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Original Research

Key Survival Strategies of the *Sawadaea tulasnei* Parasite on its *Acer platanoides* Host under Conditions of Varied Anthropopression

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Abstract

This study investigates the development cycle of *Sawadaea tulasnei* on *Acer platanoides* in urban conditions, taking into account the effect of traffic-induced pollution.

Observations were taken at 63 stations in the city of Olsztyn and surroundings, located alongside major communication routes at distances of up to 50 m, 100 m, and 300 m with distances >300 m acting as control.

S. tulasnei appeared in each experimental year. The highest mean pathological index that was statistically significant was recorded at stations located up to 50 m from the routes and the lowest at the control stations.

Differences were observed in the incidence of *S. tulasnei* depending on the maturity of the host plant, whereas the development of the parasite was seen to be undisrupted. In the zone of up to 50 m, fruiting bodies matured earlier compared to controls, suggesting environmental stress.

Keywords: *Sawadaea tulasnei*, developmental cycle, traffic-induced pollution, Olsztyn

Introduction

Sawadaea tulasnei Fuck. Homma (*Erysiphales*) is a biotrophic parasite infesting various species of the genus *Acer*. This pathogen is widespread all over Europe and Asia, but also throughout North America [1, 2]. In Central Europe it occurs on *Acer ginnala* and *A. platanoides* [3], but in Poland it has only been noticed on the latter as *Uncinula tulasnei* in Ojcowski National Park [4, 5], the Pieniny mountains [6], the Mazurian Lake District [7], Central Poland [8], Drawski National Park [9], and in the Częstochowska Uplands [10]. The biological and biotic cycle of *S. tulasnei*, and of other *Erysiphales*, are well recognized [1, 11, 12], but data are lacking on the ecology and on how the parasite employs adaptive strategies in an environment subject to strong anthropopression.

The objective of this study was to analyze the incidence and to monitor adaptive responses of *S. tulasnei* on *A. platanoides* in an urban environment.

Materials and Methods

Investigations (during 2000-02) were conducted in the city of Olsztyn and its surroundings at 63 stations, of which 30 had young and 33 had mature plants of *A. platanoides* L. Stations were located at various distances away from major traffic routes: up to 50 m, 100 m, 300 m, and >300 m. These adopted distances were based on a study by Lorenc-Plucińska and Byczyńska [13], which demonstrated that the highest concentration of vehicle exhaust gases occurs 30-50 m away from a road and is maintained there up to a level of 30%. At a distance of 200 m the level of exhaust gases decreases to 10%. Stations located >300 m away served as controls.

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Table 1. A, B, C, D. Analysis of the prevalence of *S. tulasnei* on *A. platanoides* over the experimental years.

		Years of study	2000	2001	2002
A.	Percentage of samples with *S. tulasnei* (%)		32	38	48
B.	Mean degree of *A. platanoides* infestation by *S. tulasnei* (%)		13 a	17 a	21 a
C.	Percentage of samples of *A. platanoides* infested by *S. tulasnei,* depending on maturity stage of a host plant (%)	young plants	63	67	87
		mature plants	3	12	15
D.	*Mean degree of A. platanoides* infestation by *S. tulasnei,* depending on maturity stage of a host plant (%)	young plants	25	32	41
		mature plants	1	3	3

a – values that are not statistically significantly different at p=0.05.

Experimental material was collected from the middle of the vegetative season, when the first fruiting bodies begin to appear on the farinaceous mycelium. Each sample consisted of 25 leaves collected at random from every host plant.

The degree of host plant infestation and mycelium development with its morphology, as well as development of fruiting bodies, was taken into account during macro- and microscopic analysis of the collected material.

1. A pathological index was calculated for each sample by means of a five-degree numerical scale according to the Mc Kinney formula:

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

R – pathological index as %;

Σ (a x b) x 100% – the sum of products obtained by multiplying the number of plant organs examined (a) by the degree of infestation (b)

N – the total number of examined plants (that is leaves or fruit)

4 – the highest degree of infestation according to a five-degree numerical scale;
- 0 – lack of infestation;
- 1 – up to 10%;
- 2 – 11-25%;
- 3 – 26-50%;
- 4 – 51-100% of infestation.

When analyzing the results, the final value of R was calculated using the arithmetic mean for each species of the fungus on a given host plant and was taken as representing the mean degree of infestation.

2. Developmental stages of the parasite were defined as asexual or sexual.
3. The number of fruiting bodies (both mature and immature) was determined per 1 cm^2 surface area of each infested leaf. Ten morphologically-mature fruiting bodies, selected at random, were microscopically examined and evaluated for:

a) the developmental stage of appendages on a three-level scale:
- 0 – fruiting bodies without appendages,
- I – fruiting bodies with underdeveloped appendages; and
- II – fruiting bodies with fully developed appendages

b) the degree of maturity in fruiting bodies on a three-level scale:
- 0 – fruiting bodies without sporangia and spores;
- I – fruiting bodies with sporangia but without developed ascospores; and
- II – fruiting bodies with sporangia filled with spores

c) morphological variability of fruiting bodies and the shape and diameter of fruiting bodies with particular attention paid to appendages.

