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Assessment of leaf damage in oak stands in the flood-affected Wołów Forest Division**

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Abstract. This study examines the effect of flood on oak stands in the Wołów Forest Division by assessing the loss of leaf area due to insect feeding as determined in laboratory analyses of samples collected from standing trees. We compared stands, in which water stagnated for at least one month and stands with no water stagnation. It was found that the mean damage to the carbon assimilating organs of stands with stagnating water was lowered by approximately 6% compared to stands that were not affected by flood. Thus, no definite effect of flood contributing to losses of carbon assimilating organs in oak trees could be shown.

Keywords: flood, defoliation, Wołów Forest Division, oak die-back, pest insects, oak stands

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1. Introduction

Water influences significantly on growth, development and existence of plants. Lack of water caused by, for example, long-term droughts or fluctuations in the level of groundwater, is often listed among causes of decay of oak forest stands (Oszako 2000, 2002; Bernadzki, Grynkiewicz 2006; Oszako 2007).

Drought, as one of the stress factors, weakens the trees which become more susceptible to activity of fungi pathogens and secondary invaders (Sierota 2001; Łakomy 2004; Dobrowolska 2010 za Drenkhan, Hanso 2004; Hill et al. 2005; Bendel et al. 2006; Jabłoński et al. 2013). Lack of water, through impact on physiological condition of trees, indirectly influences insects also. It weakens e.g. trees respi-ration what increases the content of sugars in leaves, what results in smaller mortality of phytophagous and greater fertility of females (Szujecki 1980).

Floods are also listed among factors negatively influencing trees. They are included in a group of so-called natural, abiotic disruptions, (Dobrowolska 2010). Despite the fact that they occur more rarely than periods of droughts, the negative influence of flood can turn out to be more dangerous and long-lasting. It depends mainly on the season of the year in which flood occurred and on the time of water stagnation.

Floods not only have impact on trees, but they influence on insects in different stages, also in the stage connected with soil environment. Floods can be a direct cause of increased mortality as a result of insect drowning, for example, in hibernating stage (Oprychałowa 1994). Soil that is too moist and wet soil sticks to insects' bodies making it difficult for them to breathe. This can lead to their death (Szujecki 1980). Flood also influences insects in indirect way. In moist soil, activated are factors disadvantageous for insects such as pathogenic fungi and nematodes (Oprychałowa 1994). At the same time, flood can influence trees and forest stands favourably or unfavourably by limiting harmful insect species that are in the soil at the time.

The aim of the study is to evaluate the influence of water stagnation on the degree of oaks assimilation apparatus damage done by insects. The study was realised on chosen areas of Wołów Forest Inspectorate that was twice affected by floods in years 1997 and 2010.

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2. Methodology

On the area of Wołów Forest Inspectorate (Regional Directorate of State Forests in Wrocław), chosen were 10 experimental areas localised in oak forest stands (Table 1). The selection of experimental areas depended on the time of water stagnation. Chosen were areas on which during flood in 1997, the water stagnated for around 3 months while in 2010, for around a month. On each area chosen and permanently marked were 25 trees (Db - oak) and initial evaluation of each of the trees was performed on the basis of detailed analysis of crown condition (including e.g. decaying branches, withering tops of shoots, canopy opening) and trunks condition (occurrence of 'wild sprouts', cracks, stains, fruit bodies of fungi, feeding grounds of insects, galls).

Trees on experimental areas were divided into three groups: average, weaker and stronger than average trees. From each group, randomly selected was one tree, from which were collected fragments of branches from the middle (well exposed to sunlight) parts of crowns (Fig. 1). Then, the percentage of leaves damaged by insects and distribution of the damage according to damage degree were defined: undamaged and damaged in following sections: up to 5%, 6–12 %, 13–25%, 26–50%, 51–75% and over 75%. Also, the type of damage was defined.

