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Life strategies of *Erysiphe palczewskii* in the conditions of diversified anthropopressure

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Diversified reactions of *Erysiphe palczewskii* in urban conditions, including the influence of biotic factors (*Ampelomyces quisqualis*, weakness parasites) and abiotic factors (transport pollution) on the morphology of the mycelium and chasmothecia, and the course of individual developmental stages, are analysed in the paper.

Key words: *Erysiphe palczewskii*, *Caragana arborescens*, transport pollution

INTRODUCTION

The powdery mildew *Erysiphe palczewskii* (Jacz.) Braun and Takamatsu 2000 (*Erysiphales*) infects mostly leaves of the type *Caragana* Lamk and *Colutea* L., usually covering them with a whitish, cobwebby or cobwebby-mealy coating, consisting of the vegetative mycelium, conidiophores and conidiospores (Braun 1987; Schmidt and Schöller 2002). Chasmothecia, usually highly numerous, develop at the end of the summer, and serve as main resting bodies. They overwinter on lignified parts of the host plant, less frequently in the soil. Six ascospores, enclosed in an ascus, are released in the early spring and cause primary infection of the hosts (Schöller 1994; Huhtinen, Alanko and Makinen 2001).

In Poland, *Erysiphe palczewskii* had been observed on *Caragana arborescens* in Urszulin near Włodawa for the first time as late as in 1981 (Sałata 1985). The pathogen is at present known from numerous localities on this host in central and north-eastern Poland (Kalinowska-Kucharska and Kadłubowska 1993; Kadłubowska and Kalinowska-Kucharska 1997; Dynowska, Fiedorowicz and Kubiak 1999). Findings on the rapid spread of *E. palczewskii* to new areas and new hosts have been reported in literature outside Poland over the last few years (Huhtinen et al. 2001; Schmidt and Schöller 2002; Nischwitz and Newcombe 2003). Reports on the ecology of this parasite whose extramatrical mycelium is exposed to a number of biotic and abiotic environmental factors that may affect mycelium and chasmothecium morphology and influence individual stages of the developmental cycle are few in Poland.

As powdery mildews are believed to react significantly to air pollution, the reactions of *E. palczewskii* in urban conditions with a diversified accumulation of transport pollution were examined.

MATERIAL AND METHODS

Studies were conducted between 2000 and 2002. Localities were established within the city of Olsztyn along major transport routes at the distance of: up to 50 m (12 localities), 100 m (3 localities), 300 m (2 localities), and 2 localities in control sites >300 m (Olsztyn-park on Jezioro Kortowskie Lake and the village of Wójtowa Rola, 2 km from Olsztyn). Leaves of *Caragana arborescens*, collected in August and September, constituted the test material.

Macro- and microscopic analyses were conducted in laboratory conditions. The infection degree was calculated for each test sample (25 randomly collected leaves from the host plant were considered to be one test sample), using a 5°-scale in keeping with the Mc Kinney formula:

$$R = \frac{\Sigma (a \times b) \times 100\%}{N \times 4}$$

R – disease coefficient in percents (index)

$\Sigma (a \times b) \times 100\%$ – sum of products obtained by multiplying the number of collected plant organs by the infection degree

N – total number of plants (or alternatively leaves, fruits) examined

4 – the highest grade in a 5-grade scale (0 – no infection; 1 – up to 10%; 2 – 11-25%; 3 – 26-50%; 4 – 51-100%)

The number of mature and immature chasmothecia was determined in 1 cm^2 of each infected leaf in the test sample. Ten morphologically mature chasmothecia were analysed. The following factors were assessed: a) morphological variability, b) developmental degree of appendages in a 3°-scale: 0-no appendages, I-appendages not fully developed, II-appendages fully developed, c) presence of asci and ascospores.

