Effect of *Melampsora larici-populina* on growth and biomass yield of eight clones of *Populus nigra*

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ABSTRACT: This study evaluates the effect of the identified pathogenic races E1, E2 and E3 of the leaf rust *Melampsora larici-populina* on some growth traits and biomass yield in the species *Populus nigra*. A field trial was conducted with 8 clones of *P. nigra* using fungicide-sprayed and unsprayed treatments in 3 replications of 4 plants. In the course of three years the occurrence of the rust was evaluated on a six-point scale. The plant height and stem diameter were measured during the trial. In the last year the plants were harvested and the dry weight was determined. In the untreated plants a significant negative correlation was found between the intensity of rust occurrence and the values of stem diameter and dry matter yield ($P < 0.05$). A decline in dry matter yield caused by the rust was low (below 9%) or zero in a half of the clones while it ranged between 19% and 28% in the other half of clones. In some clones the yield decline was relatively low although the expression of rust symptoms was rather high which could be attributed to a tolerance to the given pathogen.

Keywords: biomass yield; *Melampsora larici-populina* Kleb.; poplar; resistance

The genus *Populus* L. comprises fast-growing woody plants suitable to be grown under short-rotation systems for the production of biomass as a renewable energy source. For these purposes clones, interspecific hybrids, originating from intrasectional as well as intersectional crosses are almost exclusively used. It should be noted that up to 60% of clones have *P. nigra* (Directory of Poplar, FAO 2000) as one of the parental components.

In recent years experiments have been conducted to test the yield potential and growth of the black poplar in coppice forests with relatively promising results (Laureysens et al. 2005; Benetka et al. 2007; Al Afas et al. 2008). One of the reasons for the study of *P. nigra* was to identify clones that could replace interspecific hybrids in areas where the growing of allochthonous species is banned by law (e.g. in national parks and adjacent territories) and to replace them with an autochthonous species (Benetka et al. 2002). In the above-mentioned experiments, and in different climatic conditions, clones of the species *P. nigra* achieved relatively positive results in terms of biomass yield compared to hybrid clones.

In our evaluation of black poplars, the importance of leaf rust pathogens of the genus *Melampsora* was also kept in mind. Three *Melampsora* species are pathogenic on cultivated poplars in Europe: *M. larici-populina* Kleb., *M. allii-populina* Kleb. and *M. medusae* Thüm. The latter does not occur in the Czech Republic but can be found in southwestern France, Spain and Portugal (Pinon 1991). *M. allii-populina* is rather scarce in Central Europe (Majewski 1977; Kokeš, Müller 2004) while *M. larici-populina* is a dominant species of the genus *Melampsora* in poplars of Central Eu-

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rope. At present, five races with eight virulences and potentially 256 pathotypes are known within *M. larici-populina* (Pinon, Frey 2005). However, the intraspecific structure of *M. larici-populina* occurring in the Czech Republic has been studied only sporadically up to now (Barrès et al. 2008).

A negative impact of the leaf rust *M. medusae* on several cultivars of hybrid poplars in experiments conducted by Widin and Schipper (1981) was reflected in a decline of dry weight wood yield by up to 57%. The leaf rust *M. larici-populina* is also considered a significant pathogen that may cause great damage to poplar stands. Lemaire et al. (1998) reported that in France in the hybrid clone 'Luisa Avanzo' this pathogen caused economic losses amounting to 50% of annual increment in three- to six-years old stands as a result of reduced photosynthetic efficiency, premature defoliation and increased susceptibility to other pests and diseases. On the widely planted cultivar 'Beaupré', growth restriction due to rust was estimated to be 20% to 30% of the biomass in the first year of infection and up to 50% to 60% in the following years (Gastine at al. 2003). Laureysens et al. (2005) reported the mortality of plants due to rust as the cause of a decline in biomass yield in young stands of hybrid poplars.

The above-mentioned examples raise the question how dangerous the leaf rust *M. larici-populina* is to black poplar, in which a different type of resistance other than that in hybrid poplars is expected. As documented by literary data, in some present poplar hybrids rust resistance is qualitative (Lefèvre et al. 1994; Dowkiw, Bastien 2007), while in black poplar it is probably quantitative (Legionnet et al. 1999).