Within single sample, controlled were at least 200 leaves. Obtained results were used for evaluation of trees' assimilation apparatus damage degree. Townsend-Hauberger method was used for this purpose (Czerniakowski 2008):

$$S_u = \frac{\sum nh}{HN} x\,100$$

where:
S_u – degree of leaf damage, %,
n – number of leaves in particular damage degree,
h – degree of leaves damage from the smallest to the highest, %
H – the highest degree of infection scale,
N – total number of leaves examined in the sample.

On the basis of collected material (Fig. 1), performed was laboratory evaluation of the volume of the damage of assimilation apparatus of chosen trees. On the basis of this evaluation, defined was average degree of leaves damage. In order to conduct statistical analysis, percentage results were transformed with the use of Bliss formula (Snedecor, Cochran 1976).

3. Results

Signs of insects' feeding were found on majority of leaves. On each experimental area, the average percentage of damaged leaf blades oscillated between 90–100%. Only with one case (comp. 144k) was smaller and amounted 85% (Table 2).

In general, stated was similar percentage of damaged leaves in both groups of forest stands (post-floods and control ones). Conducted analysis (test t for independent groups) did not show any statistically significant differences at level of significance α = 0.05 (p = 0.484414). While comparing the share of damaged leaves in particular degrees, it can be

Table 1. Characteristics of experimental sites*

Compartment	Species composition	Forest site type	Area [ha]	Closure	Stocking	Quality class	Age	The effect of flood
321a	Db	Lł	11.08	moderate	0.8	II	71	stagnating water
331a	8Db 2Lp	Lł	20.58	moderate	1.1	II	81	stagnating water
249c	4Db 2Db 2Ol 1Brz	Lw	3.69	moderate	1.0	II I II II	85	outside flood area
50b	Db	Lł	7.6	broken	0.8	II	96	stagnating water
144k	9Db 1Lp	Lł	3.92	moderate	1	I	81	stagnating water
144f	Db	Lł	2.5	broken	0.8	III	126/86	stagnating water
334b	7Db 3Lp	Lł	2.9	moderate	0.9	II	101	stagnating water
41i	5Db 5Lp	Lśw	1.37	broken	1.1	II	91	outside flood area
143m	8Db 2Lp	Lł	1.68	moderate	0.9	I	86	stagnating water
19a	9Db 1Św	Lśw	5.32	moderate	0.8	II	101	outside flood area

Explantations: Brz – bearch, Db – oak, Lp – linden, Św – spruce; Lł – flood plain forest, Lśw – fresh hardwood forset, Lw – moist hardwood forest.
*źródło / source: Plan Urządzania Lasu Nadleśnictwa Wołów…, 2005

noticed that in the range of over 25% of leaf blade damage, there were more damaged leaves in the forest stands where water did not stagnate (Fig. 2).

Despite comparable average number of damaged leaves in post-flood forest stands and forest stands with no influence of flood, the average loss of assimilation apparatus ($S_{u(pow.)}$) defined on the base of Townsend-Hauberger method was smaller in forest stands in which the water stagnated (Fig. 3). For those areas, it amounted to around 56%, whereas in control forest stands - 62%.

Certain regularities occurred in terms of types of damages (Fig. 4). Leaves with no damage, same as the ones with holes in their blades, in both groups constituted less than 5%. Besides mining, which was higher in forest stands with stagnating water, remaining types of damages, on average, occurred more often in control forest stands. Still, even mining was characterised by relatively high variability within given group of forest stands.

