*Institute of Plant Genetics, Polish Academy of Sciences, Poznań
**University of Warmia and Mazury, Olsztyn

THE SEARCH FOR GENETIC SOURCES OF WILLOW RESISTANCE TO RUST (*MELAMPSORA EPITEA*)[1]

*M. Jędryczka, *J. Ciszewska-Marciniak and **J. Przyborowski

Abstract

Willow rust, caused by *Melampsora epitea*, is one of the most limiting factors in cultivation of willows. The aim of this study was to find genetic sources of willow resistance to the population of rusts in Poland.

Field experiments were located at four sites in Warmia region (north-east Poland). Observations were done for three vegetative seasons from spring 2006 till autumn 2008. The evaluation was performed four times in the season, starting in mid-June and ending in mid-August. Disease severity was evaluated according to 10 degree rating scale (0–9), ranging from 0 – the lack of infection to 9 – dry or fallen leaves. The assessment concerned 35 genotypes of willows originating from 10 species and four interspecific hybrids. Most of the examined willow species was infected with rust and the disease severity depended on plant species and genotype as well as the evaluation period and a site of plant cultivation. The most resistant species were *Salix fragilis, S. pentandra, S. rigida* and the interspecific hybrid *S. alba* × *S. fragilis*.

Key words: *Salix* sp., *Melampsora larici-epitea*, willow, rust, resistance, uredinia

Introduction

The development of power industry, systematic increase of energy consumption, limitation of fossil fuels and necessity of environmental protection, force to search of renewable sources of energy. Biomass crops, such as willows (*Salix* sp.), are projected to make important contribution to the future energy (Szczukowski et al. 2005, Trybush et al. 2008). Exploitation of willows, grown as short rotation

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coppice, is connected with the production of low input bioenergy with high heating value. It guarantees greenhouse gas balance associated with the production system. Moreover, willows have high yield potential, ease of vegetative propagation and ability to resprout after multiple harvests (Keoleian and Volk 2005). All these advantages offered by willow together with the large genetic diversity make them valuable source of renewable energy.

Leaf rust caused by *Melampsora* spp. is the most widespread and damaging disease of willows in fields planted for renewable energy. The disease is regarded as a serious threat to the production of short rotation willows (*Salix viminalis*) in many parts of Europe (Samils 2001, McCracken and Dawson 2003, Pei 2005, Rönnberg-Wästljung et al. 2008). It can defoliate willows prematurely, predispose them to other diseases and, when severe, reduce yields by as much as 40% (Parker et al. 1993). Willow rusts have different special forms and pathotypes, each capable of infecting a certain range of willow species and hybrid genotypes (Pei et al. 1996, Samils et al. 2003). It is possible that special forms and pathotypes occurrence varies between sites and geographical regions (Pei et al. 1999). The taxonomy of *Melampsora* on *Salix* is unclear. Many rust species were described in 19th century and the species were established based on their morphology, alternate hosts and the telial hosts range (Gäumann 1959, Leppik 1972, Savile 1976, Cummins and Hiratsuka 2003). However, host ranges of different rust species often overlap and there is no clear morphological distinction between forms that are identified by having different alternate hosts. This problem causes many difficulties in proper identification of rust species. The most common willow rust is *Melampsora larici-epitea* var. *epitea*, which is a complex of heteroecious rusts with alternate hosts of different genera (Wilson and Henderson 1966).

Life cycle of this biotrophic fungus is complex, including five spore stages and alternate hosts of different genera, for instance larch (*Larix*) and currant bush (*Ribes*). The epidemic phase takes place on willow in summer; it includes repeated cycle of clonal propagation of urediniospores, dicariotic, wind-transported spores. In late summer and autumn, the fungus forms telia and overwinters on fallen willow leaves. In spring, teliospores germinate and produce basidiospores, which infect alternate hosts. They in turn serve as habitats for aeciospores formation. These spores are capable of infecting new willow leaves in early summer and the cycle is completed with the uredinial stage (Pei 2005).

The willow species commonly used in short rotation coppice (SRC) plantations have been diversified with regard to rust resistance. In the most common willow in SRC, *S. viminalis*, no complete resistance has been found (Rönnberg-Wästljung et al. 2008). Breeding for resistance is the most effective method to control the rust in willow plantations. Resistance can be derived from some highly resistant species such as *S. candida, S. cordata, S. drummondiana, S. eriocephala, S. hookeriana, S. houghtonii, S. humilis, S. rigida* var. *mackenziana* or *S. sytricola* (Pei et al. 2004). Some species, such as *S. rossica* produced no symptoms in laboratory screening tests but showed low levels of infection in the field. Hybrids containing the genotype *S. schwerinii,* which originates from Siberia, also tended to express higher levels of resistance to willow rust (Dawson and McCracken 1998).

The objective of this study was to find genetic sources of willow resistance to the population of rusts in Poland. This is the first regular study of the resistance/susceptibility of different willow genotypes to these pathogens in the country.