The number of fruiting bodies, presented in the Results section, was calculated using the arithmetical means for each species of the fungus.

The fungi were identified using keys by Braun [1, 3] and Sałata [12]. Nomenclature used was according to Braun and Takamatsu [14] as well as Braun et al. [15]. Host plants were defined according to Bugała [16].

Statistical calculations were performed on STATISTICA software (data analysis software system), version 6 by StatSoft, Inc. (2003) using analysis of variance. The significance of differences between mean values was determined at a cut-off level of p=0.05. Mean values of selected variables were compiled into homogenous groups using Duncan's test. Letter indicators – a, b, c… – were applied, and the values denoted with the same letters were not significantly different at a level of p=0.05.

Results

The presence of *S. tulasnei* on *A. platanoides* was recorded in each year of the study. The number of stations with the parasite was 20 out of 63 (32%) in 2000, 24 (38%) in 2001, and 30 (48%) in 2002 (Table 1A).

The results of the mean degree of host infestation in subsequent years of the study were not statistically significant; the highest mean being in the year 2002 (Table 1B).

Differences were also observed in the occurrence of *S. tulasnei* on *A. platanoides,* depending on the maturity of the host plant. Throughout the study, a considerably more frequent infestation was seen in young plants – >63% of infested samples compared to sporadic infestation in mature plants – <15% (Table 1C).

The mean degree of infestation in young plants was also substantially higher than for mature plants, which had a very low pathological index irrespective of distance – <3% (Table 1D).

Table 2. A, B, C, D, E, F. Analysis of the prevalence of *S. tulasnei* on *A. platanoides* at various distances from traffic routes.

	Distance	up to 50 m	up to 100 m	up to 300 m	>300 m
A.	Mean degree of *A. platanoides* infestation by *S. tulasnei* (%)	23 a	20 a	13 a	1 b
B.	Percentage of samples of *S. tulasnei* at the sexual stage (%)	100	89	100	83
C.	Mean number of fruiting bodies of *S. tulasnei* per 1 cm^2 of surface area of a plant	39 a	32 ab	23 ab	15 b
D.	Percentage of mature fruiting bodies of *S. tulasnei* (%)	38	23	14	5
E.	Percentage of fruiting bodies of *S. tulasnei* with fully developed appendages (%)	43	39	8	21
F.	Percentage of fruiting bodies of *S. tulasnei* with asci and ascospores (%)	72	41	46	17

a, b – values that are statistically significantly different at p=0.05.

Statistically significant differences in the mean degree of *A. platanoides* infestation were observed between the distances to the traffic routes. The highest mean pathological index in all the study years, i.e. 23%, was recorded at stations located up to 50 m away from roads. The lowest mean infestation of *A. platanoides* was observed at control stations – 1% (Table 2A).

At all of the distances *S. tulasnei* produced fruiting bodies as well as demonstrating a substantial prevalence of the sexual stage over the asexual stage (83-100%) – (Table 2B). Results of the mean number of fruiting bodies per 1 cm^2 at each distance showed statistically significant differences. The highest number was noted in the polluted zone; 39 fruiting bodies/cm^2, whereas the lowest was in the control zone; 15 fruiting bodies/cm^2 (Table 2C).

During the study, immature fruiting bodies were found to prevail at all of the distances. A difference was seen in the percentage of young and mature fruiting bodies between the polluted and control zones, where the number of mature fruiting bodies was observed to decrease with distance, as compared to the number of immature ones (Table 2D).

The development of appendages, sporangia, and ascospores of *S. tulasnei* were undisrupted, but in the zone of up to 300 m and in the control zone, a considerably higher percentage of chasmothecia was recorded at the 0 and I stages of development (Table 2E). Throughout the study, the prevalence of chasmothecia with sporangia without ascospores as well as those with sporangia filled with spores was demonstrated with the exception of the control zone, where fruiting bodies without developed sporangia or spores were found to predominate (Table 2F).

Discussion

Investigations concerning *S. tulasnei* on *A. platanoides* are usually inventory in nature and are performed in areas under conditions resembling the natural environment, e.g. in national parks or nature reserves [4-7, 9, 10]. These places have low levels of anthropopression with a maintained biological homeostasis and do not exhibit any strong pathological symptoms [17]. In urbicenoses, however, epiphytoses are reported with increasing frequency [18, 19], which is a sign of dysfunction in biological systems.

During the whole study, *A. platanoides* was reported to be infested by *S. tulasnei*, thus it can be considered as an urbanophilic species. Furthermore, the frequent occurrence of *S. tulasnei* on maple has already been reported in Olsztyn by Dynowska et al. [20], and for a few years in Toruń by Hołownia and Kostrzewska [21]. Over the years these authors also have reported changes in the prevalence of the parasite where its almost complete disappearance was observed in the studied area. This being as likely due to the dynamic character of the urban environment and constantly varying system of contributing factors, often acting synergistically, that may cause changes in the occurrence of a particular species and intensity of plant infestation in any given location [22].