4. Discussion

For a long time, oak forest stands from Wołów Forest Inspectorate have been considered as forest stands with high degree of damage (Szewczyk, Czeryba 2010). Research conducted in the 1990s showed average trees defoliation on the level of 45%. It was caused probably by the lowering of groundwater levels in this area (Dmyterko, Bruchwald 1998). In 1997, this area was affected by the flood. Water stagnated in some places for even 3 months, causing trees decay (joint publication 2001). Following research conducted in years 2001–2002 showed average defoliation on the level of 21.9%, whereas majority of trees were in defoliation class 10–25%, unlike in previous research, where majority of trees were in defoliation class 30–40%. It was stated that after flood, the vitality of crowns improved (Dobrowolska 2007). On the other hand, research conducted on chosen areas of Wołów Forest Inspectorate in years 2001–2003 sho-

Figure 1. Collection of experimental material from trees (Wołów Forest Division)

Table 2. The degree of assimilating organ damage in trees growing on experimental sites

Compartment	No. of tree	Degree of leaf damage in control trees $S_{u(1-3)}$ (%)	Damage volume (%)							Mean degree of leaf damage $S_{u(pow.)}$ (%)	Percentage of damaged leaves (%)	
			no damage	≤5	6–12	13–25	26–50	51–75	>75		control trees	mean
321a	*12*	58.18	0.16	6.49	19.16	21.59	42.05	10.23	0.32	61.61	100.00	99.84
	1	66.50									100.00	
	5	60.14									99.52	
331a	*7*	55.32	3.50	12.18	33.33	24.81	22.68	3.50	0.00	51.82	98.58	96.50
	1	46.11									92.27	
	13	54.04									99.06	
249c	*2*	72.11	1.29	5.83	18.61	19.09	39.32	14.24	1.62	62.70	100.00	98.71
	22	53.32									96.24	
	23	62.68									100.00	
50b	*2*	67.93	2.57	4.08	16.31	21.60	38.37	15.71	1.36	63.11	99.78	97.43
	5	59.29									95.72	
	17	62.21									96.79	
144k	*15*	45.76	10.49	20.26	30.75	19.11	15.09	4.17	0.14	46.19	92.39	89.51
	10	41.50									85.40	
	1	51.30									92.00	
144f	*23*	58.98	5.91	11.15	20.44	25.17	26.69	8.95	1.69	55.54	93.36	94.09
	6	51.39									90.29	
	1	56.25									100.00	
334b	*2*	58.05	1.64	5.06	18.90	26.19	40.33	7.29	0.60	60.49	98.31	98.36
	13	65.32									99.07	
	10	58.12									97.73	
41i	*24*	58.73	1.89	6.36	14.91	19.09	36.88	18.29	2.58	64.10	97.36	98.11
	14	73.18									98.78	
	20	60.40									98.22	
143m	*4*	67.23	4.90	14.97	23.64	18.60	27.69	8.95	1.26	55.44	98.97	95.10
	15	42.75									89.80	
	20	56.34									97.37	
19a	*1*	54.26	6.49	7.68	15.57	19.66	35.13	13.77	1.70	59.46	90.22	93.51
	12	63.36									95.20	
	24	60.77									94.86	