Materials and methods

Localization of experiments

Field experiments were located at four sites in Warmia region (north-east Poland), at education and experiment stations of the University of Warmia and Mazury (UWM) in Olsztyn:

1) Tomaszkowo – Olsztyn region, district Stawiguda, N 53°43'04.4"; E 20°24'37.8",
2) Bałdy – Olsztyn region, district Purda, N 53°36'01.8"; E 20°36'14.1",
3) Łężany – field Leginy, Kętrzyn region, district Reszel, N 49°38'47.6"; E 21°48'35.8",
4) Łężany – field Kocibórz, Kętrzyn region, district Reszel, N 54°00'37.6"; E 21°10'37.4".

Soil quality of all fields was the same (class IVa).

Plant material

Observations of plant healthiness concerned 35 willow genotypes, including:

1) in Tomaszkowo – all genotypes planted in spring 2001:
   – 22 genotypes of 9 species (*S. alba* – 1, *S. daphnoides* – 1, *S. dascyclados* – 1, *S. fragilis* – 1, *S. purpurea* – 5, *S. rigida* – 4, *S. rubra* – 2, *S. triandra* – 3, *S. viminalis* – 4),
   – 4 interspecific hybrids (*S. alba* × *S. fragilis, S. viminalis* × *S. amygdalina, S. viminalis* × *S. caprea, S. purpurea* × *S. daphnoides*),
2) in Bałdy – all genotypes planted in spring 2006:
   – 8 genotypes of 5 species (*S. viminalis* – 3, *S. dascyclados* – 2, *S. daphnoides* – 1, *S. pentandra* – 1, *S. triandra* – 1),
   – 1 interspecific hybrid: *S. purpurea* × *S. daphnoides*,
3) in Leginy – all genotypes planted in autumn 2005:
   – 4 genotypes of *S. viminalis*,
4) in Kocibórz – all genotypes planted in autumn 2005:
   – 6 genotypes of 2 species (*S. viminalis* – 5, *S. alba* – 1).

Most of the genotypes (27, i.e. 77%) was cultivated or observed in one location – mostly in Tomaszkowo, but six genotypes (17%) were observed at two locations and two genotypes (cultivars: 'Spring' and 'Turbo') – constituting 6% of the plant material – were observed at three locations. Clones of the same hybrid between *S. purpurea* and *S. daphnoides* were evaluated in two locations (Tomaszkowo and Bałdy).

Experiment design

Observations were done for three years (2006–2008). The evaluation of plant healthiness was performed four times in the season, with two–three weeks intervals, starting in mid-June and ending in mid-August. The mean disease incidence (percent of infected leaves) and disease severity was obtained based on the evaluation of 30 old and 30 young willow leaves, randomly collected from each observed plant.

Evaluation scale

The authors elaborated the 10-grade disease severity scale, where:
0 – no disease symptoms, a healthy leaf,
1 – up to 3 uredinia on a leaf,
2 – from 4 to 10 uredinia on a leaf,
3 – from 11 to 30 uredinia on a leaf, ca 5% of a leaf lamina covered by the fungus,
4 – from 31 to 60 uredinia on a leaf, ca 10% of a leaf lamina covered by the fungus,
5 – ca 20% of a leaf lamina covered by uredinia,
6 – ca 33% of a leaf lamina covered by uredinia,
7 – ca 50% of a leaf lamina covered by uredinia,
8 – numerous uredinia, a drying leaf,
9 – totally dried or absent leaf.

The results were subjected to statistical analysis of variance, LSD and HSD Tukey's tests and the calculation of correlation coefficient using Statistica 6.0 Software (StatSoft, USA).

Meteorological data

The weather data were collected at two experiment sites – in Bałdy and Łężany. Mean daily temperatures (°C) and sums of daily rainfall (mm) were used to calculate the mean weather data for all months in experiment years 2006–2008. Mean monthly temperatures and monthly sums of rainfall were compared to the means for the last decade (1998–2007). As the data for November and December 2008 were not available, the mean temperature and rainfall in these months were substituted by the mean data in the last decade, respectively at both locations. This allowed drawing conclusions concerning differences between experiment years as well as comparisons with the mean weather conditions in this decade (Table 1).

Results

For the first two years of field observations (2006 and 2007) no or very little disease symptoms were found on willows grown at all locations of the experiment. The results obtained in the third season of the experiment (2008) greatly differed from two previous evaluations. In this season numerous disease symptoms were

Table 1

Differences between mean monthly temperatures and monthly sums of rainfall between experiment years and mean data for the decade 1998–2007