As this short overview shows, published papers have sporadically reported on the influence of the rust *M. larici-populina* on dry matter yield in the genus *Populus*. Yield decline was determined only for few cultivars of hybrid poplar but no consideration has been given to the species *P. nigra*.

MATERIAL AND METHODS

Field trial

Material

Eight clones of *P. nigra* with a different level of resistance to *Melampsora larici-populina* Kleb. originated from own breeding programme of *P. nigra*. Parental trees are plus trees that were found in a natural environment (Table 1). The parental components were composed in such a way that the parents would come from different climatic and geographic conditions. Their genetic diversity was confirmed by DNA analysis (microsatellites).

Methods

The trial was conceived in spring 2005 at Michovky locality in the area of the Silva Tarouca Research Institute in Průhonice. Average temperatures and precipitation amounts for the experimental period 2005–2007 are shown in Table 2. The trial was established with one-year plants grown from cuttings. Eight clones in two treatments and in three replications by four plants were set out at a spacing of 2.20 × 0.45 m. One treatment was fungicide-sprayed (s) and the other was unsprayed (u). A guard row was planted between the sprayed and unsprayed treatment. In 2005 the fungicide Acanto (Picoxystrobin) was applied at a concentration of 0.25%. Because its efficacy was low, it was replaced by a combination of the fungicides Amistar 0.25% + Impact 0.25% (Azoxystrobin + Flutriafol) in 2006 and 2007. Sprayings were always conducted before the first rust symptoms appeared (the end of June) and afterwards, before the end of residual effect (mid-July and beginning of August).

Evaluation

The trait of resistance to *Melampsora larici-populina* was evaluated in field conditions using a 6-point scale: 0 – no signs of rust infection on leaves; 1 – small patches covered by uredia on a half of the

Table 1. Localization of parental trees from which the tested clones of black poplar originate

Tested clones	♀			♂		
	altitude (m a.s.l.)	latitude N	longitude E	altitude (m a.s.l.)	latitude N	longitude E
7; 9; 107; 110; 113	420	49°14'	13°31'	242	49°36'	17°20'
37	550	49°13'	13°40'	145	50°32'	14°08'
49	295	49°39'	18°22'	± 200*	–	–
152	635	50°09'	16°08'	160	50°20'	14°29'

*pollinated by a pollen mixture

Table 2. Temperatures and precipitation amounts during the trial conducted in Michovky locality

	2005	2006	2007
Average temperature (°C)			
Year average/sum	8.8	9.2	10.2
Vegetation period (IV–IX)	15.3	15.8	16.0
Amount of precipitation (mm)			
Year average/sum	481.6	474.5	517.4
Vegetation period (IV–IX)	314.2	293.4	320.9

leaves; 2 – small patches covered by uredia on most leaves; 3 – larger patches of rust up to continuous coverage on all leaves; 4 – rust coverage of the whole leaves, incipient leaf necrosis; 5 – all leaves necrotised or shed. The overall condition of plants was also considered during the evaluation of uredial counts on leaves. The evaluation was done on several dates (from July to October). Mid-August was the best time to distinguish the resistance of clones because differences among the clones were small on earlier dates due to the lower environmental abundance of the pathogen. On later dates, toward the end of the growing season, there was an extreme increase in the inoculum amount in the environment and a significant increase in infection pressure, which caused a partial blurring of differences. This is the reason why the clones were compared around that date with regard to the pathogen development. The point values used for data processing are averages of the evaluation of three times four plants.

The growth traits of stem diameter at a height of 0.5 m to the nearest 1 mm and plant height to the nearest 0.1 m were measured at the end of the growing season. In 2007, the growth traits were measured at two-week intervals. The last measurement that was done at the end of vegetation was used for calculations. Biomass was harvested at the beginning of January 2008. All plants from the particular parcels were weighed together and the dry matter was determined from samples of fresh biomass dried to a constant weight at 105°C as described by Benetka et al. (2002).

Statistical analyses

Statistical evaluation was done using the statistical package Statistica 7.1 (StatSoft Inc., Tulsa, OK). The analysis of the effect of independent factors (clone, treatment, repetition) on dependent variables was carried out by analysis of variance, and the post-hoc comparisons were made by Duncan's test. The assumptions of homogeneity and normality were fulfilled. The differences in rust severity among clones were tested using the Kruskal-Wallis test. The differences in growth traits between sprayed and unsprayed treatments were tested by paired t-test. Correlations were tested using Spearman's coefficient of rank correlation (r_s). This test was used to evaluate the stability of the degree of infection within the particular clones of black poplar in the years of observation, the relationship between the severity of clone infection by rust and the value of the growth traits and dry weight.

