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Occurrence of *Erysiphe alphitoides* in oak stands affected by flood disaster

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Abstract. Pedunculate oak (*Quercus robur* L.) is the most valuable deciduous tree species in Poland. For almost 30 years, an oak decline resulting from stress factors leading to a decrease of tree vitality in the long-term has been observed.

The aim of the present study was to determine the proportion of leaves infected by the fungus *Erysiphe alphitoides*, the cause of powdery mildew, in post-flood oak stands situated in the Forest District Wołów (51°32'N, 16°62'E) as well as to evaluate effects of powdery mildew with respect to the oak decline.

In order to record the powdery mildew incidence, we selec ted three trees in each of the ten investigated oak stands, and 200 leaves were collected from the upper part of the crowns. The percentage of infected leaves as well as the reduction of carbon assimilation capacity was assessed. Furthermore, we evaluated the average reduction of carbon assimilation capacity and the percentage of withering branch tips in 25 adjacent trees.

Incidences of powdery mildew were observed in seven out of the ten stands. The maximum tree damage did not exceed 22% leaf infection and mean defoliation within the study areas ranged from 18% to 61.4%. Non-withering branch tips were observed in one post-flood area as well as in one area situated outside the flooded region. Within the remaining areas studied, the average proportion of withering branch tips ranged from 0.4% to 13.8%.

Statistical analyses showed that differences between the investigated stands with regard to the rate of powdery mildew occurrence were not significant. Correlating the means, however, revealed a relationship between powdery mildew incidence and branch tip withering. This relationship is a possible indication of the ongoing oak dieback. No statistically significant relationship between tree defoliation and powdery mildew incidence was found. The lack of statistical significance, as observed here, implies that water stagnation within the investigated stands had no effect on *Erysiphe alphitoides* infection.

Keywords: defoliation, branch tip withering, oak decline, Forest District Wołów

1. Introduction

In Poland, pedunculate oak (*Quercus robur* L.) is the most important deciduous forest tree species in terms of economic and ecological values. Oak stands cover approximately 6% of the total forest area in the country (Ceitel 2006). For almost 30 years, there has been observed immense oak decline all through Poland (Przybył 1995, Oszako 2007, Szewczyk et al. 2012). Scientists keep providing evidence that the decline syndrome has been a consequence of oak vitality decrease resulted from the effects of various stress factors increasing tree vulnerability to biotic agents (Oszako 2007).

Since 1997, the Forest District Wołów has experienced the effects of flood that affected 4075 ha of forests. In 2010, the area of the District was deluged again, including oak stands with decline symptoms.

One of the numerous fungus species taken into account as responsible for deterioration of oak health state is *Erysiphe al-*

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phitoides (Griffon & Maubl.) U. Braun & S. Takam – the injurer of oak assimilation apparatus. The fungus causes powdery mildew disease in oak across all age classes from young to old trees. Infected leaf areas die prematurely and fall down, then tree increments decrease, which is followed by increased vulnerability to other fungal diseases, for example, root rot caused by fungi from the genus *Armilaria*. Infected by powdery mildew, oaks often do not achieve the so called winter maturity stage in good time and become less resistant to harmful effects of early frost. The disease incidence is enhanced by ground water fluctuations (Mańka 2005).

The aim of the present study is to determine the share of oak leaves infected by *Erysiphe alphitoides* in oak stands growing in the Forest District Wołów as well as to evaluate the effects of powdery mildew incidence on the occurrence of oak decline symptoms.

2. Methods

The study areas were situated in the Odra river valley, in oak stands within the Forest District Wołów (51°32′N 16°62′E). In this region, the vegetation season lasts 226 days, average annual temperature is +8.2°C and the sum of precipitation on average amounts to 612 mm. For the study purpose, there were selected 10 oak stands that were waterlogged during the floods in 1997 and 2010. Characteristics of the study areas is presented in Table 1 (Forest District Wołów Management Plan 2005). Powdery mildew occurrence on leaves was evaluated in 3 selected oak trees on each study area. There were collected samples of 200 leaves collected from crown upper parts – those most exposed to sunlight. Next, based on *E. alphitoides* disease symptoms, the percentage share of infected leaves and assimilation apparatus loss were assessed. At the same time, in 25 oak trees surrounding the trees sampled, there were estimated assimilation apparatus losses in accordance with the Atlas of assimilation apparatus loss elaborated by Borecki and Kecz̨yński (1992) and the percentage of withering branch tips was determined.

