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# RADIAL GROWTH OF COMMON OAK AND DEFOLIATION OF TREETOPS IN POST-FLOOD AREAS*

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**Abstract.** The study was conducted on 13 areas in the Wołów Forest District in oak stands with the common oak as the dominant species. The stands in the Wołów Forest District located in the Odra valley, including the oak stands, were flooded in 1997 and 2010. The aim of this study was to analyse the influence of defoliation on radial growth of oaks in the post-flood stands. Recorded results showed an inferior growth in thickness and greater defoliation in the common oak in the post-flood stands. The average defoliation at 40% has a significant influence on radial growth. It seems advisable to include the capacity of radial growth in the assessment of the condition of trees.

**Key words:** radial growth, defoliation, common oak, flooding

## INTRODUCTION

The common oak (*Quercus robur* L.) is found almost everywhere in Europe and it is one of the most important forest species. The area contribution of the oak in forests of Poland is 7.0%, while the volume contribution is 6.1% (CSO, 2011). From time to time the phenomenon of dieback of oak stands is observed (Przybył 1995; Oszako and Delatour, 2000; Sierota, 2001; Szczepkowski and Tarasiuk, 2006; Szewczyk and Czeryba, 2010). Scientists have arrived at a conclusion that this phenomenon is a result of a long-term process, resulting in a decrease in the viability of oaks caused by the action of

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stressors (Mańka, 2005). The overexposure of treetops to stressful factors and situations, initiating disease processes of trees, leads to reversible or irreversible changes (Sierota, 1995). Defoliation leads to adverse changes in the biochemical and physiological processes and in consequence – to disorders in transformation of organic compounds (at the cell level), disorders in the circulation of organic compounds (at the tissue level), and disorders of tree growth (at the level of the organism). The state of the treetop is connected with the increase in thickness (Lemke, 1966; Lemke, 1968; Jaworski et al., 1988; Jaworski et al., 1995; Bruchwald and Dmyterko, 1999; Bruchwald and Dmyterko, 2007). The stands of the Wołów Forest District located in the Odra valley in 1997 and 2010 were flooded, which also included the oak stands that cover 18% of the forest area of the Forest District.

The aim of this study was to analyse the influence of defoliation on radial growth of oaks in the post-flood stands.

## MATERIAL AND METHODS

The study was conducted on 13 areas in oak stands in the Wołów Forest District (51.329°N, 16.629°E) in the Odra valley. The growing season lasts there 226 days, the average annual temperature is +8.2°C and the average rainfall is 612 mm. The dominant species in the selected tree stands is the common oak (*Q. rubra*). Seven areas, which during the flood of 1997 remained under the water for a long time (*P*), and 2 areas, which were flooded for several weeks (*Z*), were selected for the study. In 2010 the next flood, lasting for about a month, again covered the discussed tree stands with water. Four control areas (*K*), situated at a distance of about 12 km from the Odra river bed north of the flooded area were selected for comparison. In each of the selected plots 3 trees were selected at random from the main stand, which were subject to observations of defoliation and bore core collection.

In 2011-2013, in August, the loss of the assimilation apparatus in each of the selected trees was evaluated always by the same observer with the use of the Borecki and Keczyński atlas (1992), from two directions according to the directions of the world. In order to analyse radial growth the analytical material was collected from boreholes made by the Pressler increment borer, one for each tree, at the height of 1.30 m from the ground level. In order to obtain a clear picture of annual rings the bore cores were pasted on wooden slats, their surface polished with sandpaper and then scanned. With the help of the CooRecorder program (www.cybis.se) the width of the annual growth was measured and the accuracy of the measurements was verified in the CDendro program (www.cybis.se).