Laboratory test for race spectrum determination

In August 2005 the intraspecific structure of *Melampsora larici-populina* was preliminarily investigated by artificially infecting a set of test clones – 'Robusta', 'Ogy' (*Populus* × *canadensis*), 'Unal', 'Hoogvorst', 'Beaupré' (*Populus* × *interamericana*) and 'Aurora' (*P. candicans* Ait.) (Pinon, Frey 1997, 2005) with acquired fungus isolates. Leaves with few rust uredia were collected to minimize the chance of cross-contamination during the acquisition of isolates. The spore suspension was acquired using a micropipette to apply 20 µl of sterile water agar (0.1 $g \cdot l^{-1}$) to the particular uredia. This was then pipetted out and applied as small droplets to the set of leaf discs of test clones. The inoculated discs were cultivated in sterilized Petri dishes (20 cm in diameter) on filter paper soaked with deionized water at 20°C. Artificial radiation simulated daylight wavelength and intensity, and the discs were maintained under a 16-h light period each day. Cultivation to fully developed uredia on leaf discs lasted two weeks.

RESULTS

Field trial

Occurrence of Melampsora larici-populina

The first incidence of *M. larici-populina* was observed in mid-July in the unsprayed treatment whereas the fungicide-sprayed treatment was nearly without leaf rust occurrence throughout the vegetation period (Table 3). Only in the first year (2005) was a lower incidence (1.2–1.9) observed. After the exchange of pesticide (2006 and 2007), the treated plants were without symptoms at the end of August. The rust occurrence was low with average values from 0.6 to 1.4 points at the end of the vegetation period.

Differences in the intensity of rust infection among the clones in the unsprayed treatment were

Table 3. Occurrence of the rust *Melampsora larici-populina* during the trial in 2005–2007 on the date of the most significant infection in the particular years in both treatments – fungicide-sprayed (s) and unsprayed (u) treatments

Clone	2005 25.8.		2006 14.8.		2007 22.8.	
	s	u	s	u	s	u
7	1.2	3.4	0	2.8	0	3.2
9	1.8	4.0	0	3.6	0	3.9
37	1.8	3.1	0	3.1	0	3.5
49	1.9	3.7	0	3.5	0	3.5
107	1.4	3.1	0	2.7	0	2.8
110	1.8	3.3	0	2.7	0	3.4
113	1.6	3.4	0	3.2	0	3.6
152	1.6	2.8	0	2.6	0	2.5

tested in all observed years with the results always being quite similar. The result of the Kruskal-Wallis test was always highly significant ($P << 0.001$), i.e. the studied clones were significantly different in the intensity of rust infection. A post hoc comparison showed that clones 107 and 152 were always infected to a significantly ($P < 0.05$) lesser extent than some other clones (mainly 9 and 49). Rust symptoms of the lowest intensity (2.5–2.8) were observed in clone 152. The highest intensity of infection (3.6–4) was determined in clone 9. This clone was significantly different ($P < 0.05$) in infection from clones 7, 107, 110, 152.

The stability of the intensity of infection of black poplar clones by the rust (the rank of clones according to the intensity of infection) between the particular years was evaluated using Spearman's coefficient of rank correlation. The results demonstrated that the rank of clones according to the intensity of rust infection was significantly correlated in all years. The correlation coefficient of infection occurrence in 2005 and 2006 was 0.87 ($P < 0.01$), in 2005 and 2007 it was 0.76 ($P < 0.05$), and in 2006 and 2007 its value amounted to 0.92 ($P < 0.01$). It means that the distribution of rust infection remained stable in the tested set of clones during the trial.

The intensity of infection during the growing season in 2005 and 2007 was evaluated in the same way. The ranking of clones according to rust incidence was also similar in this case. In 2005 the coefficient of correlation between the first evaluation (when the rust incidence was little intensive) and the main evaluation was highly significant (0.89; $P < 0.01$). In 2007 the correlation between the first and the second evaluation was highly significant (0.94; $P < 0.01$) and it was significant between the second and the third evaluation (0.80; $P < 0.05$). In the critical August period no significant changes in the rank of clones caused by the rust infection were observed (Fig. 1).

