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The state of crowns of black alder (*Alnus glutinosa* (L.) Gaertn.) in Kampinos National Park (Central Poland) in years 2015–2016 – preliminary studies

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Abstract

During 2015 and 2016, in the Kampinos National Park (KNP), monitoring was conducted for the population of black alder (*Alnus glutinosa* (L.) Gaertn.), which occupies 12.5% of the tree stands in the park and, after the Scots pine (*Pinus sylvestris* L.), is the second most important species there. The aim of the observation was to obtain data about the current condition of alder in the National Park. Monitoring was carried out on eight plots designated throughout the park. Stands where alder was not the dominant species were omitted. On each plot, 20 trees were evaluated with a total of 160 plants assessed. The age of the tree stands analysed was 55–120 years. Monitoring was conducted by assessing the tree's crowns, based on the methodology of forest monitoring implemented by the National Environmental Monitoring. Based on the analyses, it was found that the average defoliation of alder in 2015 reached 28.1%, and 34.4% in 2016, with the differences being statistically significant. Among 70% of the specimens, there was no discoloration of the assimilation apparatus. There were significant differences in defoliation between research plots located inside the park and near its borders, which can be associated with the influence of anthropogenic factors. Based on the monitoring, it was found that the state of alder crowns in KNP is a warning or average, depending on the year of observation. Therefore, it is necessary to continue monitoring the state of alder crowns in KNP. On the basis of the study results, it was also found that the biosocial structure of the researched tree stands is formed correctly. The dendrometric measurements conducted show that the average diameter of the trees analysed, at breast height was 30.5 cm with an average height of 25.5 m. To analyse the changes in height and breast height, dendrometric measurements must be repeated in 2020. Monitoring will be continued in the following years to observe the changes.

Key words

defoliation, monitoring of the forest, tree vitality

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Introduction

Kampinos National Park (KNP) was established in 1959 to protect the unique complex of inland dunes and its rich diversity of flora and fauna (Lubański 2009). The park covers an area of 38.544 ha, out of which 28.255 ha is occupied by tree stands (73.3%). The dominant species in the tree stands are the Scots pine (*Pinus sylvestris* L.) with a share of 69%, black alder (*Alnus glutinosa* (L.) Gaertn.) with 12.5%, oaks (*Quercus* sp.) 10.3%, and birch (*Betula* sp.) 6.4% (Szczygielski 2002). A significant share of black alder resulted from the formation of stands on the wetland surfaces located in the depressions of inland dunes. In the past, these areas were difficult to access, and harvesting of raw resources was only possible in winter. Environmental difficulties and lack of interest in the alder as a raw material enabled the development of natural forest stands (Heymanowski 1966; Zielony 2004).

Despite its turbulent history and the 'turmoil' of war (Chudzyński 2005; Zwoliński 2005), as well as effects of human expansion, the area of KNP remains a unique and natural area, located in the vicinity of the state capital (Król and Skolimowska-Król 2004).

To expand the knowledge of the changes taking place in KNP tree stands, it is needful to conduct monitoring of the wildlife with regards to the health status of the dominant species, that is, the Scots pine and black alder among others. The monitoring of the health of forests in KNP is carried out by the Base Station of Integrated Environmental Monitoring (BSIEM) 'Kampinos'. Three areas are being analysed: two in a pine stand and one in an alder stand (Olszewski and Wierzbicki 2015). Additionally, within the framework implemented by the Forest Research Institute (FRI) for monitoring permanent observation areas of the 1st degree (SPO I), there are four existing areas – three with Scots pine and one with birch (Małachowska 2015). In total, monitoring is carried out on five plots of pine. The monitoring conducted does not warrant a clear statement about what is the health condition of the dominant species in KNP. To better identify the health condition during the course of changes in the tree stands of Kampinos Forest in 2015, independent monitoring was carried out on 26 plots of Scots pine and eight plots of black alder (Tyburski and Przybylski 2016). Forest monitoring provides important information on the state of forest environment (Jaszczak 2008) and the results presented extend the limited data on health and specific characteristics of trees in the area of KNP (Dmyterko and Bruchwald 2006; Lech 1995; Sierota 1995; Tyburski 2016; Tyburski and Przybylski 2016). The study presents the results of monitoring performed for black alder during 2015 and 2016.