The influence of other fungi, mostly *Ampelomyces quisqualis*, and so-called weakness parasites (*Alternaria*, *Cladosporium*), on the development of powdery mildew was examined:

a) appropriately modified McKinney formula was suggested for the calculation of the infection degree of the mycelium of the *Erysiphales* by *A. quisqualis*:

$$R_{A.q} = \frac{\Sigma (c \times d) \times 100\%}{N \times 4}$$

$R_{A.q}$ – infection index of *Erysiphales* mycelium by *Ampelomyces quisqualis* (%)

$\Sigma (c \times d) \times 100\%$ – sum of products obtained by multiplying the number of collected plant organs infected by the powdery mildew (c) by the infection degree (d)

N – total number of organs infected by the *Erysiphales*

4 – highest degree in a 5-grade scale.

b) when weakness parasites occurred, 10 mature chasmothecia from 1 cm^2 of the area colonised by these parasites of each leaf in the sample were examined and the following was determined: a) developmental degree of appendages, b) presence of asci and ascospores.

RESULTS

The presence of *Erysiphe palczewskii* on *Caragana arborescens* was recorded in 15 out of the 19 localities (79% of all localities) in 2000, 13 localities (68%) in 2001, and 11 localities (61%) in 2002. The host plant was infected in all the zones studied, and the infection degree ranged between 0% and 100% in individual localities. The mean infection index was high for 50 and 100 m, ranging between 50 and 77.3%, and decreased proportionally to the increasing distance from the pollution source: from 50% to 0% (Tab.1).

Regardless of the distance, chasmothecia were characterised by fully developed appendages in ca. 90% (stage II) in all the years. The participation of chasmothecia with unbranched appendages (stage I) was from 2% to 12%, and was the greatest (8%, 10%, and 12%) in control localities (>300 m). Chasmothecia without appendages (stage 0) were recorded at all the distances. They constituted from 0 % to 4% (Fig. 1 a, b, c).

Table 1
Mean infection degree (%) of *C. arborescens* by *E. placzewskii*

year	distance			
	up to 50m	up to 100m	up to 300m	>300m
2000	64%	72%	42%	32.5%
2001	49%	77.3%	50%	0%
2002	50%	55%	49%	8.5%

A very high infection degree of *C. arborescnes* (over 60%) was recorded in each year studied. Plants with >60% infection degree constituted 63% in 2000, 42% in 2001, and 50% in 2002. Plants were infected abundantly if their height was <2m (mean infection degree ranged between 66.7 and 86.5%). Plants >2 m, however, were always characterised by a low disease index, and the mean infection index ranged between 0 and 5.7% (Tab. 2).

Table 2
Mean infection degree of *C. arborescens* leaves by *E. palczewskii* depending on the height of the host plant in the vegetative seasons between 2000 and 2002

year	plant height	mean infection degree
2000	1-2m	66.7%
	>2m	0%
2001	1-2m	79.7%
	>2m	5.3%
2002	1-2m	86.3%
	>2m	5.7%

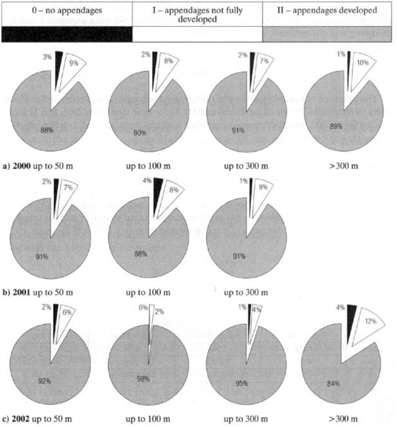

Fig.1 a, b, c. Degree of the development of chasmothecium appendages of *E. palczewskii* at various distances from transport routes between 2000 and 2002.

Atypical appendages, with abnormal and deformed branching (branching from half the height), were recorded in all the distances studied. They constituted between 2% in control localities and 6.6% at 50 m (Tab. 3).