Month	2006		2007		2008	
	temperature difference (°C)	rainfall difference (mm)	temperature difference (°C)	rainfall difference (mm)	temperature difference (°C)	rainfall difference (mm)
Olsztyn region						
I	–5.5	–8.2	5.8	63.4	3.5	45.2
II	–0.5	7.6	1.1	6.0	5.5	3.0
III	–3.3	–19.0	4.6	6.8	2.3	36.4
IV	0.8	–7.4	2.1	–6.4	2.1	–5.0
V	–0.5	40.2	3.6	11.0	1.8	–21.6
VI	0.0	–4.8	1.6	–10.5	2.9	–73.4
VII	3.9	–45.7	3.0	–64.0	4.2	–73.8
VIII	0.2	158.0	3.1	57.4	1.6	53.0
IX	1.8	–8.0	–0.2	–33.2	–1.2	–32.4
X	2.1	–8.7	0.1	–7.6	0.5	–6.4
XI	2.3	28.3	–1.3	–26.6	nd	nd
XII	5.6	8.4	2.1	–12.2	nd	nd
Mean	0.6	76.5	2.2	–80.1	2.0	–139.2
Kętrzyn region						
I	–6.0	–16.0	4.6	57.0	2.5	12.0
II	–2.8	–4.0	–1.6	–8.0	4.5	4.0
III	–3.7	–27.0	4.5	–2.0	1.5	34.0
IV	–0.6	–17.0	–0.5	–10.0	0.5	–1.0
V	–0.1	9.0	1.0	40.0	–0.4	–37.0
VI	0.2	–17.0	1.8	15.0	0.7	–18.0
VII	1.9	–60.0	–1.6	54.0	–0.8	–1.0
VIII	–0.4	94.0	0.4	–6.6	–0.1	11.0
IX	2.8	20.0	0.2	3.0	–0.8	–17.0
X	2.2	2.0	–0.1	3.0	1.0	47.0
XI	2.7	40.0	–1.0	21.0	nd	nd
XII	5.1	–6.0	1.5	–24.0	nd	nd
Mean	0.2	39.0	0.8	167.0	0.8	80.0

Negative numbers point out months that are colder and drier as compared to the last decade; positive numbers point out months that are warmer and/or more humid.

nd – no data available.

observed on willows, especially in the Olsztyn region. The analysis of weather conditions revealed this year was unusually dry (–139.2 mm of rain less as compared to the decade 1998–2007). Statistical analysis of willow leaf infestation with rust

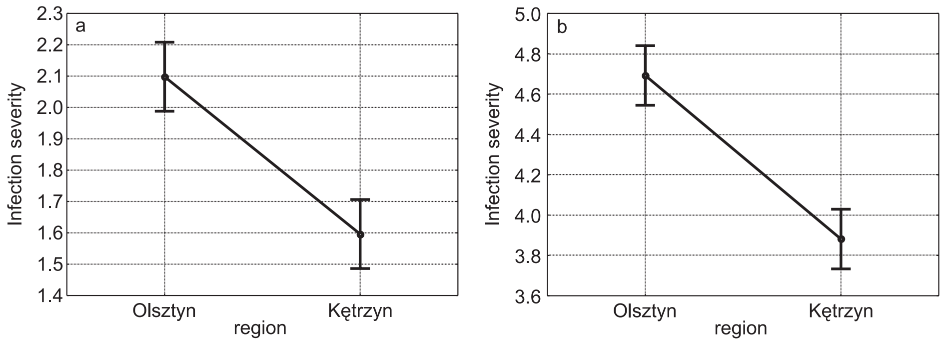


Fig. 1. The comparison of disease severity of willow (*Salix viminalis*) cultivars between two regions located in Warmia, differing with weather conditions. Mean leaf infestation with rust: a – 30 July 2008, b – 11 August 2008

demonstrated significant differences between both regions, with higher disease symptoms in Olsztyn (Figs. 1 a, b). Starting from April till September the rainfall in Kętrzyn region was also much less as compared to the average (Table 1), what also explains high disease scores obtained in this region.

The correlation coefficients between disease severity and disease incidence were very high; on 10 August in Olsztyn region the coefficient reached 0.813 and for the same period in Kętrzyn it was 0.823. Generally, in August the mean correlation coefficient was statistically significant (0.820 at $P = 0.001$), what was nearly identical to the same coefficient calculated for data obtained in October in Bałdy (0.818).

The disease symptoms greatly varied between species and genotypes; some willow genotypes were entirely free of the pathogen whereas some of them were highly infested. The earliest and highest infestations were found on UWM 005 – the genotype of *S. daphnoides*. This was the only species with rust pustules formed on leaves in mid-June. The disease symptoms on this genotype have quickly expanded and by mid-August uredinia have covered in average ca 25% of leaf laminas (Fig. 2). However, this result is an average of evaluations performed at two different locations (Tomaszkowo and Bałdy). The results obtained at these locations greatly varied from each other, with very high disease index obtained at Bałdy and much smaller disease symptoms found in Tomaszkowo.

Short rotation willows (*S. viminalis*) formed a group of genotypes with high levels of susceptibility to *Melampsora* rust fungi (Fig. 2). However, great differences were found between the studied genotypes, ranging from UWM 157 that was early and highly infected by *M. epitea* to UWM 095 which by mid-August showed no disease symptoms. No pustules were found in mid-June on *S. viminalis*. The mean disease index for genotypes belonging to this species increased from 0.3 in the beginning of July, *via* 1.4 at the end of July to 3.3 in mid-August. In Olsztyn region six tested genotypes, including three cultivars ('Sprint', 'Start' and 'Turbo') reached the average score of 4.4 (Fig. 2). In the beginning of July single uredinia could be found on leaves of four out of 10 tested genotypes. At the end of July the symptoms were observed on seven genotypes and they varied from few to tens of