Mean values of the parameters measured and their standard errors (SE) were computed. Before analysis of variance (ANOVA) tests, the data obtained was transformed follow-

Table 1. Characteristics of study areas

Study area number	Dominant species	Forest site type	Area (ha)	Canopy density	Growing stock	Soil class	Age	Area type
1	Db	Ł	11.08	moderate canopy closure	0.8	II	71	post-flood
2	8Db 2Lp	Ł	20.58	moderate canopy closure	1.1	II	81	post-flood
3	4Db 2Db 2Ol 1Brz	Lw	3.69	moderate canopy closure	1.0	II I II II	85	outside flood area
4	Db	Ł	7.60	broken canopy closure	0.8	II	96	post-flood
5	9Db 1Lp	Ł	3.92	moderate canopy closure	1.0	I	81	post-flood
6	Db	Ł	2.50	broken canopy closure	0.8	III	126/86	post-flood
7	7Db 3Lp	Ł	2.90	moderate canopy closure	0.9	II	101 56	post-flood
8	5Db 5Lp	Lśw	1.37	broken canopy closure	1.1	II	91	post-flood
9	8Db 2Lp	Ł	1.68	moderate canopy closure	0.9	I	86	post-flood
10	9Db 1Św	Lśw	5.32	moderate canopy closure	0.8	II	101	outside flood area

Explanations: Lśw – fresh hardwood forest, Lw – moist hardwood forest, Ł – flood plain forest, Db – oak, Lp – linden, Ol – alder, Brz – birch, Św – spruce

ing the equation $z = \log_{10}(y+1)$. In the case of percent values (p), the probit function by Bliss was used.

Evaluation of the effect of the study area location was carried out with the use of one-way ANOVA. The following statistical model was applied:

$$y_{ij} = \mu + a_i + e_{ij}$$

where:
y_{ij} – value of j-th feature in i-th area location
μ – mean value of observed feature,
a_i – effect of i-th area location,
e_{ij} – effect of error.

If the result of ANOVA was positive, that is, the effect of location of a given area was proved significant, Duncan's multiple range test was performed to determine significant differences between locations. Nonparametric measures of statistical dependencies between mean values obtained for the study areas were assessed using the Spearman's rank correlation coefficient (Spearman's rho, Spearman's)

3. Results

Powdery mildew incidence was observed in 7 out of 10 observed stands. Within the study area No. 1, in each of analysed trees, the percentage of infected leaves was 3–12%. Within the remaining locations with disease occurrence, powdery mildew was most often observed on 2 out of 3 analysed trees. Maximum infection did not exceed 22% of the leaves. The assessment of assimilation apparatus loss showed that the defoliation degree differed depending on the study area and was from 18% to 61.4%. Within the study areas No. 4 and 10, there were observed no withering branch tips. In the rest of the areas analysed, the percentage of withering branch tips was from 0.4 to 13.8%. ANOVA results showed significant differences between the study areas with reference to defoliation degree and the number of withering branch tips. However, the differences in the intensity of powdery mildew occurrence within the areas were not significant (Table 2), hence there are no reasons to conclude that there exists a relationship between flooding and disease occurrence in the stands (Table 3). On the other hand, correlation between the means proved the existence of the relationship between powdery mildew presence and withering branch tips. Within the areas where more withering tips were found, there was also observed increased incidence of powdery mildew. The relationship was confirmed by a high value of rho (0.7165) at p = 0.0197 (< 005). In turn, a negative correlation (rho −0.4185) was found between tree defoliation and powdery mildew occurrence. The results of observations are presented in Table 4.

Table 2. ANOVA results on crown features observed

Defoliation (%)		Withering branch tips (%)		Leaves infected by powdery mildew (%)	
F	*p*	*F*	*p*	*F*	*p*
19.14	0.0000	16.77	0.0000	1.74	0.1444

Table 3. Means and multiple comparison test results on crown features studied

Study area number	Defoliation (%)		Withering branch tips (%)		Leaves infected by powdery mildew (%)	
	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
1	55.00 ab	4.23	13.80 a	5.12	7.00 NS	2.65
2	61.40 b	3.78	5.60 b	0.97	0.67 NS	0.67
3	52.00 abc	3.37	7.60 ab	1.48	5.00 NS	5.00
4	50.40 acd	3.03	0.00 c	0.00	0.00 NS	0.00
5	18.00 e	3.10	7.68 ab	1.70	9.33 NS	4.98
6	42.00 cdf	4.12	16.00 d	1.63	3.67 NS	2.73
7	35.60 f	2.40	1.20 c	0.66	0.67 NS	0.33
8	58.80 ab	4.01	0.40 c	0.10	0.00 NS	0.00
9	18.60 e	2.91	5.40 b	1.15	9.67 NS	6.49
10	38.80 df	2.60	0.00 c	0.00	0.00 NS	0.00

