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HEALTH CONDITION AND STRUCTURE OF PINE STANDS ON PERMANENT EXPERIMENTAL PLOTS IN THE KWIDZYN FOREST DIVISION

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Abstract. The study presents the health condition and structure of pine stands growing on permanent experimental plots in the Kwidzyn Forest Division, the Ryjewo working circle, the Lisewo Forest District. Forest mensuration analyses were performed in a 127-year old pine stand (compartment 214), in five plots of 0.26 ha each. The health condition of the stand was determined on the basis of the losses of the assimilatory organs, i.e. defoliation. Mean defoliation of tree crowns was 20.3% (below the warning level), which corresponds to the damage rate of 1.14. A vast majority, i.e. 67% of the 176 analysed trees, represented damage rate 1 (Table 2). Taking into consideration the age of the stand (127 years) and its provenance (it was planted on former farmland) the health condition may be considered good. The structure of social classes of tree position in the stand shows an appropriate share of the upper storey (81.2-95.1%) and the second storey (4.9-18.8%). When analysing the basic characteristics of the stand structure it was found that the biggest variation was observed in crown length (from 17% to 30%), while the smallest – in height (from 6% to 9%). The mean relative crown length in the stands ranged from 0.21 to 0.24. Tree slenderness, defining resistance of trees to damage caused by wind and snow took mean values below 1.0 (from 0.71 to 0.83). This shows good stability of the analysed stands. Those stands are characterized by high yields of 465-614 m^3 large timber per 1 ha and stocking of 1.0 to 1.3. As a result of the analyses of the interdependencies between the basic mensuration characteristics the most significant relationship was found for diameter at breast height and slenderness (from –0.718 to –0.913), height and absolute crown length (0.619-0.715) and diameter at breast height and height (0.161-0.708; Table 4). The trends in the annual increment in diameter at breast height showed the biggest decreases in the years 1977-1983, 1969-1974, 1962-1967, 1956-1960 and 1949-1952 (Fig. 6). Those periods coincide with gradations of nun moths and adverse weather conditions.

Key words: pine stands (*Pinus sylvestris* L.), health condition, structure, breast height diameter increment

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INTRODUCTION

The study presents results of mensuration analyses and biological monitoring of pine stands growing on permanent experimental plots in the Kwidzyn Forest Division, the Ryjewo working circle, the Lisewo Forest District [Wudarczyk 2005]. The history of the plots dates back to 1877, when an employee of the Association of Prussian Forest Experimental Stations, Adam Schwappach (* 2 November 1851 Bamberg, † 9 February 1932 Eberswalde) [Assmann 1968, Beker and Ceitel 2001] established five plots of 0.26 ha each on former farmland. His aim was to collect data needed to evaluate the effect of thinning on the productivity and structure of stands and as a consequence to develop stand yield and volume increment tables. The first plots of this type were established in 1865 and such studies were continued by Schwappach and his successor Wiedemann. On the basis of German concepts permanent experimental plots were established on a wide scale in Central Europe. As early as the 1950s the network included over 1000 permanent experimental plots and thousands of other temporal experimental plots. During WWII some of them were partially or completely destroyed [Beker 2000]. In the 1950s, thanks to the cooperation of the Forestry Research Institute with the Institute of Forestry Sciences in Eberswalde, studies on permanent experimental plots were resumed. A total of 68 plots in the area of 22.1287 ha were classified for further operation [Pirogowicz 1983]. Thanks to the continuation of this line of research, changes occurring in those stands may be observed and factors affecting their structure may be determined. Periodical surveys make it possible to analyse the dynamics of growth and development and due to the long biological production cycle it is necessary to extend studies over the period of at least several decades. It needs to be stressed that there are plots of a similar character to those investigated within this study, also located in north-eastern Poland, in the area of the Würm glaciation, in Ruciane [Buchwald and Zasada 1995] and Krutynia [Pirogowicz 1983].

The present study is a continuation of the investigations conducted for many years on permanent experimental plots and aiming at the determination of health condition and structure of stands.

MATERIAL AND METHODS

The object of the study was a 127-year old pine stand (compartment 214), growing on five plots of 0.26 ha each. The stand was established on former farmland. Individual taxation traits of the experimental plots in compartment 214, according to the forest management plan of 30 December 1996 are as follows: the area of each plot – 0.26 ha, forest site type – fresh mixed forest [LMśw], silvicultural type of crop – pine-oak [So-Db], forest functions – protection forest (experimental plot), soil cover type – green soil cover, lowland undulating area, brown podzolic soil, loose sands, medium deep on loamy sands. Characteristics of the experimental plots in 2004 are given in Table 1. A detailed description of the experimental plots may be found in a study by Pirogowicz [1983].