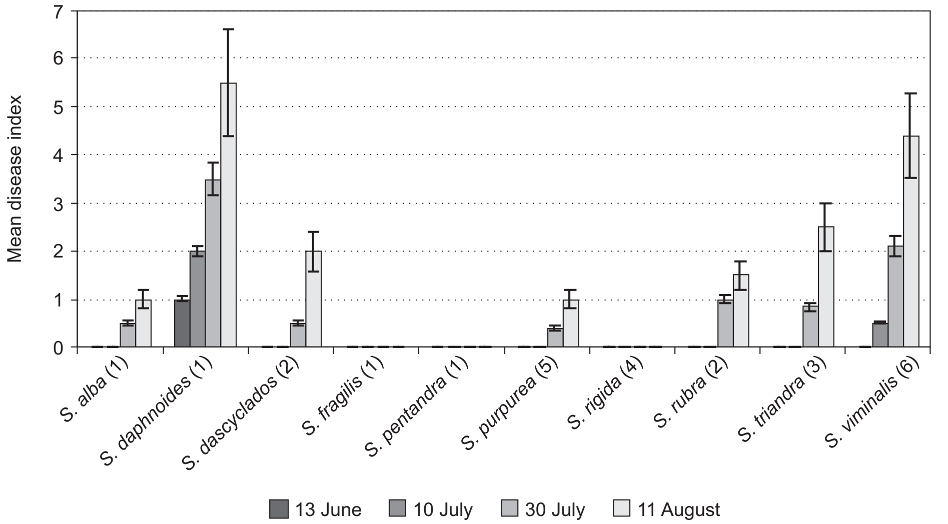


Fig. 2. The mean disease severity of 10 willow species (*Salix* spp.) infected by rust (*Melampsora epitea*)

uredinia on leaves, depending on a genotype. The lowest numbers of pustules were present on UWM 046 and UWM 196, whereas on UWM 157 pustules were numerous and on average they covered ca 10% of leaf laminas (Fig. 3).

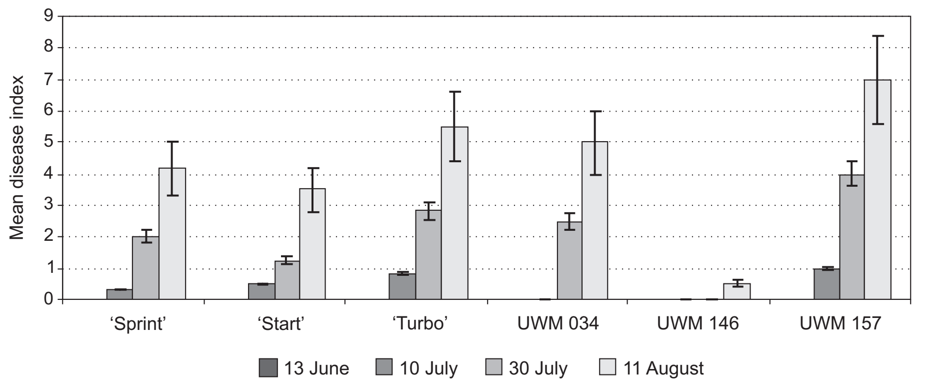


Fig. 3. The mean disease severity of willow (*Salix viminalis)* genotypes in Olsztyn region infected by rust (*Melampsora epitea*)

Great variation in susceptibility to willow rust was also observed in *S. triandra* (Fig. 4). Genotype UWM 055 showed only few pustules on leaves whereas UWM 056 was highly infested with nearly half of leaf areas covered by uredinia. In case of all genotypes of *S. triandra* no disease symptoms were found until the end of July (Fig. 2). More profound symptoms in July led to much higher disease index in mid-August (Fig. 4).

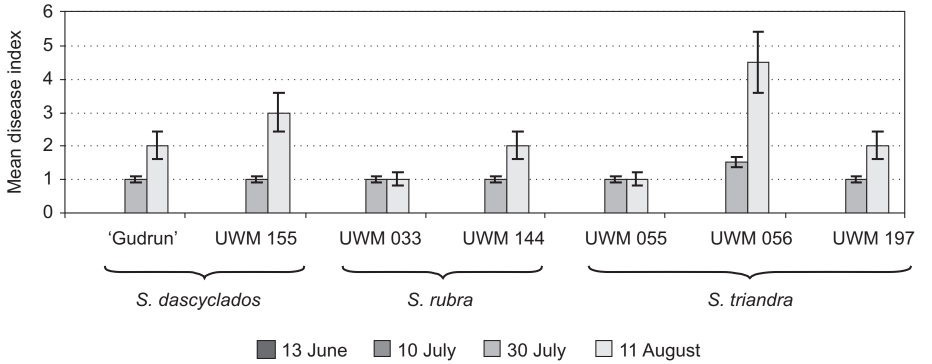


Fig. 4. The mean disease severity of willow genotypes from *Salix dascyclados, S. rubra* and *S. triandra* to rust (*Melampsora epitea*)

In case of *S. dascyclados* average symptoms in mid-August did not exceed 10 uredinia on a leaf (Fig. 2). However, UWM 155 was hosting ca three times more uredinia per leaf, constituting about 5% of leaf areas, as compared to Swedish cultivar 'Gudrun' (Fig. 4).