The compatible incremental sequences were used to develop the actual chronology. The period from 1993 to 2013 was analysed. Based on the recorded results the correlation was analysed between defoliation of a particular tree in a particular year and its radial annual ring growth. In order to present the incremental reaction of the trees the average annual ring growths of trees in the selected areas from before the flood of 1997 were analysed. To evaluate the prevailing weather conditions in the study area in 2011–

2013 the data from the meteorological stations of the Wołów Forest District were used. The fluctuations of precipitation and the temperature range are shown in the Table 1. On the basis of the data on temperature and precipitation the Sielianinow hydrothermal coefficient $K = 10P / \Sigma t$ was calculated for growing seasons in 2011–2013.

Table 1. Average monthly temperatures and precipitation in the Wołów Forest District in 2011–2013
Tabela 1. Średnie temperatury miesięczne oraz sumy opadów w poszczególnych miesiącach na terenie Nadleśnictwa Wołów w latach 2011–2013

| Months<br>Miesiące | Average monthly temperatures, °C<br>Średnie miesięczne temperatury, °C | | | Monthly precipitation, mm<br>Suma miesięcznych opadów, mm | | |
|---|---|---|---|---|---|---|
| | years – lata | | | years – lata | | |
| | 2011 | 2012 | 2013 | 2011 | 2012 | 2013 |
| January<br>Styczeń | 0.68 | 1.42 | –0.68 | 0 | 51 | 18 |
| February<br>Luty | –1.26 | 3.69 | 0.36 | 11 | 27 | 46 |
| March<br>Marzec | 7.38 | 6.84 | –0.53 | 3 | 12 | 72 |
| April<br>Kwiecień | 12.38 | 10.70 | 9.46 | 18 | 38 | 65 |
| May<br>Maj | 15.21 | 16.30 | 14.69 | 58 | 28 | 161 |
| June<br>Czerwiec | 19.86 | 17.78 | 17.92 | 34 | 111 | 247 |
| July<br>Lipiec | 18.76 | 20.72 | 20.90 | 45 | 126 | 56 |
| August<br>Sierpień | 19.85 | 20.06 | 19.17 | 71 | 55 | 116 |
| September<br>Wrzesień | 16.14 | 15.26 | 13.20 | 39 | 35 | 132 |
| October<br>Październik | 9.56 | 8.88 | 10.85 | 10 | 24 | 23 |
| November<br>Listopad | 3.95 | 5.67 | 5.04 | 0 | 32 | 47 |
| December<br>Grudzień | 4.19 | –0.44 | 3.07 | 15 | 31 | 32 |

## RESULTS

Based on observations of treetops in the selected oaks the average defoliation of the analysed trees in the post-flood area in 2011 was found to be 28%, in the next year defoliation rate grew to 37%, to reach 48% loss of the assimilation apparatus in 2013. In the control tree stands the selected trees were characterised by a lower loss of the assimilation apparatus, in 2011 defoliation was 22% and in the following years it remained at 26%. The average radial growth in the post-flood stands was as follows: in 2011 – 1.03 mm; 2012 – 1.33 mm and in 2013 – 1.29 mm, respectively. The control tree stands in this period were characterised by a greater radial growth: in 2011 – 1.59 mm; 2012 – 2.13 mm and 2013 – 1.97 mm. The analysis of the correlation showed that in 2011 (Fig. 2) there was no significant relationship between growth and the defoliation rate ($r$ = –0.3). In the following years 2012 and 2013 a significant inversely proportional relationship was shown, as the defoliation rate decreased with an increase of the growth ($r$ = –0.52 and $r$ = –0.49, respectively).