Explanations: a, b, c … numbers in columns marked with same letter do not significantly differ, NS – not significant effect, SE – standard error

4. Discussion

Powdery mildew caused by *E. alphitoides* is one of the most important diseases of pedunculate oak (*Q. robur* L.) growing in Europe (Mańka 2005; Hajji et al. 2009). It is commonly believed that the presence of this pathogen is more harmful in young oak stands when compared to those older. The disease can have a significant effect on tree survival, since in unison with other factors, such as defoliation due to insect feeding, powdery mildew can lead to tree death (Delatour 1983; Thomas et al. 2002; Marcais et al; Breda 2006; Hajji et al. 2009). It seems that in recent years, powdery mildew has also been a part of the cause of oak decline in north-western Germany (Thomas et al. 2002). Together with insect pests, powdery mildew is listed as the main factor in oak defoliation. Nevertheless, there can pass 5–10 years from the start of powdery mildew disease to the end its development and then slow retraction, sometimes finished with tree healing (Denman et al. 2010).

In the areas under the study, there dominated pedunculate oak – a tree species with high capability to regenerate its crown, followed by restoring its vitality after harmful factor withdrawal (only within the 1 degree of vitality) (Dmyterko 1998). After flooding in 1997, in forest stands situated in the valley of the middle Odra river, there was observed an improvement of oak crown vitality. Vitality of oak crowns increased and tree defoliation decreased (Dobrowolska 2007).

Table 4. Tree parameters studied

Study area number	Selected trees				mean per studied areabased on 25 trees	
	tree number	leaves infected by powdery mildew (%)	defoliation (%)	withering branch tips (%)	defoliation (%)	withering branch tips (%)
1	1	12	50	5	55	13.8
	2	3	90	100		
	3	6	25	25		
2	1	0	40	0	61.4	5.6
	2	0	80	0		
	3	2	60	10		
3	1	0	30	0	52	7.6
	2	0	60	5		
	3	15	80	20		
4	1	0	80	0	50.4	0
	2	0	60	0		
	3	0	70	0		
5	1	17	50	10	18	7.68
	2	0	30	15		
	3	11	0	20		
6	1	9	30	20	42	16
	2	2	40	20		
	3	0	60	20		
7	1	1	50	0	35.6	1.2
	2	0	10	0		
	3	1	30	0		
8	1	0	80	0	58.8	0.4
	2	0	50	0		
	3	0	30	0		
9	1	22	30	10	18.6	5.4
	2	0	50	0		
	3	7	0	0		
10	1	0	10	0	38.8	0
	2	0	30	0		
	3	0	60	0		

The results of the present study did not show any significant relationship between powdery mildew incidence and oak tree defoliation. Undoubtedly, tree defoliation can also be due to insect pest feeding. In the stands analysed, there was earlier observed the browntail moth (*Euproctis chrysorrhoea* L.). In 2007, this species was observed in solid oak stands as well as in trees growing on wooded land. Single oaks were always attacked by this insect (Szewczyk and Czeryba 2010). The problems connected with foliophages in this area arose probably in the 1800s, and one of the attempts to control insect pests was planting late flushing pedunculate oaks (Szewczyk and Czeryba 2010). These are less vulnerable to damage by the green oak moth (*Tortrix viridiana* L.), however – more sensitive to powdery mildew infection (Hesmer 1955).

No significant differences between the study areas with regard to the intensity of powdery mildew occurrence suggest that the floods in 1997 and 2010, which caused long-term waterlogging of forest stand sites, did not enhance fungal infections in these stands at present, that is in 2013. Based on the results of the present study, the reasons are not to be found for seeking relationships between stand canopy density (at the same time – sunlight exposure) and powdery mildew incidence. Giertych and Suszka (2010) confirmed commonly known strong relationships between sunlight exposure and *E. alphitoides* infections. Nevertheless, in the present study, there was observed a significant relationship between the incidence of powdery mildew and branch tip withering. It seems that branches attacked by powdery mildew did not achieve the so called winter maturity on time and were damaged by early frost (Mańka 2005). Leafless and dried out branch tips can be accounted for as one of the symptoms of oak decline.

Conflict of interest

None declared.

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Authors' contribution

W.S. – research concept, observations and analysis of research material, manuscript. RK participation in development of research concept, observations and analysis of research material. M. M., H. K., P.L., M. B-W. and J. B-B. also contributed to the results contained in the discussion.