The variation between the healthiness of *S. rubra* genotypes was not high. It did not exceed 10 uredinia per leaf, on both UWM 033 and UWM 144 genotypes (Fig. 4). The disease symptoms of the genotype UWM 144 of *S. rubra* were comparable to these on *S. daphnoides* cv. 'Gudrun'. The results obtained for *S. rubra* UWM 033, *S. triandra* UWM 055 and *S. alba* UWM 180 were identical. In general, the *S. alba* genotypes were among the most resistant among the tested selection of willows. The genotype UWM 200 of *S. alba* showed no disease symptoms for the whole season; however, it was tested only in Kętrzyn region (Kocibórz), where average plant infestation was lower than in Olsztyn area.

Genotypes of *S. purpurea* showed similar levels of resistance as compared to *S. alba* (Fig. 2). Disease symptoms were observed on two out of five tested genotypes of this willow species whereas the remaining three genotypes (UWM 142, UWM 147 and UWM 164) were highly resistant to willow rust and no disease symptoms were found on these forms (Fig. 5). The genotypes UWM 143 and UWM 199 showed no symptoms until mid-July. Later on, the symptoms on the former genotype expended to greater extent and in mid-August the fungus covered ca 5% of leaf laminas, whereas on the latter genotype no more than 10 uredinia were observed on leaves.

The evaluation of disease severity was also performed for four natural interspecific hybrids of willows. In general, the rust symptoms were not severe. Moreover, the hybrid between *S. alba* and *S. fragilis* was free of willow rust (Fig. 6). None of the studied genotypes showed symptoms of early plant infection (mid-June); no disease symptoms were also found in the first half of July. At the end of July few rust pustules were found on leaves of UWM 154 (*S. viminalis* × *S. caprea*) and UWM 145 (*S. viminalis* × *S. amygdalina*). In mid-August the highest disease index was obtained for the latter hybrid, but on average no more than 5% of leaf laminas

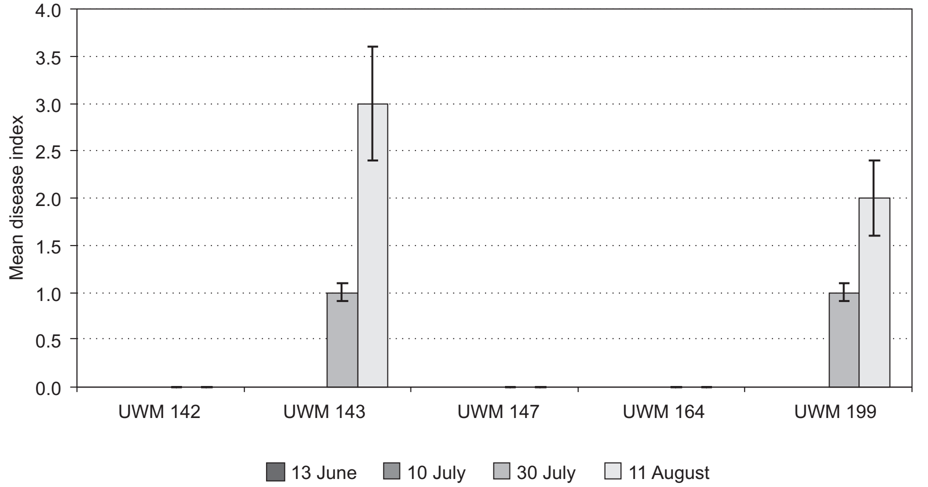


Fig. 5. The mean disease severity of *Salix purpurea* genotypes to rust (*Melampsora epitea*)

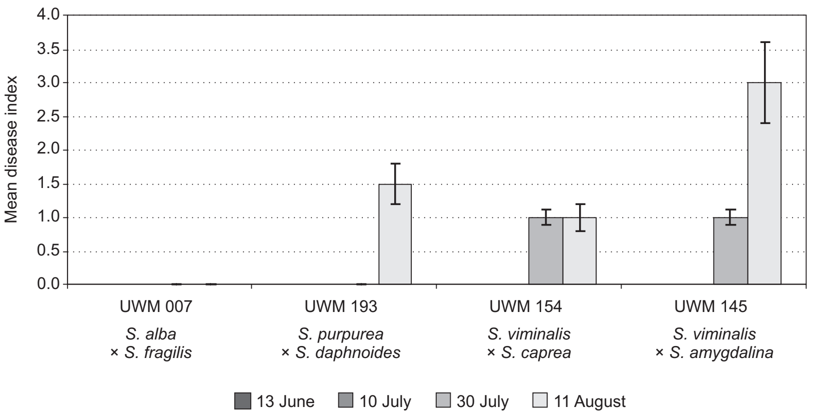
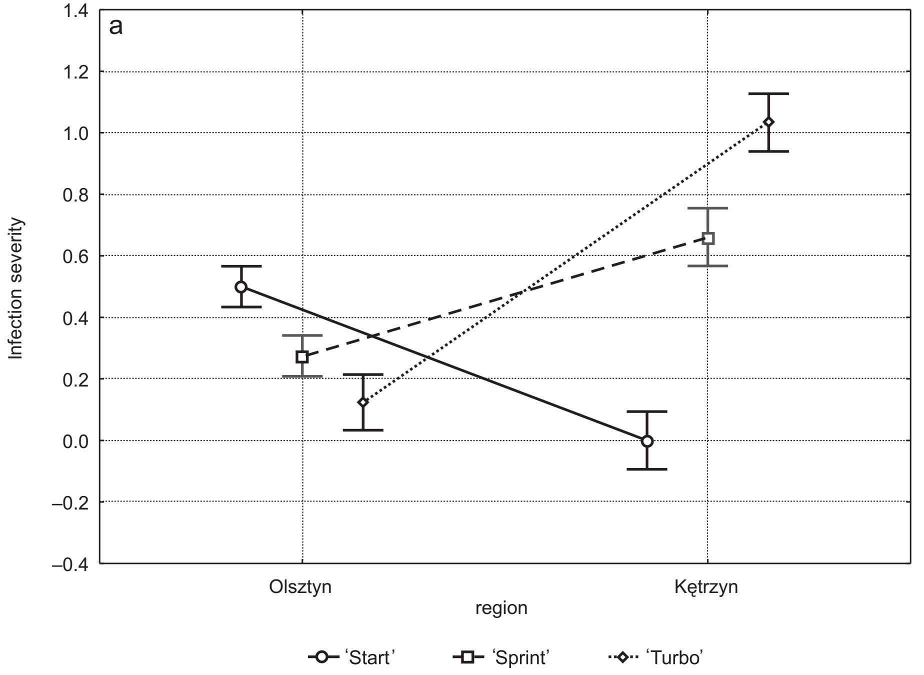