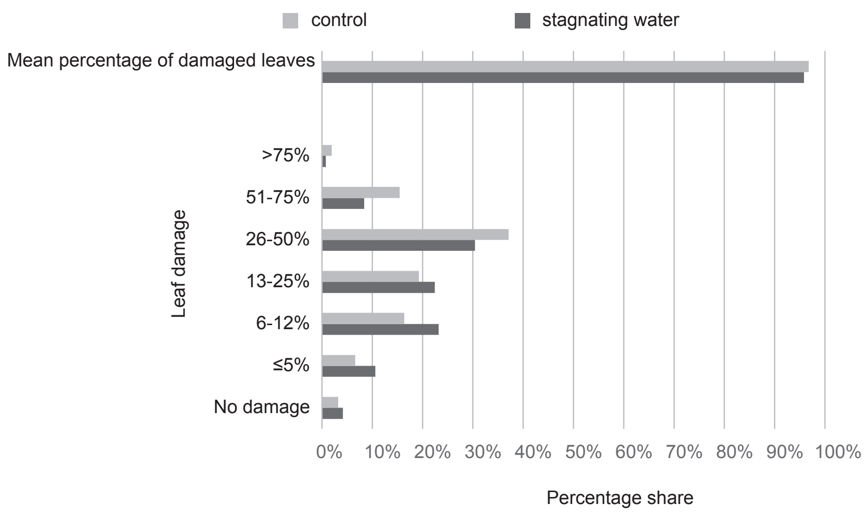

Figure 2. Percentage distribution of mean assimilating organ damage in trees

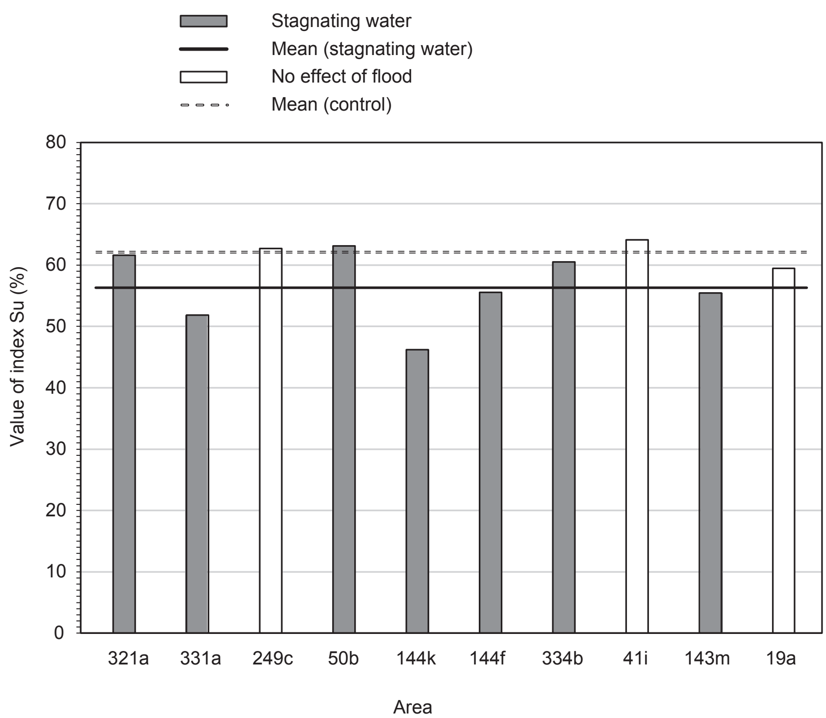

Figure 3. Average loss of assimilating organ area determined in laboratory analyses

wed average defoliation level of 46% and 56%; almost 97% of oaks analysed in those areas were included in two or three defoliation classes that correspond with damage of assimilation apparatus over 25% (Tarasiuk, Szczepkowski 2006).

Research conducted 2 years after flood in 2010 allowed for direct comparison of the degree of leaves damage in forest stands where water stagnated during the flood in 1997 and 2010 and forest stands where flood did not occur. Despite shorter period of water stagnation and 2 years having passed since the last flood in this area and the period in which the research was conducted, certain regularity can be observed. Moderately smaller leaf damage done by insects, defined by Townsend-Hauberger method, occurred in forest stands where the stagnation of water occurred. Higher leaf damage occurred in forest stands that were not affected by the flood. Thereby, smaller damage of assimilation apparatus appears in post-flood forest stands compared with control forest stands. That confirms results obtained by Dobrowolska (2007). This division can be explained, for example, by smaller number of folivores