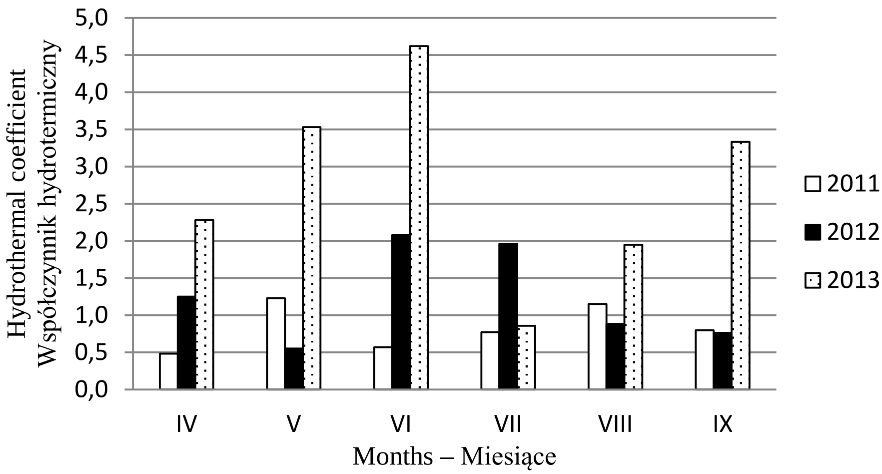


Fig. 1. Hydrothermal coefficient during the growing season in of 2011–2013 in the Wołów Forest District

Rys. 1. Wartości współczynnika hydrotermicznego w sezonie wegetacyjnym w latach 2011–2013 na terenie Nadleśnictwa Wołów

In the analysed period of 20 years it was observed that since the flood of 1997 the annual tree growth in the post-flood area was lower in comparison to the control tree stands, but the incremental reaction of trees in both areas largely overlapped (Fig. 5). The average annual growth in the post-flood tree stands was 1.26 and it was by 25% lower than that in the control stands. The longest period with the negative growth reaction was observed in the years of 2003–2005. Values of the hydrothermal coefficient $K$, describing the relation between air temperature and precipitation in the growing season show that in the analysed area in 2011 unfavourable conditions for plant growth prevailed

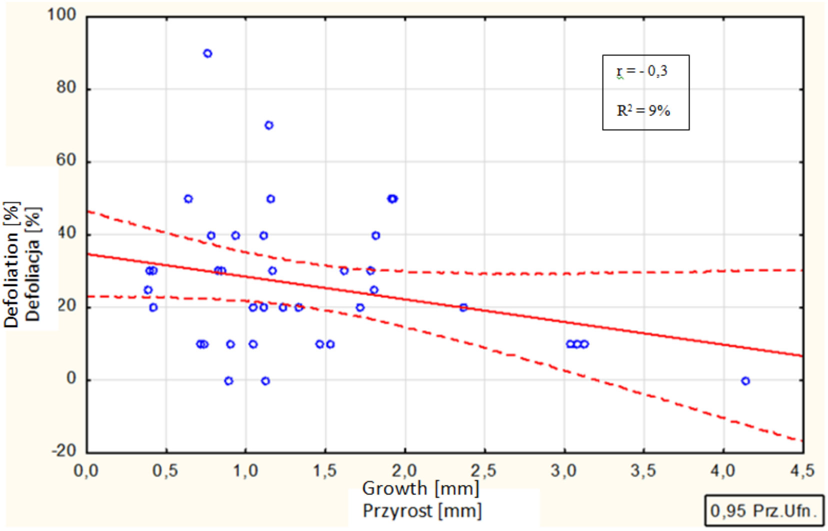


Fig. 2. Correlations between growth and the defoliation rate in 2011
Rys. 2. Korelacje pomiędzy przyrostami a wskaźnikiem defoliacji w 2011 roku