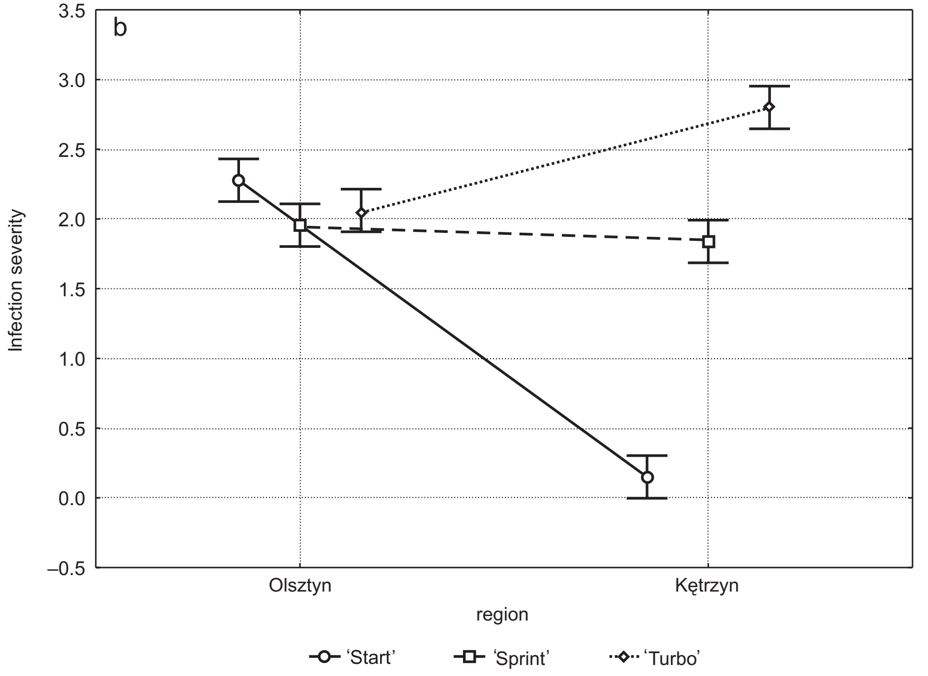
Fig. 6. The mean severity of leaf rust symptoms on interspecific hybrids of willows

were covered by the fungus. At the same time *S. purpurea* and *S. daphnoides* hybrid (UWM 193) showed a few uredinia on its leaves.

The variation of disease symptoms was observed not only for different genotypes belonging to the same willow species, but also for the same genotype tested at different locations. Five genotypes of four species (*S. daphnoides, S. dascyclados, S. triandra* and *S. viminalis*) were tested at two locations and two cultivars of *S. viminalis* were observed at three experiment sites. Some disease symptoms on willows were identical at different locations, e.g. the numbers of rust pustules on leaves of the genotype UWM 155 of *S. dascyclados* or UWM 043 of *S. viminalis*. Similarly, the differences between the healthiness of willow plants were not very high for cultivars 'Sprint' and 'Turbo' of *S. viminalis*, although the results were not identical (Fig. 7). In each case the symptoms started to appear in the first decade of July at two out of three sites, being not profound but very scarce – a few uredinia on



a
Infection severity
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
–0.2
–0.4
Olsztyn
Kętrzyn
region
'Start'
'Sprint'
'Turbo'



b
Infection severity
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
–0.5
Olsztyn
Kętrzyn
region
'Start'
'Sprint'
'Turbo'