In the course of field studies the following characteristics of all trees were investigated: the social class of tree position in the stand using the Kraft classification [Assmann 1968], diameter at breast height ($d_{1,3}$) accurate to 1 cm (measured inside bark

Table 1. Characteristics of experimental plots (2004)
Tabela 1. Charakterystyka powierzchni badawczych (2004)

Plot Po-wierz-chnia	Division Oddział	Area Po-wierzch-nia ha	Art Gatunek	Age Wiek	Number of trees ha/plot Liczba drzew ha/pow.	D_g cm	G/ha G/plot powierzchnia próbna m^2	H_l m	Bon.	Large timber Grubizna m^3 ha	plot powierzchnia próbna	WZ*
I	214 / l	0.26	So	127	323/84	40	42.5/11.0	33	I a	601	156	1.2
II	214 / k	0.26	So	127	239/62	42	33.5/8.7	32	I	465	121	1.0
III	214 / i	0.26	So	127	235/61	44	36.8/9.6	31	I	496	129	1.1
IV	214 / j	0.26	So	127	327/85	40	42.5/11.0	32	I	586	152	1.3
V	214 / h	0.26	So	127	254/66	47	43.6/11.4	33	I a	614	160	1.2

*Stocking index.
*Wskaźnik zadrzewienia.

in two directions E – W and N – S, the mean of two measurements was considered the actual value), height (h) accurate to 0.1 m, crown position height (h_k) accurate to 0.1 m (the measurement point was the first live branch continuously connected with the crown). Height parameters were measured using a VERTEX – FORESTOR ultrasound hypsometer (HAGLÖF). Pith bore cores were collected using an accretion borer (the analysis was conducted on 10 trees, representing Kraft's classes I or II, from each plot, bore holes were drilled from the northern side). With a colour atlas [Borecki and Keczyński 1992] defoliation rates were estimated for crowns of trees from Kraft's classes I and II. Observations were performed in July, due to the complete physiological development of assimilatory organs of Scots pine. The estimate was based on two basic criteria [Beker 1994]:

1) the share of needles from individual years
2) type of crown opening.

The plots were characterized in terms of their plant sociology types.

Indoor work included the processing of data collected during field work using mathematical and statistical methods [Bruchwald 1999]. Characteristics for the stands and for Kraft's classes were defined for the following traits: diameter at breast height, height, crown length, relative crown length and slenderness. For the above mentioned traits the following statistical parameters were determined: the mean, standard deviation, the coefficient of variation and the coefficient of skewness. For diameter at breast height, height and crown length their normal distribution was established using the W Shapiro-Wilk test and the significance of differences between means was analysed. For the stand the following parameters were established: the number of trees, breast height basal area, volume and stocking index. The current annual breast height diameter increment accurate to 0.01 mm was determined for ten pith borings from each plot using a DPM 001 electronic increment meter according to K. Johann. Trees were classified to the following damage rate classes: 0 – no damage (crown defoliation from 0 to 10%), 1 – slight damage (loss from 11 to 25%), 2a – moderate (defoliation between 26 and 40%), 2b – medium (defoliation between 41 and 60%), 3 – strong (defoliation rate over

60%), 4 – complete (defoliation rate 100%). In this study STATISTICA ver. 6.1. software was applied for all statistical analyses.

RESULTS

A vast majority, i.e. 67% out of the 176 analysed trees, represented damage rate 1, only in plot V strong damage was recorded. Mean defoliation rate was 20.3% (below the warning level of 25%), which corresponded to damage rate of 1.14 (Table 2).

The structure of social classes of tree position in the stands was analysed in the plots. The shares of trees in terms of Kraft's classes in individual plots are given in Table 3. The highest frequency of trees was found for class III, except for plot I, where the biggest number of trees was classified to class II. The smallest shares were recorded for classes IVa and IVb. Predominant trees represent from 6.4 to 10.6% all trees. The dominant stand accounts for 81.2% to 95.1% trees.