The main objective of this study was to assess the state of crowns of black alder located in KNP, during the years 2015–2016. Additionally, a comparison was drawn between the areas located near the borders of KNP and those further away from them. This combination allowed the authors to address the issue of overall condition of this species in the National Park area.

Material and methods

The health assessment was made by adapting the methodology of monitoring forests performed by the State Environmental Monitoring (SEM). The assessment of trees was performed within Permanent Observation Areas (SPO I) spread across the country (www.gios.gov.pl 2015).

The assessment of tree health in KNP was applied using the following criteria: defoliation, discoloration of foliage, biosocial position, visibility and shading of crown, foliage density, the size of leaves, the type of thinning of the crowns and share of dead branches.

Defoliation was assessed based on the images of the 'Atlas ubytku aparatu asymilacyjnego drzew leśnych' (*Atlas of the loss of assimilation apparatus in forest trees*) (Borecki and Keczyński 1992), which is specified with an accuracy of 5%. Due to the lack of methodological studies for black alder, the assessment was carried out based on methodologies developed for oak.

The results of defoliation and discoloration estimations are grouped into the following classes:

class 0 – from 0 to 10% – no defoliation
class 1 – from 11 to 25% – slight defoliation (warning level)
class 2 – from 26 to 60% – average defoliation
class 3 – over 60% to 99% – strong defoliation
class 4 – 100% dead trees.

The following types of crown thinning were distinguished: none (in case of defoliation below 10%), peripheral, outward-spreading from the centre, bottom-up, top-down, under treetop, regular, gapped and foliage in clumps (Wawrzoniak and Zajączkowski 2014).

The assessment of discoloration of the assimilation apparatus was made based on Table 1.

Table 1. Classes of assimilation apparatus discoloration

Class	Degree of discoloration	Assimilation apparatus discoloration (%)
0	None	0–10
1	Slight	11–25
2	Medium	26–60
3	Strong	Over 60%
4	Dead tree	Dead tree

Several classes of tree stand damage were distinguished; assuming that the damage class is a combination of defoliation and discoloration, classes according to the scheme shown in Table 2.

Table 2. Classes of tree damage (Wawrzoniak and Zajączkowski 2014)

Defoliation classes	Discoloration class				
	0	1	2	3	4
	damage class				
0	0	0	1	2	
1	1	1	2	2	
2	2	2	3	3	
3	3	3	3	3	
4					4

Where: 0 – class without damage; 1 – warning class; 2 – minor or average damage; 3 – major damage; 4 – dead trees.

The evaluation of biosocial position according to Kraft's classes (Jaworski 2013):
1 – predominant trees
2 – dominant trees
3 – co-dominant trees
4 – suppressed trees
5 – overtopped trees

The assessment of crown visibility was made based on the following divisions: full visibility of the crown, partial visibility, larger part of the crown visible, smaller part of the crown visible, visible outline of the crown and crown invisible.

Assessment of crown shading:
– crown significantly shaded (or in physical contact) on one side,
– crown significantly shaded (or in physical contact) on both sides,
– crown significantly shaded (or in physical contact) on three sides,
– crown significantly shaded (or in physical contact) on four sides,
– crown with an open space development without evidence of shading effects.

For an assessment of the participation of dead branches, the following divisions were made: no dead branches, single dead branches (10%), from 11% to 50% dead branches and more than 50% of dead branches.

The following causes of tree damage were distinguished: undamaged trees, annosum root rot, other infectious diseases, pests, wind, fire, snow (branch breakage), flooding, direct human intervention and multiple causative factors which were unidentified.

Monitoring was carried out on 8 research plots (Fig. 1). On each plot, 20 trees were subject to evaluation, with a total of 160 specimens of black alder assessed. The average age of the stands analysed in 2016 was 90 years. The youngest stand was 55 years and the oldest 120 years. Two of the analysed populations were older than 100 years (information by Kampinos National Park). Monitoring was conducted during 2015 and 2016. On each designated plot, the first tree served as a central tree, around which the neighbouring specimens were determined circularly. Monitoring is planned for the following years and in case of death of a tree, the neighbouring living tree will be selected.