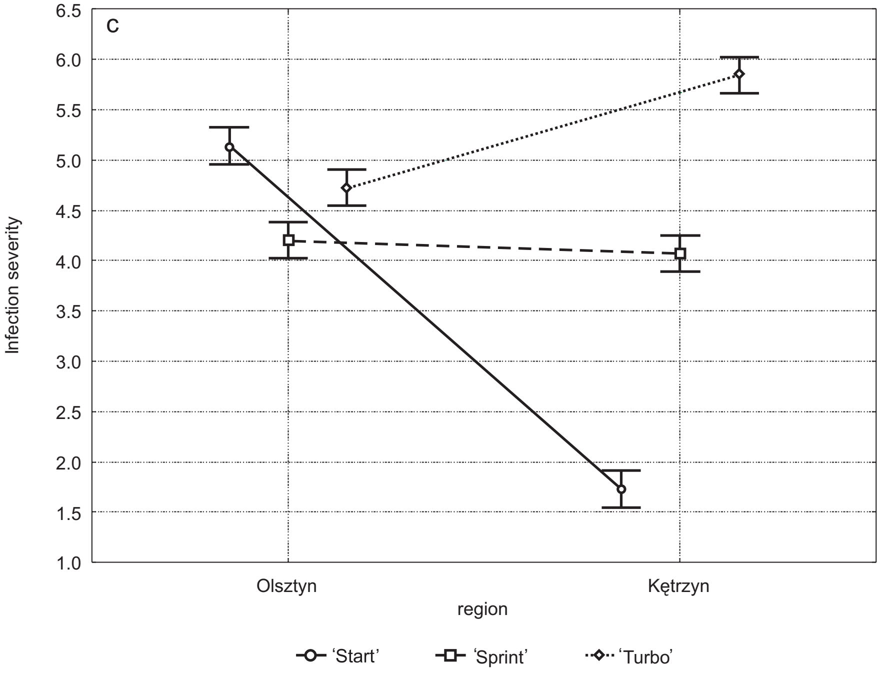


Fig. 7. The mean severity of rust on the registered cultivars of coppice willows (*Salix viminalis*) evaluated at different regions: a – 10 July 2008, b – 30 July 2008, c – 10 August 2008

leaves. However, slightly higher numbers of rust pustules on a genotype indicated these forms that were infested at higher rates at the end of the season.

In two out of seven cases the reaction of willow plants to infestation by *M. larici-epitea* greatly differed between experiment sites. In case of the cultivar 'Start' of *S. viminalis* the symptoms found in Bałdy appeared on willow plants one month earlier (10 July) than in Leginy. Moreover, they reached much higher scores, with ca 25% of leaf area covered by the fungus on willows grown in Bałdy and only few uredinia on willow leaves in Leginy (Fig. 7). Strong differences between the severity of infection of variety 'Start' was the main reason for more severe plant infestation in Olsztyn region (Fig. 1). Variety 'Turbo' was highly infected in Kętrzyn. Apart from the evaluation on 10 July, no statistical differences were found for variety 'Sprint'.

The differences between plant reactions concerning the genotype UWM 005 of *S. daphnoides* were even more dramatic, with late and scarce disease symptoms in Tomaszkowo and very early and extremely severe symptoms in Bałdy, both located in Olsztyn region. On 11 August, the disease score at UWM 005 reached the highest score equal to 9; most of leaves of this genotype had fallen off the plant and the remaining leaves were half or fully dry, with numerous black spots suggesting that telia were already formed at this early period of the season.

Discussion

The important way of increasing productivity of willows is breeding for resistance to main pests, including leaf rust as one of the key factors reducing biomass production. Higher yielding plants can be obtained through constant selection of genotypes that are more resistant or tolerant to leaf rust. The other way is to introduce and propagate resistant materials available in nature.

The goal of this study was to find genetic sources of willow resistance to the population of rusts that are currently present in Poland. By now no research on rust population genetic structure has been done for Poland. Based on the literature it can be deduced that the main pathogen present on willows is *Melampsora larici-epitea* with its three special forms: f.sp. *larici-epitea typica* (LET) that infects *S. viminalis*, f.sp. *larici-retusae* (LR) infecting *S. dascyclados* and f.sp. *larici-daphnoides* (LD) that is capable of infecting *S. daphnoides*. Moreover, two additional *Melampsora* species: *M. ribesii-viminalis* and stem-infecting-form (SIF) are possible pathogens present on willows with leaf rust disease symptoms (Pei et al. 1996).

Our evaluation of healthiness of 35 different genotypes of willows, including 10 species and four natural interspecific hybrids, showed great differences in the resistance of particular plant genotypes. The assessments performed under field conditions proved the susceptibility of numerous genotypes to willow rusts. Some species, such as *S. daphnoides*, were highly infested, what indicated both the susceptibility of plant material and the presence of inoculum capable of propagation on such host plants. Disease symptoms were also present on basket osier willows (*S. viminalis*), the most popular species used in SRC (Short Rotation Coppice) system. However, considerable differences were found between the genotypes, suggesting that selection or intraspecific crossings are perspective ways of increasing the levels of resistance. One of the genotypes of *S. viminalis* (UWM 095) was fully free of the disease. Genotypes resistant to leaf rust were also found among *S. alba* and *S. purpurea*. Several genotypes, including *S. fragilis, S. pentandra, S. rigida* and the natural interspecific hybrid *S. alba* × *S. fragilis*, did not show any disease symptoms. They can serve as potential sources of willow resistance to leaf rust. High disease pressure was observed in only one out of the three years studied (2008), so further plant resistance data are desirable to confirm these findings.