Table 2. The percentage share of trees in damage degrees
Tabela 2. Procentowy udział drzew w stopniach uszkodzeń

Degree of damage Stopień uszkodzenia	Plot – Powierzchnia					
	I	II	III	IV	V	total razem
0	17.0	17.8	–	5.7	3.1	9.7
1	66.0	53.6	85.7	74.3	56.3	67.0
2a	15.1	28.6	14.3	17.1	37.5	21.6
2b	–	–	–	2.9	3.1	1.1
3	1.9	–	–	–	–	0.6

Table 3. The percentage of share trees in Kraft's classes
Tabela 3. Procentowy udział drzew w klasach Krafta

Kraft's classe Klasa Krafta	Plot – Powierzchnia				
	I	II	III	IV	V
I	9.5	6.4	6.6	10.6	7.6
II	53.6	38.7	39.3	30.6	40.9
III	28.6	45.2	49.2	40.0	45.3
I + II + III	**91.7**	**90.3**	**95.1**	**81.2**	**94.0**
IVa	8.3	9.7	4.9	14.1	4.5
IVb	–	–	–	4.7	1.5
Va	–	–	–	–	–
IVa + IVb + Va	**8.3**	**9.7**	**4.9**	**18.8**	**6.0**

The first mensuration parameter characterizing stand structure is diameter at breast height and in individual plots it ranged from 26 to 66 cm. The range in terms of diameter sub-classes was from 22 to 34 cm, with the mean of 40.2-46.3 cm, while diameter at breast height of the central stem was 44-48 cm. Standard deviation, as a measure of distribution dispersion, defines the rate of clustering of the variable around the arithmetic mean, was from 5.2 to 7.0 cm, which corresponds to variation within the range of 12.3 to 17.4%. The coefficient of skewness was also determined, being a measure of skewness of distribution. In 4 out of 5 plots positive skewness was observed (0.06--0.66), while in 1 it was negative: –0.16. The normal distribution of diameter at breast height was assessed using the W Shapiro-Wilk test. Only in 2 out of 5 plots the distribution was found to be normal (Fig. 1-5). In 4 out of 5 cases the significance of differences was recorded between mean values of diameter at breast height. The analysis of diameter in Kraft's classes confirmed a decrease of mean values of diameter at breast height with a reduction of social position of trees in the stand.

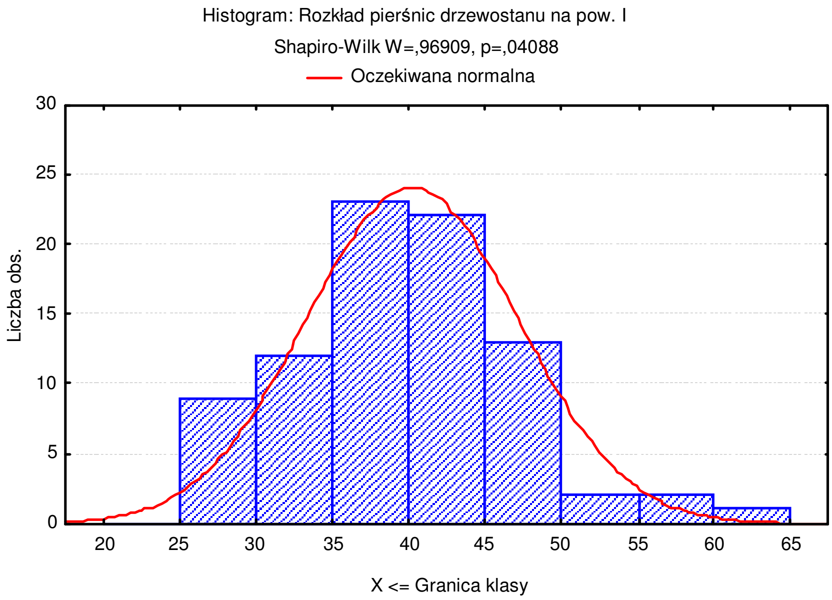

Fig. 1. Histogram of distribution of breast height diameter (plot I)
Rys. 1. Histogram rozkładu pierśnicy (powierzchnia I)

Another investigated characteristic was height, which in individual plots ranged from 22.6 to 40.5 m. The mean was 31.2-33.4 m, standard deviation ranged from 2.01 to 3.02 m, which corresponds to the coefficient of variation of 6.0-9.4%. The coefficient of skewness was determined, which – in contrast to the previously analysed diameter at breast height – in 4 out of 5 plots exhibited negative skewness (–0.86; –0.07), while in 1 plot – positive skewness of 0.29. The normal distribution for height was tested using the W Shapiro-Wilk test, for which in 4 out of 5 plots consistency with normal distribution was confirmed. In 3 out of 5 cases differences between mean heights were significant. Based on the analysis of height in Kraft's classes it was found that mean heights of