Effect of independent variables on growth traits (Table 4)

In the first year after planting (2005) only plant height was assessed because the shoots were still too little differentiated in stem diameter. The average plant height in the fungicide-sprayed treatment was almost identical (1.764 m) to that of the unsprayed treatment (1.759 m).

The average values for the sets of fungicide-sprayed and unsprayed treatments were different only in the stem diameter trait in 2006 (25.9/22.6 mm) but they were not significantly

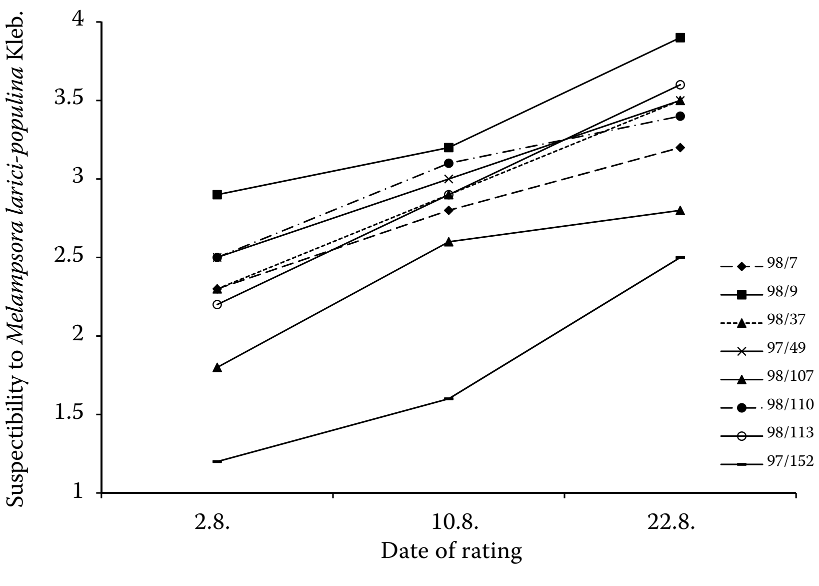

Fig. 1 Development of *Melampsora larici-populina* occurrence in 2007 in fungicide-treated variant

Table 4. The values of the traits of stem diameter and plant height with their differences (d) in the fungicide–sprayed (s) and unsprayed (u) treatments in 2006 and 2007

Clone	Stem diameter (mm)				Plant height (m)			
	u	s	d	P*	u	s	d	P*
2006								
7	23.6	23.8	−0.2	–	3.2	3.2	0.0	–
9	18.8	24.7	−5.9	0.01	2.9	3.5	−0.6	0.001
37	23.1	28.4	−5.3	0.01	3.4	3.6	−0.2	0.01
49	22.2	23.5	−1.3	–	3.3	3.5	−0.1	–
107	27.1	28.1	−1.0	–	3.6	3.4	0.2	–
110	20.8	25.5	−4.7	–	3.1	3.5	−0.4	–
113	19.5	23.5	−4.0	0.01	2.9	3.4	−0.5	0.01
152	26.0	29.5	−3.5	–	3.6	3.8	−0.2	–
Mean	22.6	25.9	–	–	3.2	3.5	–	–
P†	0.03		–	–	0.07		–	–
2007								
7	31.8	30.9	−0.9	–	4.1	3.8	0.3	–
9	27.3	33.0	5.7	0.01	3.9	4.2	−0.3	0.01
37	31.8	36.5	4.7	0.01	4.3	4.2	0.1	–
49	32.3	30.1	−2.2	–	4.4	4.3	0.1	–
107	36.8	36.6	−0.2	–	4.3	4.3	0.0	–
110	32.0	33.1	1.1	–	4.3	4.2	0.1	–
113	26.1	29.6	3.5	–	3.9	4.0	−0.1	–
152	35.5	37.1	1.6	–	4.5	4.5	−0.1	–
Mean	31.7	33.4	–	–	4.2	4.2	–	–
P†	0.34		–	–	0.90		–	–

*Duncan's test, †paired *t*-test

different in 2007 (33.4/31.7 mm). The average values of plant height did not differ either in 2006 (3.47/3.24 m) or 2007 (4.20/4.21 m) (paired *t*-test).