Field work was carried out during the months of June–July 2015 and in 2016, which took into consideration the optimal time for foliage growth. In 2015 the following dendrometric measurements were performed:
– diameter measurement at breast height (with accuracy to 1 mm) using a diameter tape,
– measurement of the tree height (with an accuracy to 0.5 m), using a Suunto altimeter.

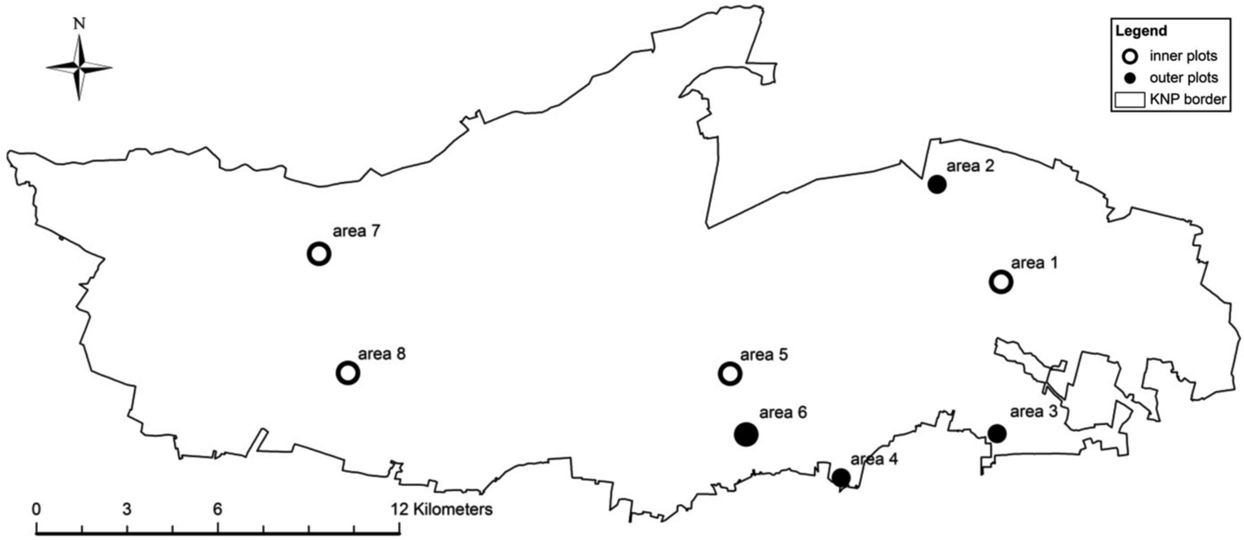

Figure 1. Distribution of the research plots related to the evaluation of health condition of black alder in Kampinos National Park

Statistical analysis

The data collected were imported to a Statistica 8.0 program, which performed statistical analysis. The aim was to describe the main characteristics of the statistical level of defoliation and determine the significance of differences in defoliation between the years examined, depending on the plot's internal or external location (inner and outer). Comparative analyses were performed using the t-student test with a significance level of α 0.05.

Research area

The plots selected for research were located throughout KNP (Fig. 1). They were distributed optimally in a way that allowed for comparison of the plots located on the outskirts of the park, where the influence of anthropogenic factors can affect the tree stands to the plots located inside the park, where the potential impact is limited. The irregular distribution of plots resulted from the mosaic of dune areas and wetlands. The monitoring included the wetlands, where alder is the dominant species. Dune areas have been omitted because alder does not occur in these stands or is an additional species in terrain depressions.