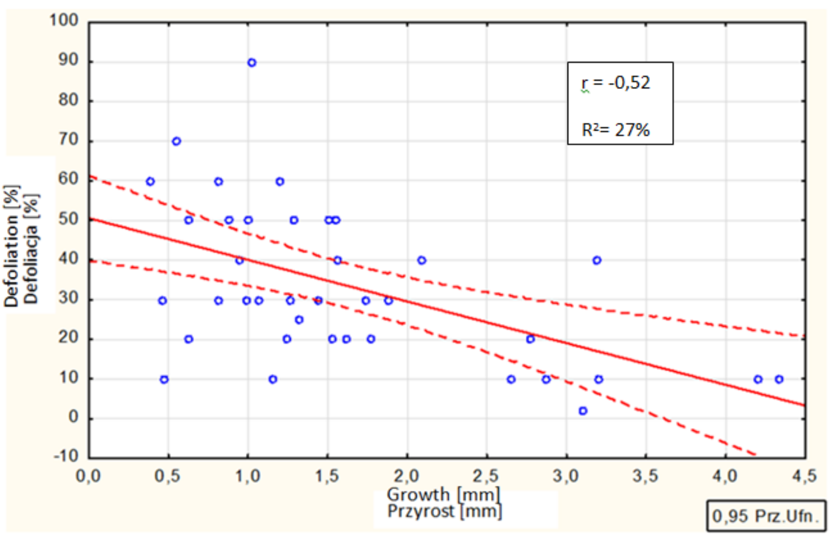


Fig. 3. Correlations between growth and the defoliation rate in 2012
Rys. 3. Korelacje pomiędzy przyrostami a wskaźnikiem defoliacji w 2012 roku

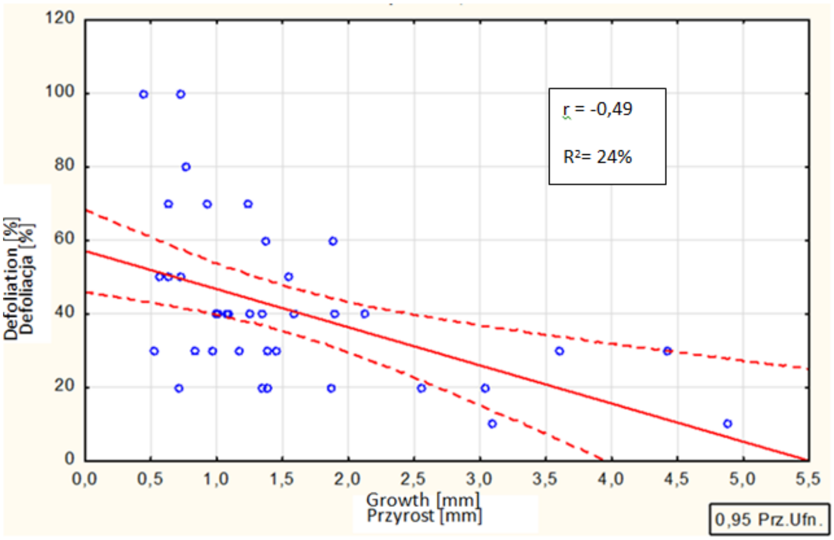


Fig. 4. Correlations between growth and the defoliation rate in 2013
Rys. 4. Korelacje pomiędzy przyrostami a wskaźnikiem defoliacji w 2013 roku