In 2008 the weather conditions in Warmia region were conductive for disease development. In spite of close location of all experiment sites in distances not exceeding 90 km, the weather data showed substantial differences of rainfall and temperature between the fields. Severe disease symptoms were observed both at more wet locations of Leginy and Kocibórz and much drier (277 mm of rainfall less) and warmer (by 0.5°C) experiment sites at Bałdy and a nearby Tomaszkowo. In Łężany the sum of rainfall from the beginning of January till the end of October was 622 mm; assuming that November and December would not differ from the decade, the yearly sum of precipitation was 717 mm of rain. In contrast, in Bałdy the rainfall till the end of October was 352 mm (270 mm less that in Łężany) and – with the addition of the average precipitation in the last two months of the year –

the sum of rainfall was 440 mm, what constitutes only 61.4% of the rainfall in Łężany. This difference is even more profound in the case of rainfall from May to August, when the main infection process starts and develops on willow leaves. In Łężany the sum of rainfall in this period of time was 300 mm and in Bałdy –126 mm, what constitutes only 42% of water supply as compared to Łężany, located only 90 km apart. The most dramatic difference in rainfall between Łężany and Bałdy was noted in June and July with respectively 60 mm and 76 mm of rain in the former experiment site and only 11 mm (June 2008) and 1 mm (July 2008) at the latter location. High severity of plant infestation at both regions suggests that a prerequisite of a strong willow infection is good establishment of the pathogen on a secondary host plant leading to the abundance of a primary inoculum – aeciospores formed on larch and/or currant.

Very broad range of weather conditions suitable for the initiation and development of the disease indicate great importance of breeding and growing resistant genotypes. When weather is not a limiting factor, susceptibility of plant hosts combined with availability of inoculum inevitably lead to plant infection. It seems that once started, the disease can easily develop both in a wetter and drier climate. On the other hand, the differences between reactions of the same clone grown at various experiment sites suggest a great role of the microclimate and/or the composition and availability of the local pathogen population.

In our experiments willows cultivated at particular locations were planted at different years, what influenced the size and shape of plants and could have had its impact on final development of the disease. The age and shape of plants at SRC fields is influenced by the grower to a small extent, hence – apart from cultivation of genotypes resistant to local forms of the pathogen – planting of genotype mixtures is an alternative strategy for the non-chemical control of willow rust (McCracken et al. 2001, Hunter et al. 2002, Samils et al. 2003). In this case issue such as maturation dates does not apply, as the end product is wood collected at winter months (McCracken and Dawson 2003).

In most cases the reaction of willow genotypes to leaf rust was comparable between the experiment sites, however, in two out of seven cases considerable differences were observed, suggesting that the most reliable tool of assessing genetic resistance of plant materials are tests under controlled conditions, using suitable species, forms and pathotypes of the fungus (Pei et al. 2004). Nevertheless, regardless of all constraints and problems connected with field studies, uniform and reproducible testing in growth chambers should never fully replace evaluations of disease resistance under natural conditions. One of the main reasons is the possibility of emergence of new pathotypes, capable of breaking resistance genes introgressed to plant cultivars (Ramstedt 1999, Samils et al. 2001). The occurrence of new pathogen forms, such as SIF, brings novel challenges for current resistance breeding programmes.

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Streszczenie

POSZUKIWANIE GENETYCZNYCH ŹRÓDEŁ ODPORNOŚCI WIERZB NA RDZE (*MELAMPSORA EPITEA*)

Jednym z czynników ograniczających otrzymywanie obfitej biomasy wierzb są rdze rodzaju *Melampsora.* Celem badań było poszukiwanie genetycznych źródeł odporności wierzby na rdze występujące w Polsce.

Doświadczenia polowe zlokalizowano w czterech miejscach na Warmii. Badania prowadzono przez trzy sezony wegetacyjne, od wiosny 2006 do jesieni 2008 roku. Obserwacji zdrowotności roślin dokonywano czterokrotnie, w okresie od połowy czerwca do połowy sierpnia. Stopień porażenia roślin oznaczano na podstawie dziesięciostopniowej skali (0–9), gdzie 0 oznaczało brak objawów chorobowych, a 9 – suche lub opadające liście. Oceniono poziom odporności 35 genotypów wierzby, w tym 10 gatunków i czterech mieszańców międzygatunkowych. Większość badanych genotypów wierzby była porażona przez rdzę, a stopień porażenia zależał od gatunku, genotypu rośliny, terminu obserwacji oraz miejsca uprawy. Do najbardziej odpornych należały gatunki: *Salix fragilis, S. pentandra* i *S. rigida* oraz mieszaniec międzygatunkowy *S. alba* × *S. fragilis.*

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Authors' addresses:
Doc. Dr. hab. Małgorzata Jędryczka, **Joanna Ciszewska-Marciniak M.Sc.,** Institute of Plant Genetics, Polish Academy of Sciences, ul. Strzeszyńska 34, 60-479 Poznań, Poland, e-mail: mjed@igr.poznan.pl
Dr. hab. Jerzy Przyborowski, Department of Plant Breeding and Seed Production, University of Warmia and Mazury, Olsztyn, Poland

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