plots in 4 replications with 500 germinating seeds/m^2. The disease assessment time was selected according to the appearance of infection in most susceptible lines. Disease scoring was made *ca* two weeks after the establishment of infection in susceptible lines. The incidence of disease infection was estimated according to the 1–9 scale (1- no disease, 9- severe infection) on the whole plot.

RESULTS AND DISCUSSION

The evaluation of new germplasms to identify potential donors of disease resistance is of prime importance in crop improvement. Obtained information on host reactions to pathogenic fungi is especially valuable.

The incidence of *Puccinia coronata* f. sp. *avena* in EMODN varieties in 1996–2002 has been presented in Table 1. There was no virulence to any of the gene lines used in the EMODN set in earlier trials conducted at Jõgeva in 1992 and 1993. Moderate to high incidence of *Puccinia coronata* was recorded in 1996 and 1997 when conditions for disease incidence were very favourable. Pc-gene lines Pc 50, Pc 55, Pc 63, Pc 67, Kr 3813/73 and Garland were very susceptible. Pathogenic situation was different in the dry conditions of 1998, when infection pressure was weak until the end of August. The trial in 1999 failed because of the hot and dry June and July. Disease incidence was moderate in 2000, when dry and warm weather during sowing was followed by a cool and rainy summer. The warm and rainy summer of 2001 favoured spread of the infection. Warm and droughty weather with foggy nights favoured development and spread of *Puccinia coronata* in 2002.

Lines Pc 39, Pc 54-2, Pc 59, Pc 60 and Pen2xCAV1376 were resistant throughout the whole trial period 1996–2002. Susceptibility of the oat lines Pc 48, Pc 54-1, Pc 58, Pc 61, Kr 288/73L/569 and variety 'Pirol' against crown rust was increased during the trial period. The effective resistance of these genotypes was lost in the last years. Lines Pc 50, Pc 55, Pc 56, Pc 63, Pc 64, Pc 67, KR 3813/73 and 'Garland' have been highly susceptible and were severely attacked.

Moderate to high incidence of *Puccinia coronata* was also recorded in natural conditions (Table 2). Very high incidence of crown rust was recorded in 1998, when the rainy and warm June was a reason for the strong attack of the pathogene. Natural infection was at a moderate level in 1999 and 2000, when both, main and side shoots became infected. Favourable conditions for spread of crown rust were in the warm and rainy summer of 2001. All the varieties were infected up to a moderate level in the droughty and warm vegetation period of 2002.

A breakdown of the race specific resistance of the variety 'Alo' is considerable. 'Alo' was resistant to crown rust until 1997, but it became highly infected the first time in 1998 after the appearance of new rust races, and, during the last years, has been infected at the level of the most susceptible varieties. Similar infection pattern is also shown by the varieties 'Jaak', 'Edit' and 'Pirol'. Considerable similarity is found in the infection pattern of these varieties and the line Pc 58. Supposedly, the varieties 'Alo', 'Jaak', 'Edit' and 'Pirol' have the same crown rust resistance gene as the differential Pc 58.

The differential Pc-gene lines Pc 39, Pc 55, Pc 58 and Pc 68 have been resistant to local populations of *Puccinia coronata* f. sp. *avenae* in field trials carried out in different regions of Europa. Genotypes with these genes were completely resistant also in laboratory infection tests with pathotypes of *Puccinia coronata* f. sp. *avenae* isolated from different European countries.

Table 1. Incidence of *Puccinia coronata* on EMODN oat differential Pc-gene lines at Jõgeva in 1996–2002. Data from 1999 are not presented because of the absence of the disease infection.

Variety/line	Disease incidence (1–9 points)					
	1996	1997	1998	2000	2001	2002
Pc 38	7	8	2	3	5	4
Pc 39	2	2	2	2	2	3
Pc 48	3	2	2	2	5	3
Pc 50	3	5	1	4	7	3
Pc 50–2	5	3	2	6	X	3
Pc 50–4	5	5	2	1	5	5
Pc 54–1	2	2	2	1	5	4
Pc 54–2	2	2	2	3	2	2
Pc 55	3	7	2	3	2	7
Pc 56	7	7	1	4	8	7
Pc 58	1	2	2	2	5	6
Pc 59	2	2	2	1	1	2
Pc 60	2	2	2	1	X	2
Pc 61	2	2	2	2	5	6
Pc 62	5	3	1	5	5	4
Pc 63	3	8	1	4	7	7
Pc 64	7	7	1	7	5	7
Pc 67	3	6	1	5	X	6
Pc 68	5	2	2	2	1	X
Pen2xCAV1376	3	2	2	1	2	2
KR 3813/73	3	7	1	7	7	6
Pirol	2	2	2	5	7	6
KR288/73L/569	3	2	1	2	3	5
Garland	2	8	1	5	7	7

The lines Pc 48, Pc 50-2, Pc 50-4, Pc 54-1 and Pc 59 are of importance for the European crown rust resistance breeding of oats. In most countries they have been resistant or have shown only moderate infection in certain regions (Sebesta et al., 1998). Pc 48 has shown somewhat higher effectiveness against crown rust compared to Pc 50-2 in Estonian trials. Pc 54-1 was only slightly infected until 2000, after that the susceptibility increased. The most resistant lines in Estonia have been Pc 39, Pc 54-2, Pc 59, Pc 60 and Pen2xCAV1376. They have importance in crown rust resistance breeding. The Pc-gene lines Pc 50-4 and Pc 67, effective in Europe, are susceptible in Estonia (Table 1).

Table 2. Incidence of *Puccinia coronata* on oat varieties of the Estonian Variety List at Jõgeva in 1996–2002.