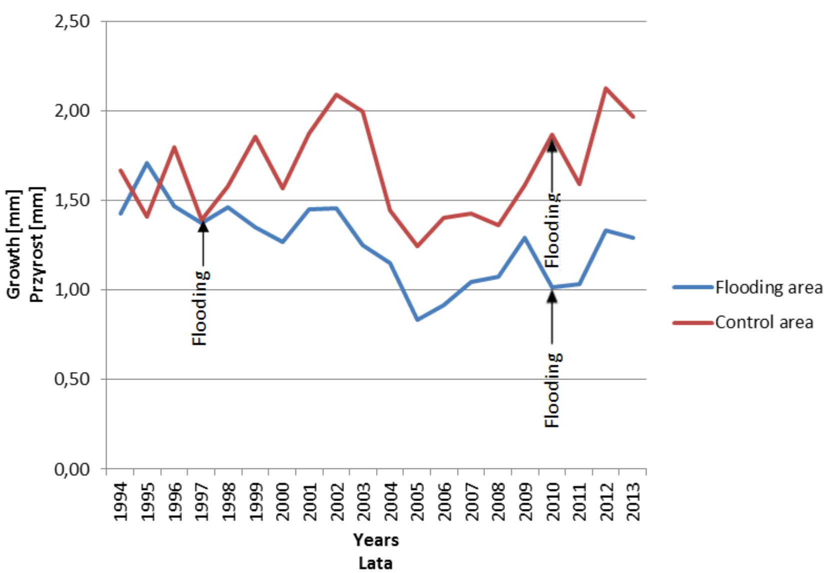


Fig. 5. The average radial growth of oaks in the post-flood and control tree stands
Rys. 5. Średnie przyrosty radialne dębów w drzewostanach popowodziowych i kontrolnych

due to drought, while in the next growing season the conditions were optimal (Fig. 1). In 2103 from April till June very wet conditions prevailed, whereas in July the vegetation conditions deteriorated due to insufficient rainfall and the prevailing high temperature (Table 1, Fig. 1).

## DISCUSSION

In a study by Kędziora and Tomusiak (2012) the average radial growth of the common oak from the Mazury Landscape Park ranged from 1.35 to 1.91 mm, which in their opinion indicates good growing condition of the species. In the analysed post-flood stands located directly in the floodplain terrace of the Odra the annual radial growth was 1.26 and it was lower than that of the control tree stands, which shows the effect of the flood on growth rates in oak trees. Witek et al. (2014) in their study on the dendrohydrological analysis of the reduction in the floodplain terrace showed the effect of the flood on a decrease in growth of the analysed oaks. On the other hand, the average width of annual rings in common oaks at the plot located in the floodplain of the Warta river valley was 1.95 (Okoński and Koprowski, 2012).

A study conducted by Cieśla (2008) showed that in river terraces the dominant growth factor, at a relatively stable course of the other analysed climate characteristics, is the river stage and the related ground water table in the analysed tree stands. The water relations in the abovementioned area were distorted in 1903 when a flood embankment was built (Kołodziejczyk, 2005), which resulted in the periodical deprivation of meadow flooding. A significant role in the analysed area has also been played by a barrage built in 1958 in Brzeg Dolny. Cieśla (2008), while analysing the incremental reaction of oaks showed a significant effect of lowering the ground water table due to the construction of this barrage. A certain role has also been played by the periods of drought in the area in 2002–2005. It may be assumed that the periods of e.g. two-year-long droughts have influenced physiological processes in oaks for about six years (Siwecki 1994). Probably it was the drought that caused the negative incremental reaction in 2002–2008, which was observed in the oaks in both the post-flood and control areas. It is the weather anomalies and/or droughts during the growing season, which are an important factor that initiates diseases of oak stands in Central Europe (Sierota, 2001; Thomas et al., 2002).

According to the latest dendroclimatological studies, an important role in modifying growth of oaks is played by the supply of moisture, especially during the summer months (Bednarz, 1994; Ufnalski, 2001; Cedro, 2004; Ważny, 2006). According to the data of the meteorological station in Tarchalice (Table 1), total precipitation in the summer months (June, July) in this area was: 2011 – 79 mm, 2012 – 237 mm and 2013 – 303 mm, respectively. This data shows that the availability of moisture, especially in the last two years, was good. However, radial growth decreased in comparison with the previous year, thus it may be presumed that despite the availability of water, other factors contributed to this state of things. Perhaps it was related to a lower average temperature in 2013 or a rapid change in vegetation conditions due to the drought prevailing in July of that year.