Using the analysis of variance the influence of the factors clone, treatment and replication and their interactions on plant height and stem diameter of plants was studied in 2006 and 2007. We primarily examined the differences between the treatments in the particular clones. The values of the traits were lower in the unsprayed treatment.

Table 5. Increments of stem diameter and plant height from the beginning of vegetation to the first rust incidence (beginning of July 2007) and their percent proportion in the total value of the given trait over vegetation in the unsprayed treatment

Clone	Stem diameter (mm)		Plant height (m)	
	increment until time of rust incidence	% of total diameter increment	increment until time of rust incidence	% of total diameter increment
7	8.2	98	0.69	73
9	8.5	96	0.82	80
37	8.7	100	0.67	76
49	10.1	96	0.72	67
107	9.7	95	0.67	90
110	11.2	100	0.73	68
113	6.6	100	0.73	79
152	9.5	92	0.60	90

Table 6. Dry weight in fungicide-sprayed (s) and unsprayed (u) treatment and percentage depression in dry matter yield due to the rust *Melampsora larici-populina*

Clone	Dry weight/plant (kg)		Paired *t*-test between s and u *P*	Change in weight in u treatment (%)
	s	u		
7	1.12	1.25	–	+12
9	1.28	0.92	0.074	–28
37	1.57	1.24	0.099	–21
49	1.40	1.28	–	–9
107	1.55	1.58	–	+2
110	1.25	0.95	–	–24
113	1.21	0.98	0.052	–19
152	1.50	1.41	–	–6

In clone 9 the significant difference in the traits of stem diameter (5.9 and 5.7 mm) and plant height (0.55 and 0.30 m) was found out in both years. In clone 37 the significant difference in stem diameter was found out in both years (5.3 and 4.7 mm) and in plant height only in 2006 (0.23 m). In clone 113 significant differences were confirmed in both traits only in 2006 (4 mm and 0.46 m).

In 2007 stem diameter and plant height increments were monitored throughout the vegetation period. The spring increment was found to cease in the studied clones already at the first incidence of rust (2.7.). It is stated that the summer increment usually amounts to few millimetres but is characterized by enormous hardness compared to the spring increment. In our case, this change in stem diameter was no longer observed in a subsequent summer period. Plant height at the beginning of July ranged from 67% to 90% of the final measurement (Table 5).

Effect of independent variables on dry matter yield

The analysis of variance documented that both the factor clone ($F = 4.95$; $P < 0.01$) and the factor treatment ($F = 4.29$; $P < 0.05$) had a significant influence on the amount of harvested biomass. No influence of their interaction was observed ($F = 1.45$; $P = 0.22$).

Yield decline that can be related to the effect of the rust (a difference between fungicide-sprayed and unsprayed treatment) ranged from 6% to 28% (Table 6). In some clones (clones 7 and 107) no yield decline was observed at all or it ranged only from 6% to 9% (clones 49 and 152). It is to note that clone 107 and clone 152 were among the highest-yielding ones. In the remaining clones (9, 37, 110, 113) yield decline ranged between 19% and 28%. The yield decline between the fungicide-sprayed and unsprayed treatment was significant in clones 9, 37 and 113 ($P < 0.1$).

Differences between higher-yielding clones (107, 152, 49, 7, 37) and lower-yielding clones (113, 110 and 9) in the unsprayed (u) treatment were significant ($P < 0.1$ to $P < 0.01$). A significant difference in yield ($P = 0.088$) existed between clones 107 and 37 in unsprayed (u) treatment whereas in the fungicide-sprayed treatment these two clones had the same yield (Table 6).

Relationship between the intensity of Melampsora larici-populina occurrence and the value of growth traits and biomass yield in Populus nigra

The correlation between the growth traits of stem diameter and plant height and the intensity of rust occurrence was studied. If the rank of clones was determined according to a difference in the values between sprayed and unsprayed treatment, no correlation was found between the value of this difference and the intensity of rust occurrence. If the rank of clones was determined according to the values attained in the unsprayed treatment, a significant correlation was calculated for the trait of stem diameter in both years ($r_s = 0.7857$ and $r_s = 0.8988$; $P < 0.05$). This correlation was not proved in the sprayed treatment.