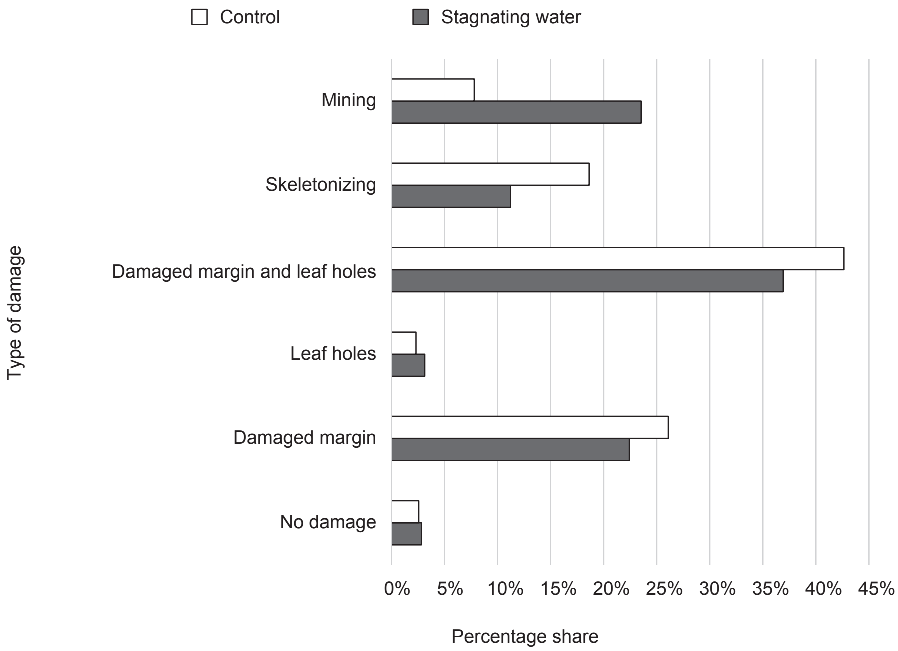

Figure 4. Percentage share of individual leaf damage types

which area of occurrence is slowly changed.. This refers to species where flightless females have limited possibilities of migration. Water stagnating for a long time, in case of flood from July 1997 that occurred in summer season, could have been the cause of high mortality among species that underwent transformation under forest litter at the time. Similar, though slightly smaller, influence of the flood may have occurred in year 2010 due to earlier time of flood appearance. Small number of repetitions in forest stands not affected by the flood and those in which water did not stagnate, does not allow for drawing clear and certain conclusions. Nevertheless, the outlined dependence encourages for such conjectures. Especially, since known is the negative influence of excessive moist soil on insects. It refers to species for which the soil is the environment for life or a place for diapause or hibernation. For example, in humus soil, which better retains moisture, the percentage of cockchafer infected by *Beauveria brongniartii* (Sacc.) is higher (Szujecki 1980). Colorado potato beetle, hibernating in excessively wet soil, can be characterised by lowered fertility or infertility (Oprychałowa 1994) and the flooding can efficiently exterminate some species feeding in soil (Oprychałowa 1994). It should be noticed, however, that 6% difference in loss of assimilation apparatus area between post-flood forest stands with stagnating water and control forest stands was stated in laboratory conditions. Evaluation of defoliation, conducted in terrain conditions, with the use of atlas developed by Borecki and Keczyński (1992), both by, for example, Forest Protection Instruction scale and by European Classification (Wyszykowski and Zajączkowski 1995) may not show such small differences. Therefore, it is probable that it will be impossible to show the influence of stagnating water on defoliation of controlled oak forest stands, 2 years after last flood in this area.

5. Conclusions

1. Post-flood forest stands and control forest stands are characterised by high and comparable share of damaged leaves of 96% and 97%, respectively.
2. In forest stands with stagnating water, stated was slightly bigger share of leaves with no damage and damaged in the range up to 25% of loss of leaf blade. Leaves damaged in degree over 25% of area occurred more often in control forest stands.
3. In forest stands in which water stagnated, average loss of assimilation apparatus area was smaller than in control forest stands.
4. Stated 6% difference in loss of assimilation apparatus area between post-flood forest stands with stagnating water and control forest stands may be a result of flood impact and stagnating water on stages diapausing under forest litter and in soil. However, this value can be difficult to state in case of conducting on-ground evaluation of forest stands' defoliation.

Conflict of interests

The authors declare lack of potential conflicts.

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Author's contribution

R.K. – concept of research methodology, field work and analysis of research samples, manuscript preparation, W.S. – field work and analysis of research samples, manuscript preparation, I.K. – analysis of research samples and research data formulation; P.Ł. – field work and research data formulation.

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