Chasmothecia at various developmental stages were observed in all the infected localities throughout the vegetative period during the three years of the observations. Regardless of the pollution source, chasmothecia constituted between 77.5% and 96% on the average, while young, developing chasmothecia – between 5% and 23% (Tab. 4). All the mature chasmothecia analysed had in 99% developed asci and ascospores. Empty chasmothecia were recorded at 50 and 100 m each study year. They constituted between 0.63% and 1.8% (Tab. 3).

Table 3
Atypical appendages and empty *E. palczewskii* chasmothecia at various distances between 2000 and 2002

Year	2000				2001				2002			
Distance (m)	50	100	300	>300	50	100	300	>300	50	100	300	>300
Atypical appendages (%)	5.6	5	2.8	3.8	6.6	1.3	4	-	6.1	5.9	4.4	2
Empty chasmothecia (%)	0.67	0	0	0	0.7	1.8	0	-	1.0	0.63	0	0

Table 4
Mean percentage participation of mature and immature chasmothecia in 1cm² at various distances between 2000 and 2002

year		distance chasmothecia participation (%)			
		up to 50m	up to 100m	up to 300m	>300m
2000	mature	89.4	91	81	95
	immature	10.6	9	19	5
2001	mature	77.5	85	95	-
	immature	22.4	15	5	-
2002	mature	92.1	95	94	77
	immature	7.8	5	6	23

The mean number of *E. palczewskii* chasmothecia in 1 cm² was very high regardless of the distance and ranged between 494 ch./cm² and 820 ch./cm². The lowest number of chasmothecia was recorded in 2001 in a control locality: 225 ch./cm² (Fig. 2).

The occurrence of *Ampelomyces quisqualis* as well as fungi mostly of the genera *Alternaria* and *Cladosporium* in the localities situated up to 50 and 100 m was recorded throughout the study period. *A. quisqualis* occurred in 4 localities in 2000, 7 in 2001, and 3 in 2002. The infection degree of *E. palczewskii* mycelium ranged

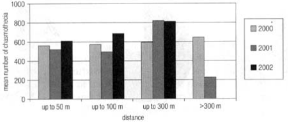

Fig. 2. Mean number of *E. palczewskii* chasmothecia in 1cm² at various distances in study years.

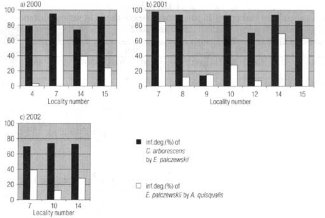

Fig. 3 a, b, c. Infection degree of *E. palczewskii* by *Ampelomyces quisqualis.*

between 3% and 85%. The hyperparasite occurred three times in localities 7 and 10, and twice in locality 14 (Fig. 3 a, b, c).

Weakness parasites, mostly those belonging to the genera *Alternaria* and *Cladosporium*, were observed in 4 localities in 2000, and in 3 both in 2001 and 2002. These fungi significantly disturbed the development of chasmothecia. A greater participation of appendages at stage 0 and I of the development was recorded: they always constituted over 50% (Fig. 4). Numerous chasmothecia without asci and ascospores were recorded, and the mean percent of empty chasmothecia ranged between 8% and 15% (Fig. 5).

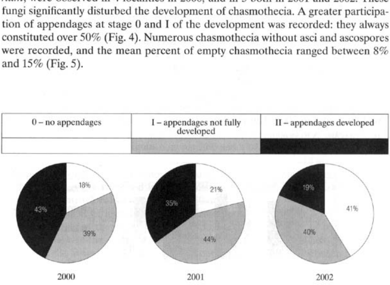

Fig. 4. Mean developmental degree of *E. palczewskii* appendages with the participation of weakness parasites in study years.

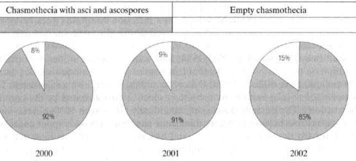

Fig. 5. Mean percentage of empty *E. palczewskii* chasmothecia colonised by weakness parasites in study years.