In a study by Kędziora and Tomusiak (2012), the precipitation total in the vegetation period was found to have no effect on radial growth of the analysed trees. A study by Dmyterko and Bruchwald (1998) showed that average defoliation in the tree stands in Wołów in the 1990's was 45%, ranging from 0 to 95%. According to Dobrowolska (2007), after the flood the foliage condition in the oak stands improved: in 2001–2002 the average defoliation was 21.9% and most of the treetops were classified to class 2 (10–25%). The first symptoms of oak stands dieback in that area were observed in 2004 (Szewczyk and Czeryba, 2010). It may be presumed that after the flood of 2010 the foliage of oaks improved, which could be explained by the lower defoliation in 2011 when compared to the research results of 2005–2007 (Szewczyk and Czeryba, 2010). According to Bruchwald and Dmyterko (1999), the evaluation of the degree of treetop damage does not provide the basis to conclude about the occurrence of a particular incremental reaction. However, the conducted analysis of the correlation showed that in 2012 and 2013 there was a significant relationship between defoliation and radial growth. This study did not include treetop dimensions, which have a significant effect on DBH growth (Bijak, 2013) and trees density in stands.

Fungi have a considerable effect on the health condition of trees. Roots of oak trees, apart from mycorrhizal fungi (Dickie et al., 2001), may be colonised by endophytic fungi (Halmschlager and Kowalski, 2003; Halmschlager and Kowalski, 2004). Because mycorrhizal fungi are definitely aerobic, mycorrhizae are rare in flooded soils (Theodorou, 1978; Lodge, 1986). A flooding event decreases the amount of fungi around the roots of trees and inhibits the formation of new mycorrhizal populations (Wilde, 1954; Mikola, 1973; Filer, 1975). Soil flooding may lead to the development of root rot, increasing the activity of fungi and the susceptibility of the host. The investigations conducted in the oak stands of the Wołów Forest District showed that the roots of common oaks may be colonised by 126 fungal taxa, mostly endophytes.

It was shown that there is an moderate positive correlation between the occurrence of *Pezicula radicicola* in the roots of *Q. rubra* with an average defoliation of the treetops and a low negative correlation between the frequency of occurrence the *Trichoderma* species in the roots and the average defoliation of the trees. The structure of the population of endophytic fungi suggests that they probably contribute to the deterioration of the health condition of oaks as well as their dieback. Some fungi were found at higher frequencies or they colonised solely the oaks subjected to flooding. The fungal communities from the flooded areas were more abundant and more diverse (Kwaśna et al., 2015a). The analyses in the same tree stands conducted in 2012 showed an occasional occurrence of *Globisporangium attrantheridium*, *G. intermedium*, *Phytophthora gibbosa*, *P. plurivora* and *Pythium* spp. in the roots of small single trees and in the soil of the post-flood area and outside the flooded area. The occurrence of Oomycota only marginally contributed to the deterioration of the health condition of trees (Kwaśna et al., 2015b).

## SUMMARY

Based on the recorded results it may be stated that the common oak in the post-flood stands exhibits a deterioration of growth in thickness and a greater defoliation. The average defoliation at 40% has a significant effect on the radial growth. It seems that to evaluate the condition of trees, their ability of radial growth should be taken into account.


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## PRZYROST RADIALNY DĘBU SZYPUŁKOWEGO A DEFOLIACJA KORON DRZEW NA TERENIE POPOWODZIOWYM

**Streszczenie.** Badania przeprowadzono na 13 powierzchniach w drzewostanach dębowych z dębem szypułkowym jako gatunkiem panującym na terenie Nadleśnictwa Wołów. Drzewostany Nadleśnictwa Wołów położone w dolinie Odry w 1997 oraz 2010 roku zostały zalane przez powódź, która objęła również drzewostany dębowe. Celem pracy było zbadanie wpływu defoliacji na przyrost radialny dębów w drzewostanach popowodziowych. Na podstawie uzyskanych wyników można stwierdzić, że dąb szypułkowy w drzewostanach popowodziowych gorzej przyrasta na grubość, jest też bardziej podatny na defoliację. Średnia defoliacja na poziomie 40% ma istotny wpływ na przyrost radialny. Wydaje się, że do oceny kondycji drzew należy brać pod uwagę zdolność przyrostu radialnego.

**Słowa kluczowe:** przyrost radialny, defoliacja, dąb szypułkowy, powódź

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