A significant correlation in biomass yield was determined between the rank of clones according

Table 7. Differences in yield among clones in the unsprayed (u) treatment

Clone		113	110	9
	Dry weight/plant (kg)	0.98	0.95	0.92
			P	
37	1.24	0.082	0.950	0.007
7	1.25	0.042	0.930	0.095
49	1.28	0.032	0.888	0.075
152	1.41	0.006	0.535	0.015
107	1.58	0.001	0.284	0.002

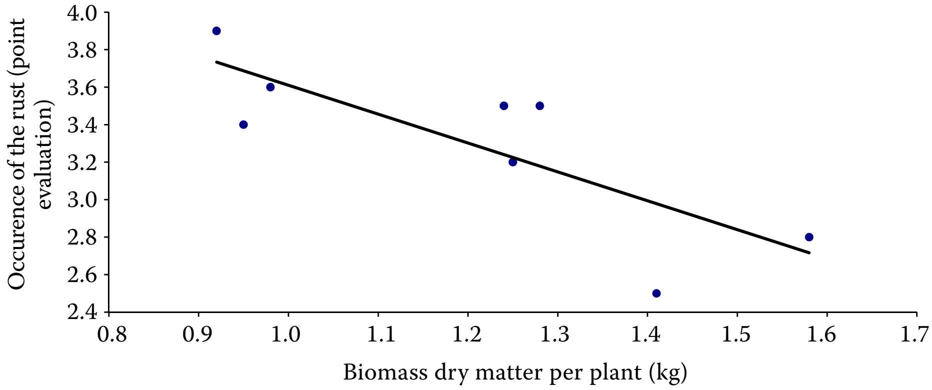

Fig. 2. Correlation between the intensity of occurrence of rust and the weight of biomass dry matter

to the yield level in unsprayed treatment and the intensity of rust infection (r_s = 0.7185; $P < 0.05$). There was also a significant correlation between the rank of clones according to the percentage change in yield (in relation to sprayed treatment) and the intensity of rust infection (r_s = 0.8333; $P < 0.05$) (Fig. 2).

Laboratory test for race spectrum determination

To specify the pathogen, tests that clearly confirmed the pathogen classification to the species *M. larici-populina* and to some of its races were carried out. Thirty-three rust isolates were acquired from black poplar. Isolate cultivation allowed race identification. All the isolates belonged to *M. larici-populina* considering the observed resistance of *P.* × *interamericana* 'Beaupré' to all acquired isolates. 'Beaupré' is resistant to *M. larici-populina* races E1, E2, E3 and some pathotypes of the race E5 (with missing V7 virulence) and susceptible to *M. allii-populina* (Pinon, Frey 1997). Three races E1, E2 and E3 were identified. In total, race E1 was the most frequent. Nearly half of the acquired isolates (16 isolates, ca 48%) belonged to this race. Eight isolates (ca 24%) were classified as race E2 and nine isolates (ca 27%) as race E3. Neither race E4 nor E5 was found.

DISCUSSION

The extreme cases of resistance to rust (0 and 5) are missing among the clones selected for the trial. In our experience no fully resistant *P. nigra* clone (score of 0) was yet detected at the end of the growing season (mid-September in conditions of this country). Clones with a score of 5 occur infrequently at this time. Because of the absence of fully susceptible clones in the trial we could not estimate the maximum decline in biomass yield caused by rust in black poplar.

The pathogen race spectrum was determined to define it explicitly. Races E1, E2 and E3 were identified during the investigation whereas only race E1 was identified by Barrès et al. (2008) in another stand in the Czech Republic. The absence of races E4 and E5 on black poplar in investigated stands is not surprising because these races evolved on hybrids of *P. trichocarpa* × *P. deltoides* in France only in the 1990s (Pinon, Frey 2005). However, the presence of these two races somewhere else in the Czech Republic is possible. They could have been introduced by poplar trade or by the long-distance wind transport of uredospores or by aphids. The complete determination of the population structure of *M. larici-populina* in the Czech Republic and pathotype identification require a more extensive investigation.