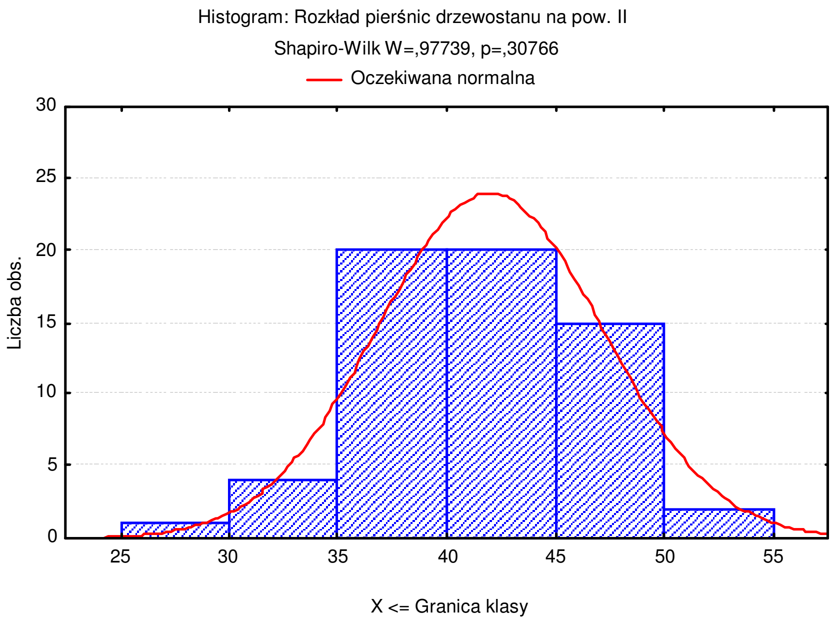

Fig. 2. Histogram of distribution of breast height diameter (plot II)
Rys. 2. Histogram rozkładu pierśnicy (powierzchnia II)

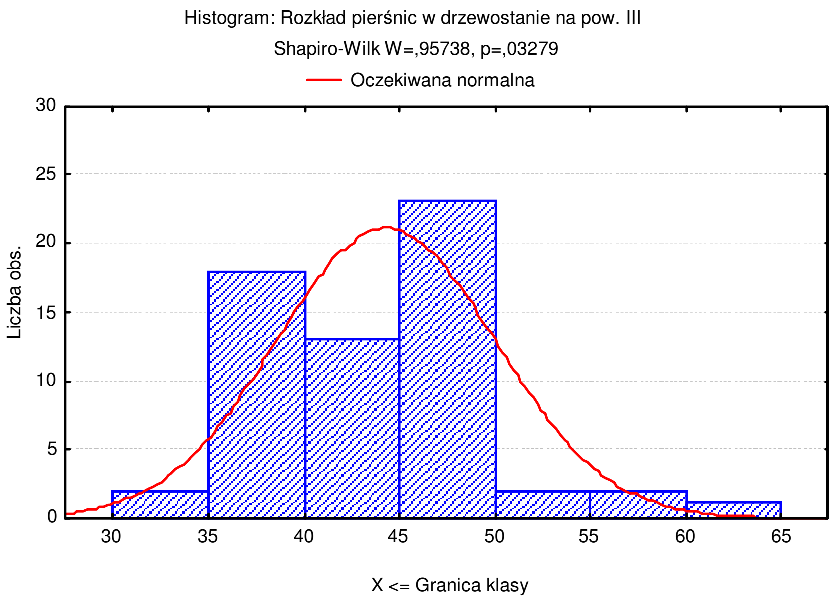

Fig. 3. Histogram of distribution of breast height diameter (plot III)
Rys. 3. Histogram rozkładu pierśnicy (powierzchnia III)