Our study showed that the development of parasites was influenced by weather conditions. *Erysiphales* are a group of parasites characterized by their ability to infest a plant over a wide range of temperature and humidity. Due to the high cellular water content in most types of this order, germination of spores occurs even at relatively low air humidities.

The highest degree of a host plant infestation was reported in 2002, when the dry vegetative season was warm and dry; July, August, and September were scorching months with the May-to-September months having precipitation below normal levels. Similar results were reported by Durska [23], who noted (during a dry and hot summer) a stronger development of powdery mildew during a hot dry summer.

Our study demonstrated that *S. tulasnei* infested *A. platanoides* with the greatest intensity at roadside stations, i.e. those located up to 50 m away from traffic routes. In research done by Kalinowska-Kucharska [11], 100% of all maple trees observed along the most polluted street in Zduńska Wola were infested by that parasite. However, neither the age nor variety of the maple were specified. Our own observations indicate that the parasite occurs mostly on young plants and significantly takes them over. In contrast, *S. tulasnei* has seldom been reported in mature plants showing a low pathological index. Therefore, the success of the parasite seems to be age-dependent where host resistance increases as the plant matures; i.e. older trees are more resistant and healthier than young ones. Similar findings were reported in a study by Arula and Mandre [24]. In addition, the development of some parasites is also affected by what variety the host plant is [25]. Indeed, although not analyzed, our study demonstrated that the parasite severely infested mature trees of the *A. platanoides* and 'Globosum' varieties, as well as those of 'Faassens Black.'

The intensity of interaction between individual elements of a parasite-host system that are strongly influenced by different environmental factors is reflected in the expression of phenotypic pathological symptoms, the intensity of disease, and its dissemination [17]. The condition of a host plant is also significant in determining the success of establishing a parasite contact and for allowing the parasite to fully develop [26]. It has been claimed by some authors that *A. platanoides* is susceptible to environmental pollutants, particularly nitrogen dioxide [24, 27]. The Voivodship Sanitary and Epidemiological Station in Olsztyn reported relatively high concentrations of NO_2 at high-traffic crossings, but substantially lower ones at the peripheries and outside the city, which may have an effect on the results of this study.

Our investigations showed a full developmental cycle of *S. tulasnei* ending with the formation of characteristic fruiting bodies of the chasmothecia type. These fruiting bodies are a primary form of powdery mildew that ensures survival under unfavorable environmental conditions [28]. Gadoury and Pearson [29] also observed the formation of fruiting bodies in *Uncinula necator* during drought. They claim that the initiation of chasmothecia occurs under unfavorable environmental conditions in which the pathogen is forced to terminate the cycle and form endospores, the function of which in the *Erysiphales* is taken over by fruiting bodies. Moreover, in urban environments their earlier appearance and maturation in some species of *Erysiphales*, compared to outside areas of the city, was observed by Dynowska [26]. It was explained that this phenomenon is a typical defence reaction of the fungi, analogous to the response of a number of plants which shorten their vegetative season in strongly polluted conditions, i.e. they bloom and produce seeds earlier. The literature indicates that most of the *Erysiphales* enter the reproductive stage at the end of the vegetative season, from August to November [12, 28, 30, 31].

Throughout the whole study period, young chasmothecia in *S. tulasnei* were recorded in the second half of August and the mature ones in September. Chasmothecia appearing in August were also observed by Kalinowska-Kucharska [11]. Thus it is seen that young fruiting bodies were formed at the end of vegetative seasons. The study of Mmbaga [31] provides an explanation for the late summer being the best period for reproduction in that too high a temperature (over 26ºC during very hot summer months) may cause degeneration of fruiting bodies as a result of drying up. Hence, chasmothecia are not formed too early.

The parasite was noted to generate the highest number of fruiting bodies at a distance of 50 m away from traffic routes, whereas the lowest ones were observed at a distance of >300 m. These differences may be due to variation in the extent of host plant infestation at the different stations. Similar findings were reported by Füzi [28].

Differences were observed in the number of fruiting bodies of *S. tulasnei* per 1 cm^2 surface area of a leaf between young and mature trees of maple which are likely due to the low pathological index.

No significant disruption was seen in the development of fruiting bodies of the powdery mildew at the major traffic routes tested. They were seen to be at various developmental stages, from white, yellow, orange, and brown to dark brown and black, with appendages at various stages of development. Even in September, at all the distances studied, observations revealed numerous young fruiting bodies next to mature ones, which indicates a high reproductive potential of the pathogen. Fruiting bodies of *S. tulasnei* at different stages were also observed on maple leaves in September by Kalinowska-Kucharska [11].

In conclusion, analyses of mature fruiting bodies demonstrated the prevalence of chasmothecia with fully-developed appendages at distances of up to 50 m and up to 100 m compared to the control zone. This was also reflected in the sporangia and spores formed; the prevalence of their mature forms was reported in the zones of up to 50 m and 100 m. It is obvious that this is linked with a more rapid development of the parasite on a debilitated host, faster termination of the biotic cycle and, thus, with a successful strategy of survival.

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