Results

From the assessment of 160 trees in 2015, 73.8% of the specimens were characterized by slight defoliation or the absence of foliage (Tab. 3). In 2016, this value decreased to 44.4% (Tab. 4). The average defoliation of alder in the observation period was 31.3%. Statistical analysis demonstrated a significant (P = 0.0002) increase of the level of defoliation in the years studied. Defoliation was 28.1% in 2015 and 34.4% in 2016 (Fig. 2). On the plot monitored within BSIEM 'Kampinos', the average defoliation was 37.4% (2015 – 33.8%, 2016 – 41.0%) (Olszewski and Wierzbicki 2015; Olszewski et al. 2016). The plots analysed were divided into inner and outer ones (see Chap. Material and methods), and the statistical analyses performed demonstrated the significant differences between them. The analysis showed the average defoliation on plots defined as inner was equal to 28.7% and the outer plots were 33.8% (Fig. 3). This difference is significant at P = 0.003. The differences observed between the plot groups remained stable during these years. In 2015, the difference in the level of defoliation between the outer and inner plots was equal to 5.6%; however, in 2016, it was 4.6%. For both types of plots, there was a significant increase in the level of defoliation during these years (Fig. 4 and 5).

Table 3. The number of black alder classified as to their assessed parameter of health in Kampinos National Park in 2015

Estimated degree of defoliation – number of trees	The type of crown thinning – number of trees	The degree of discoloration – number of trees	The damage class – number of trees	Kraft's class - number of trees	Crown visibility – number of trees	Crown shading – number of trees	The share of dead branches – number of trees
(0–10%) – 30 (18.8%) (11–25%) – 88 (55.0%) (26–60%) – 39 (24.4%) (61–99%) – 3 (1.9%)	none – 1 (0.6%) outward-spreading from the centre – 2 (1.3%) bottom-up – 8 (5.0%) top – 1 (0.6%) regular – 77 (48.1%) gap number – 59 (36.9%) foliage in clumps – 12 (7.5%)	none – 160 (100%)	without damage – 30 (18,8%) warning – 88 (55,0%) minor or average damage – 39 (24,4%) major damage – 3 (1,9%)	predominant – 24 (15.0%) dominant – 104 (65.0%) co-dominant – 22 (13.8%) suppressed – 10 (6.3%)	full – 34 (21.3%) partial – 31 (19.4%) larger part visible – 74 (46.3%) smaller part visible – 21 (13.1%)	from 1 side – 9 (5.6%) from 2 sides – 40 (25.0%) from 3 sides – 71 (44.4%) from 4 sides – 40 (25.0%)	none – 69 (43.1%) up to 10% – 79 (49.4%) (11–50%) – 10 (6.3%) >50% – 2 (1.3%)

Table 4. The number of black alder classified as to their evaluated parameter of health in Kampinos National Park in 2016

Estimated degree of defoliation – number of trees	The type of crown thinning – number of trees	The degree of discoloration – number of trees	The damage class – number of trees	Kraft's class – number of trees	Crown visibility – number of trees	Crown shading – number of trees	The share of dead branches – number of trees
(0–10%) – 1 (0.6%) (11–25%) – 71 (44.4%) (26–60%) – 81 (50.6%) (61–99%) – 7 (4.4%)	none – 0 outward from the centre – 0 bottom-up – 7 (4.4%) top – 2 (1.3%) regular – 64 (40.0%) gaps – 81 (50.6%) foliage in clumps – 6 (3.8%)	none – 160 (100%)	without damage – 1 (0.6%) warning – 71 (44.4%) minor and average damage – 81 (50.6%) major damage – 7 (4.4%)	predominant – 30 (18.8%) dominant – 101 (63.1%) co-dominant – 23 (14.4%) suppressed – 6 (3.8%)	full – 6 (3.8%) partial – 29 (18.1%) large part visible – 117 (73.1%) smaller part visible – 8 (5.0%)	from 1 side – 3 (1.9%) from 2 sides – 41 (25.6%) from 3 sides – 82 (51.3%) from 4 sides – 34 (21,3%)	none – 35 (21,9%) up to 10% – 98 (61,3%) (11–50%) – 26 (16,3%) >50% – 1 (0,6%)