A decline in dry matter yield that could be caused by the effect of leaf rust ranged from 6% to 28% in our trial. The dry matter yield decline below 28% we are reporting is relatively low in comparison with the reported losses of biomass yield around 50% which were described in the important hybrid clones of 'Luisa Avanzo' (Lemaire et al. 1998), 'Beaupré' (Gastine et al. 2003), 'Hazendans' and 'Hoogvorst' (Laureysens et al. 2005). These cultivars belong to *P.* × *canadensis* and *P.* × *interamericana* hybrids in which pathotype-specific resistance is known. Both hybrids have *P. deltoides* as a parent, which is a probable source of pathotype specific resistance (Dowkiw 2003). This resistance can be broken down due to changes in the pathotype spectrum (Lefèvre et al. 1994; Dowkiw, Bastien 2007). In 'Luisa Avanzo' and in 'Beaupré' the loss of resistance to *M. larici-populina* was sustained in response to the occurrence of new races E3 and E4 while in 'Hazendans' and 'Hoogvorst' it was a result of the detection of race E5 (Pinon, Frey 2005).

If we analyse the causes of the lower decline in biomass yield due to the effect of *M. larici-populina* in our trial, there are several factors to mention. One of the main factors may be a different genotype of the tested material. The species *P. nigra* itself probably possesses resistance of quantitative character (Benetka et al. 2005) which applies at least to races E1, E2 and E3 (Legionnet et al. 1999). Another cause may be the spectrum of selected *P. nigra* clones, among which the clones with high susceptibility to the rust are missing. Their genetic diversity could also decrease the rust effect in our trial because the *Melampsora* infection in the stand with a mixture of poplars can have a smaller impact on growth reduction (Miot et al. 1999).

Interesting is the effect of the rust on yield decline in the particular clones evaluated on the date when it was possible to distinguish the clones from each other in the best way as for the intensity of rust infection. Yield decline was quite low (9%) in clone 49, which belonged to the most infected clones. Similarly, in clone 7, which was infected to a lesser extent, no decline in dry matter yield was observed at all (on the contrary, there was a 12% increase in this parameter).

Similar results were reported by Dowkiw (2003) in the offspring of *P. deltoides* × *P. trichocarpa*. It seems to be a phenomenon designated as tolerance; it was defined by Caldwell et al. (1958) as the ability of a crop to endure severe epidemics by the pathogen while sustaining only insignificant yield losses, as compared with an infected intolerant cultivar. Dowkiw (2003) showed that the link between resistance (expressed by symptoms) and tolerance (growth under infection) is weak and consequently, these two characters may have to be selected independently. In the early stages of selection breeders ask a question whether intensive selection for resistance to rust is correct when it is decided only according to the symptoms of pathogen expression. Our own observations have indicated that in spite of a high level of the expression of pathogen symptoms many seedlings are among the best individuals by their growth. Nevertheless, the genotype with such susceptibility to rust could hardly become a new cultivar even though it was a high-yielding one. Such a clone might be a reservoir of infection as reported by Miot et al. (1999). This is the reason why selection for tolerant genotypes with a higher expression of pathogen symptoms will apparently be undesirable.

Significant negative regression of the expression of rust symptoms on the values of dry matter yield in the unsprayed treatment was another result. It confirmed a significant inhibitory effect of the pathogen on the final traits of dry matter yield, which is in accordance with the results of Widin and Schipper (1981). This correlation, however, was confirmed only partly in growth traits. This can probably be explained within the time frame these traits are mostly realised and within the time frame of the main incidence of the rust. Stem diameter and the main part of plant height were realized before the onset of the pathogen incidence while the production of storage compounds in poplar mostly starts in late summer and this process peaks in autumn (Nguyen et al. 1990; Dickmann et al. 2001). However, at the beginning of vegetation the initial growth of shoots depends on storage compounds from the preceding year (Nguyen et al. 1990).

If the clones are compared using their yield potential, expressed as yield in the sprayed treatment (s), in clone 37 with the highest yield potential there was a sharp decline in dry matter yield in unsprayed treatment in agreement with the higher incidence of rust symptoms. On the contrary, in clone 107 with similarly high yield potential of dry matter no decline in dry matter yield was observed in unsprayed treatment at all. But the lower rust infection was recorded in this treatment. Clone 152 behaved similarly like clone 107, even though a small decline in dry matter yield was determined in this clone. These results prove that the mentioned genotypes are different from the aspect of resistance to rust, which was expressed by the relevant reaction to a decline in dry matter yield.

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