Variety	Origin	Disease incidence (1–9 points)						
		1996	1997	1998	1999	2000	2001	2002
Miku	Estonia	7	6	7	3	6	7	4
Alo	Estonia	1	2	6	3	2	7	4
Jaak	Estonia	3	3	7	3	2	7	3
Villu	Estonia	7	7	9	3	4	7	5
Salo	Sweden	7	6	9	2	4	7	7
Freja	Sweden	7	5	8	4	3	7	5
Edit	Sweden	2	3	5	2	5	7	5
Lena	Norway	5	6	8	4	3	6	4
Leila	Norway	6	3	8	4	2	7	5
Revisor	Germany	7	6	9	3	3	7	4

Table 3. Incidence of *Puccinia graminis* on EMODN oat differential Pg-gene lines at Jõgeva in 1996–2002. Data from 1999 are not presented because of the absence of the disease infection.

Variety/line	Disease incidence (1–9 points)					
	1996	1997	1998	2000	2001	2002
Rodney A (Pg 2)	2	1	1	1	1	2
Rodney B (Pg 4)	5	1	1	1	1	1
Rodney H (Pg 9)	3	2	1	1	1	1
Rodney M (Pg 13)	2	2	1	1	1	1
Pg 15	2	1	1	1	1	1
Pg 16	3	2	1	1	1	1
Pg a	1	1	1	1	1	1
Rodney ABDH	2	1	1	1	1	1

Compared with the situation in the foregoing periods, the virulence spectrum of oat stem rust populations and the effectiveness of resistance genes has changed considerably during the last decade in Central Europe (Sebesta et al., 1998). The same has occurred in Estonia.

Stem rust (*Puccinia graminis* f. sp. *avenae)* incidence on EMODN differential Pg-gene lines was low throughout the trial period 1996–2002 (Table 3). Favourable conditions for stem rust infection were in 1996, when moderate infection of lines Rodney B, Rodney H and Pg-16 (3–5 points) were recorded. Almost no stem rust infection was observed during the last five years. The trial failed totally in the droughty year 1999.

Table 4. Incidence of *Puccinia graminis* on oat varieties of the Estonian Variety List at Jõgeva in 1996–2002.

Variety	Origin	Disease incidence (1–9 points)						
		1996	1997	1998	1999	2000	2001	2002
Miku	Estonia	3	4	2	1	3	1	1
Alo	Estonia	1	2	1	1	1	1	1
Jaak	Estonia	1	2	2	1	1	1	1
Villu	Estonia	3	2	3	1	1	1	1
Salo	Sweden	3	4	4	1	1	2	1
Freja	Sweden	1	5	3	1	1	1	1
Edit	Sweden	1	1	1	1	2	1	1
Lena	Norway	2	3	1	1	1	2	1
Leila	Norway	3	2	2	1	1	1	1
Revisor	Germany	3	3	4	1	1	2	1

More severe infection was recorded in trials with oat varieties of the Estonian Variety List (Table 4). All the varieties were infected at a moderate level in 1996–1998. The weather of the following years did not favour development and spread of stem rust. Almost the absence of or very low stem rust infection has not allowed monitoring of changes in race compositon of this pathogen.

The Pg-gene lines Rodney A, Rodney M, Pg 15, Pg a and Rodney ABDH were highly effective in Estonia. The line Rodney M carries the major resistance gene Pg 13 and the line Rodney A gene Pg 2. Line Pg a has 3 recessive resistance genes (Table 3).

The recessive gene Pg 13 has been considered one of the most effective stem rust resistance genes available to breeders. The first stem rust isolate able to overcome resistance of gene Pg 13 was detected in the framework of the EMODN trial network in Estonia (Sebesta et al., 1999).

CONCLUSIONS

Early teliospore formation could be included in the genetic control of those cereal rust populations in which it functions. Selection for this trait might be carried out in the field or even in seedling tests. However, more research on both pathogens – host relationships and the effect of external factors on the early development of teliospores – process is needed (Sebesta et al., 1999).

The pathogenic situation of *Puccinia coronata* Cda. f. sp. *avenae* Eriks. has changed in Estonia during 1996–2002. The Pc-gene lines Pc 39, Pc 59, Pc 60, Pc 68, Pen2 x CAV1376 were resistant throughout the trial period. Pc 58 and Pc 61 were relatively resistant up to 2000 and attacked moderately (5–6 points) in 2001. The variety ‘Pirol’ was resistant up to 1998, but highly (5–7 points) infected in 2000. The lines Pc 38, Pc 50, Pc 56, Pc 62, Pc 63, Pc 64, Pc 67 and the varieties Kr 3813/73 and

'Garland' were highly susceptible to crown rust all the years. The varieties 'Alo', 'Jaak' and 'Edit'of the Estonian Variety List have lost resistance to *Puccinia coronata* f. sp. *avenae*. They were first time infected in 1997.

Oat stem rust (*Puccinia graminis* Pers f. sp. *avenae* Erikss. et Henn) is potentially a more destructive disease than crown rust (*Puccinia coronata* Cda f. sp. *avenae* Erikss.), however, fortunately, it occurs at a high incidence only in some areas in Europe (Sebesta et al., 1998). High or moderate levels of stem rust were recorded at Jõgeva in 1995 and 1996. Uredial samples of *Puccinia graminis* f. sp. *avenae* from Estonia were analysed for their virulence in relation to Pg lines.

Testing of the effectiveness of resistance sources to *Puccinia coronata* and *Puccinia graminis* creates a good basis for a selection of initial material for resistance breeding of oat.

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