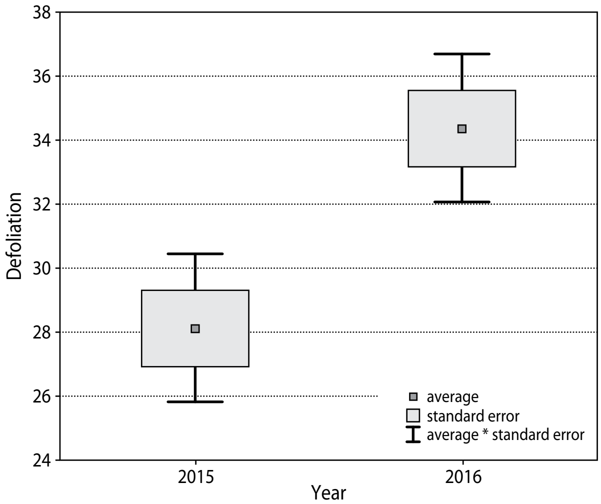

Figure 2. Average defoliation of alder in KNP in 2015 and 2016

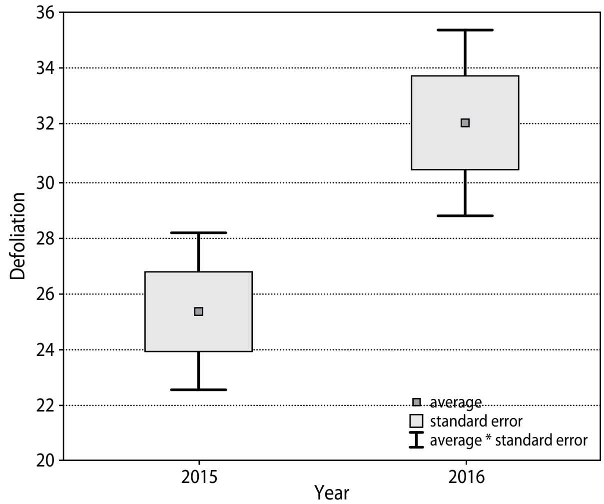

Figure 4. Defoliation in the inner plots in 2015 and 2016

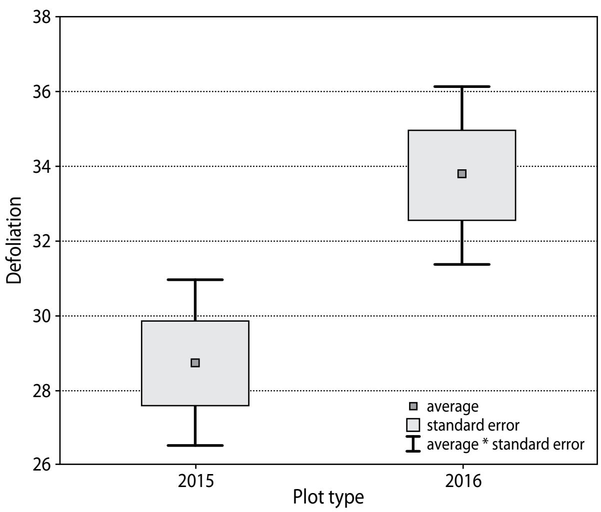

Figure 3. Defoliation of inner (1) and outer (2) areas

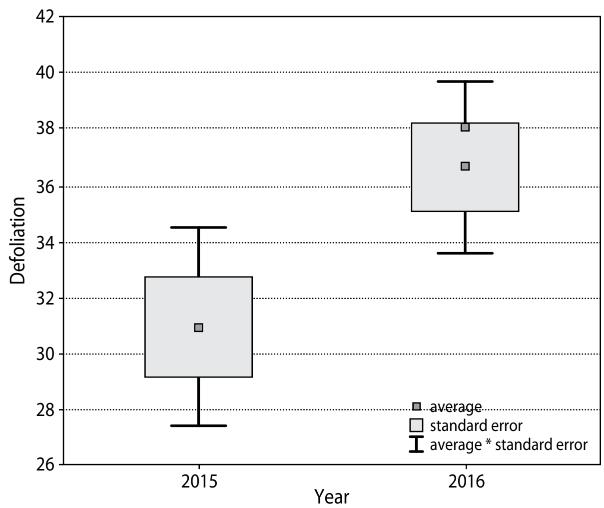

Figure 5. Defoliation in outer plots in the years 2015 and 2016

Despite the increase in defoliation observed in the areas studied, there was no discoloration of foliage or morphological changes in leaf structure that could indicate a lack of trace elements contained in the soil or the permanent weakening of the specimens observed.