DISCUSSION

Erysiphe palczewskii is a species rapidly spreading in Europe and the world (Huhtinen et al. 2001; Nischwitz and Newcombe 2003). The present studies show that it finds very good development conditions in urban areas. The parasite was recorded in each study year, and the infection degree of the host plant was very high at the majority of the studied distances from the pollution source. This results first of all from its immunity and high pathogenicity potential as the fungus shows affinity to infection resistant to air pollution of the host on which it undergoes a full developmental cycle: from ascospore to ascospore (Kowalkowski 1987; Kabała and Gren 2002). The occurrence of *E. palczewskii* on *Colutea arborescens* was observed only in the anamorph stage (Schmidt and Schöller 2002). According to Rubin and Arcichowska (1971), the parasitic fungus strongly affects the overall nature of biochemical processes occurring in the host plant cells, causing metabolic changes favourable for the parasite. The higher the specialisation degree of the parasitic micro-organism, the better its biochemical processes are adjusted to the host's metabolism. The fact that another parasite occurring on *Caragana arborescnes*, *Erysiphe trifolii*, recorded by Dynowska et al. (1999), was not observed throughout the study period shows the high specialisation and expansion of *E. palczewskii*. The elimination of the species is also corroborated by Huhtinen et al. (2001), who did not record the occurrence of *E. trifolii* on *Caragana arborescens* in Finland in 1998, observed on this host for 20 years.

The abundant occurrence of *E. palczewskii* on the host studied is connected with the process of the weakening of *Caragana arborescens*, which has been systematically and intensively pruned in urban conditions (Schöller 1994). The present observations are also suggestive of these findings as the parasite was not recorded at all (0% in localities 6, 11, 16, and 18 in all study years) or a very low infection degree was observed (14%-35%), only on plants whose height was >2 m. It seems that the host plant has passive resistance, cuticular resistance that constitutes the barrier to the pathogen (Rubin and Arcichowska 1971). This is confirmed by the present observations: leaves that developed at the beginning of the vegetative period (April/

May) were not infected probably because the period of discharging ascospores from chasmothecia coincides with May/June (first infection symptoms were observed at the time), when the leaves are already covered with the cuticule, and only young leaves are infected.

Studies by Dynowska (1993; 1994; 1996 a and b) on the influence of transport pollution on the *Erysiphales* show that reactions of powdery mildew species to transport pollution are differentiated. Dynowska indicated sensitive and resistant fungi. *Erysiphe palczewskii* belongs to the latter, which is corroborated by the continued observations. The parasite developing abundantly (R = even 100%) in the vicinity of transport routes produced very numerous chasmothecia with appendages which were normally developed in ca. 95%, and had asci and ascospores in as much as in 99%. The presence of empty chasmothecia as well as atypical appendages in sites located up to 50 m and 100 m may be indicative of developmental disturbances. They constituted, however, a very low percent (empty chasmothecia ca. 1%; atypically developed appendages ca. 5%), and their occurrence may be caused by natural disturbances resulting form the production of such a high number of chasmothecia or, as Moore-Landecker (1992) suggests, may be influenced by increased temperature. The presence of young chasmothecia, produced throughout the vegetative period, also shows the enormous reproduction potential of the pathogen.

Ampelomyces quisqualis, a hyperparasite of powdery mildews, was recorded in each study year. It did not affect significantly the infection degree of *C. arborescens* by *E. palczewskii* as it was recorded by the end of the life cycle of the powdery mildew, i.e. the stage of chasmothecium formation. The authors' studies correspond with those by Falk et al. (1995), where the hyperparasite was observed on an ageing mycelium of *Uncinula necator*. Thus, it did not affect the infection degree but it reduced the number of chasmothecia of the species. As *E. palczewskii* chasmothecia were produced throughout the entire vegetative period, *A. quisqualis* infected young chasmothecia which it transformed into its own reproductive organs. This influenced the mean number of chasmothecia in the samples where the hyperparasite was recorded. During detailed mycosociological studies in the Białowieża National Park, Majewski (1971) did not record the occurrence of *A. quisqualis* on powdery mildews. Majewski suggests that *A. quisqualis* is a species connected with the environment strongly affected by anthroporessure, which the present authors' findings corroborate. Its presence was recorded only in the city and in localities situated up to 50 and 100 m from transport routes. A very low and insignificant influence of *A. quisqualis* on the development of powdery mildews is reported in other studies on natural communities (Adamska et al. 1993; Kiss 1997).