In 2016, it was found that 50.6% of trees had gaps in the crown, and 40% of the trees showed regular thinning (Tab. 3 and 4). Compared to 2015, the number of gaps increased by 13.7% and crown thinning decreased by 16.3%. According to the methodology used, 44.4% of trees were classified in the warning damage class, which is closely related to the assessment of defoliation. In comparison to the previous year, this share decreased by 46.6%. The share of trees classified in the light to medium damage range increased from 26.2% to 50.6%.

The biosocial locations of trees have not undergone any significant changes – 65.0% of trees were classified as dominant ones in 2015, and 63.1% in 2016 (Tab. 3 and 4). This biosocial structure is the evidence of a well-developed stem of the stand (Szymański 2001). Of the 160 trees assessed in 2015, 3 of them died, one had been broken and two were classified as standing deadwood. In 2016, according to the same methodology, other adjacent trees were selected in order to assess each plot with a comparable number of trees.

The assessment of trees was made as to the different conditions of crown visibility, which was 61.3% in 2015; while in 2016, 73.1% of trees had a larger part of the crown visible (Tab. 3 and 4).

Since alder has a compact crown formed at the upper part of the tree, in 2015, no dead branches were observed in 43.1% of the trees, and during 2016, in 21.9% of the trees. In 2015 and 2016, in 49.4% and 61.4% of the trees respectively, the presence of dead branches did not exceed 10%. In trees, in which an increased number of dead branches was recorded, the value was in the range close to 17%. Two trees in 2015, and one in 2016 were characterized by 50% dead branches.

Discussion

The stands assessed were characterized by a single-storey structure with loose or dense undergrowth. The lack of a secondary stand and natural regeneration occurring in those stands results from the ecology of species. Vegetative renewal from rootstocks usually occurs in the case of tree damage. This manner of renewal is usually possible in production tree stands. Generative reproduction is connected with access to light on the forest floor. To survive the first year, a seedling requires 5% of full daylight, and in later stages of development this amount rises to almost 20% of full daylight needed. Oftentimes, a continuous canopy covering the alder stands inhibits the fulfilment of sunlight requirements for generative reproduction (Pancer-Kotejowa and Zarzycki 1980).

As a hardwood species, alder is characterized by strong competitiveness in securing access to the most optimal light conditions. For this reason, alder frequently come into direct contact with the crowns of neighbouring trees – 25.6% in 2015 and 51.3% in 2016. Trees contacting tree crowns of other trees from 3 sides were 25.0% in 2015, and in 2016, 21.3% of the trees came into contact with neighbouring tree crowns from 4 sides (Tab. 3 and 4).

During the period analysed, statistical analysis confirmed increased defoliation. Among other reasons, defoliation changes resulted from the small amount of rainfall in 2015 (388.1 mm) and in 2016 (629.8 mm.), while the 20-year average amounted to 567.2 mm (unpublished KNP data). Additionally, the period of spring of 2016 was also characterized by reduced rainfall. In March–May 2015, the rainfall sum was 109.3 mm, and in March–May 2016, it was 103.8 mm. It is believed that during the development of leaves, the trees did not have access to a sufficient reserve of subsurface water, which contributed to a slight limitation during the process of their formation. Considering the age of the trees surveyed and corresponding health assessment, it was recognised that the black alder in KNP has a good health status. However, further observations of the specified areas should be conducted in subsequent years to evaluate any changes. In the event of surface and subsurface water levels rising to their average value, the health condition of stands of alder in the areas studied should not deteriorate. In the event of a chronic water shortage, the alder may be weakened and more easily subjected to pathogenic infection and damage caused by wind (Jaworski 2011). Monitoring made for black alder in plots within KNP only show changes taking place in a short (one-year) period of monitoring. The results obtained in subsequent years of monitoring may show both improvement (Beker 2014) and weakening of the health condition of trees.