E. palczewskii mycelium was also colonised by other fungi, mostly belonging to the genera *Alternaria* and *Cladosporium*, in sites where transport pollution concentrations are high. Their presence in the localities with the highest pollution accumulation may be indicative of the weakening of the mycelium of *E. palczewskii.* These fungi mostly colonised the upper side of the infected leaf of the host plant, affecting the number and the development of chasmothecia of the powdery mildew. They inhibited the appendage development: unbranched or completely undeveloped appendages were numerous. These fungi may be considered to be external mycoparasites. As claims (Pięta 1995), external hyperparasitism occurs when the parasite is outside the mycelium or chasmothecium agglomerations of the fungus pathogenic to plants. It is interesting, however, that despite external parasitism, a significant number of empty chasmothecia that were morphologically mature but did not develop asci and ascospores was recorded. The presence of elements of the mycelium of weakness parasites was observed inside the appendages of *E. palczewskii* chasmothecia. This is indicative of internal intervention: they may secrete destructive and unspecific toxins, causing the death of the fungus-host.

E. palczewskii exhibits a big resistance to all kinds of changes resulting from progressing anthropopressure. This shows a high degree of ecological flexibility of the species that leads to adaptation conditioned by genetic mechanisms which are activated when more important and long-term fluctuations of environmental factors are in operation (Stearn 1992).

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Strategie życiowe *Erysiphe palczewskii* w warunkach zróżnicowanej antropopresji

Streszczenie

Celem pracy było prześledzenie poszczególnych etapów cyklu rozwojowego *Erysiphe palczewskii* oraz ocena występowania tego pasożyta na *Caragana arborescens*, w warunkach poddanych silnej antropopresji. Obserwacje prowadzono w latach 2000-2002 na terenie miasta Olsztyna i okolic. Stanowiska w liczbie 19 zlokalizowane były wzdłuż głównych szlaków komunikacyjnych w odległościach do 50m (12 stanowisk), do 100m (3), do 300m (2) oraz >300m (2 kontrolne: w Olsztynie i Wójtowej Roli). Materiał badawczy stanowiły losowo zebrane liście z rośliny żywicielskiej (sierpień, wrzesień)

We wszystkich latach badań *E. palczewskii* wystąpił na *C. arborescens* z dużym nasileniem. Stopień porażenia wahał się od 0 do100%, niezależnie od odległości. Rośliny o wysokości ponad dwa metry, charakteryzowały się zawsze niskim – 14 do 35% lub zerowym stopniem porażenia. Nie zaobserwowano zakłóceń w rozwoju pasożyta. Owocniki dojrzałe z dobrze rozwiniętymi przyczepkami stanowiły we wszystkich próbach około 90 %. Przy 50 i 100 m odnotowano największy, choć nieznaczny udział nietypowych przyczepek (5-6 %), oraz pustych owocników (1%).

Występowanie nadpasożyta mączniaków prawdziwych *Ampelomyces quisqualis* i pasożytów słabości, głównie z rodzaju *Alternaria* i *Cladosporium,* na grzybni analizowanego gatunku, stwierdzono tylko na stanowiskach o wysokiej koncentracji zanieczyszczeń komunikacyjnych. Nadpasożyt nie wpływał w znaczący sposób na stopień porażenia roślin żywicielskich i rozwój *E. palczewskii.* Natomiast inne grzyby hamowały rozwój mączniaka - znacznie zakłócały wykształcanie owocników (brak worków z zarodnikami i nierozwinięte przyczepki).