Changes in the health quality of alder result from excessive dryness or humidity of soil. The alder is sensitive to excessive aridity (Pancer-Kotejowa and Zarzycki 1980) or flooding, which can lead to root damage and weakened specimens. In recent years, summer droughts and warm snowless winters have been an important factor in the weakening of the tree's health condition (Sierota 1998). Intensive changes in the formation of stands having a dominance of black alder in KNP, can be seen in open areas and in small depressions not covered with trees. With favourable moisture conditions, that is, a continuation of suitable surface and subsurface water levels, a new generation of black alder that have grown for several years in stable conditions of soil humidity, should develop. As a result of an increase in the surface water level and stagnation of water for several months, along with subsequent drying of the surface, an entire young generation died. It is probable that under favourable moisture conditions, the cycle of alder overgrowing wetlands will be repeated, but the stability of the development of new trees is difficult to predict.

Throughout the sample period, no damage was found in 70% of the trees assessed, which could be caused by biotic and abiotic factors. In single specimens, the following were reported (among others):

– the development of a one-sided crown, which resulted from neighbouring specimens competing for light,
– damage to the crown as a result of strong wind,
– development of rotting wood (one individual) in a stand over 100 years.

On alder, as well as on other deciduous trees, it may come to infections and diseases caused by pathogenic fungi (Sierota and Szczepkowski 2014) or by insects (Stocki et al. 2008). However, alder may be considered as a species more resistant to harmful action of these groups. For instance, it was established that insects feeding on alder do not independently cause withering of tree stands, but may cause physiological weakening of trees (Borowski et al. 2012).

Statistical analysis showed significant differences between the outer and inner plots. Based on the analysis and available knowledge, it is not possible to determine what the causes of these differences are. The outer plots are more exposed to air pollution. From measurements made in the Base Station BSIEM 'Kampinos', it follows that in KNP in recent years, an increase in the concentration of sulphur dioxide (SO_2) in the air has been recorded, whose value in 2015 amounted to 8.3, and for precipitation, there has been an increase of potassium content recorded (Olszewski et al. 2016). Due to the localised range of measurements, it is not possible to carry out a detailed analysis of health monitoring for the entire area. Most likely, a slight increase in concentrations of sulphur and potassium should not cause changes in defoliation of the black alder. It is of importance that black alder is resistant to many impurities, and these properties led to it being recommended for introduction on, industrial brown fields among others (Pancer-Kotejowa and Zarzycki 1980; Jaworski 2011). It is believed that the stands located inside KNP have more stable water conditions which, in the event of rainfall shortage, could undergo greater disturbance in the case of the outer plots.

The monitoring carried out on the research areas demonstrates good health of the black alder observed during the study period. However, in the future it is expected that the health quality on the first level of trees will gradually decrease, which will result from the ecology of the species and the likelihood that collapse of the first level will initiate natural regeneration.

In KNP, the most important changes for the alder stands and for the long-term cyclical modifications are those resulting from differences in the groundwater and subsurface water levels. Although alder is a species associated with areas of high humidity, it is sensitive to excessive dehydration (Pancer-Kotejowa and Zarzycki 1980) or flooding, which can lead to root damage and weakening of individual specimens that can appear through producing shorter main sprouts (Dmyterko 2003 a, b).

Undoubtedly, black alder has its own place in the functioning of the Kampinos Forest areas. Due to the environmental sensitivity of the sites occupied, it cannot be clearly predicted what changes will occur in the alder stands of KNP. Conducting monitoring and field observations in subsequent years will allow for a better understanding of the changes that occur.

Conclusions

Monitoring of black alder health condition in KNP during the years 2015–2016 shows that:

– there is a significant difference between defoliation on the plots which are classified as inner and those which are outer; based on the conducted research, the factor determining observed differences between surface groups cannot be clearly stated,
– increased defoliation in 2016, as compared to 2015, most likely resulted from a limited amount of rainfall in 2015 and early 2016,
– the biosocial structure of alder on the plots analysed is consistent with the ecology of the species,
– considering the results obtained and the age of trees, it can be concluded that the black alder crowns in KNP were in a warning condition in 2015 and in average condition in 2016,
– because of the observed damage of assimilation apparatus of black alder, a continuation of monitoring in Kampinos National Park is recommended.

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