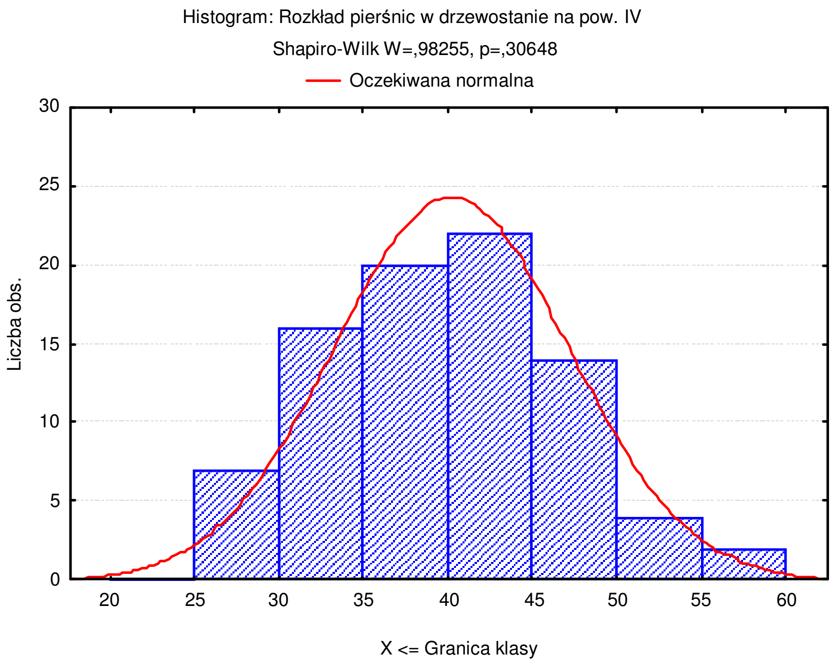

Fig. 4. Histogram of distribution of breast height diameter (plot IV)
Rys. 4. Histogram rozkładu pierśnicy (powierzchnia IV)

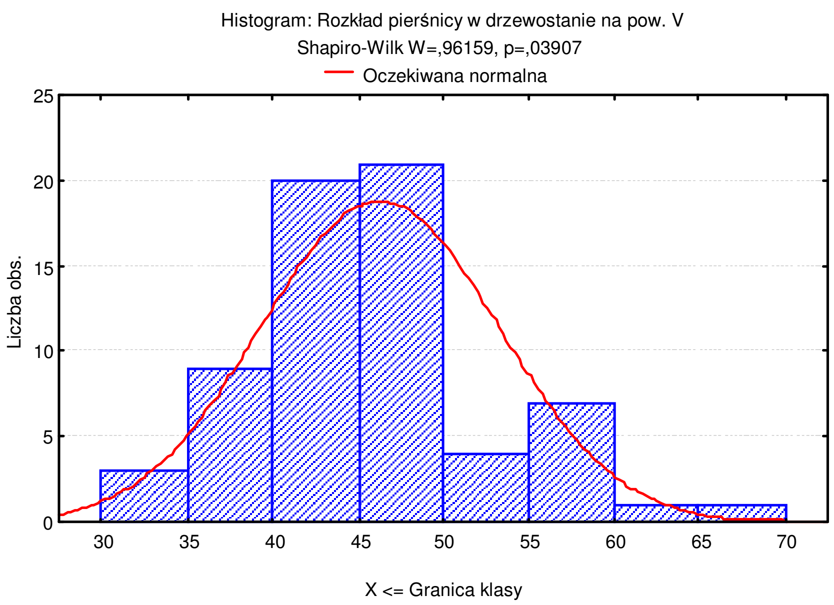

Fig. 5. Histogram of distribution of breast height diameter (plot V)
Rys. 5. Histogram rozkładu pierśnicy (powierzchnia V)

Table 4. Correlation coefficients of dendrometrics features
Tabela 4. Współczynniki korelacji cech dendrometrycznych

Plot Powierzchnia	$d_{1.3} - h$	$h - l_k$	$d_{1.3} - s$	$h - s$
I	0.54**	0.671**	–0.823**	0.079
II	0.443**	0.624**	–0.718**	0.431**
III	0.161	0.715**	–0.815**	0.421**
IV	0.708**	0.619**	–0.843**	–0.185
V	0.603**	0.637**	–0.913**	–0.238*

*Significant for α = 0.05.
**Significant for α = 0.01.
In Zieliński and Zieliński [1987].
*Istotny dla α = 0,05.
**Istotny dla α = 0,01.
W Zieliński i Zieliński [1987].

the stand are closest to the mean height for social class 3 and – similarly as in the trait analysed above – these values decreased with a reduction of the social class of tree position in the stand.

Absolute crown length, calculated from the difference of tree height and the point where the crown commences, ranged from 2.6 to 14.8 m. At the established mean value of 6.56-7.86 m and standard deviation of 1.46-2.35 m. This trait exhibited high variation, falling within the range of 17.9 to 30.1%. In 4 out of 5 plots positive skewness was recorded (0.28-0.89), while in 1 case it was minimal negative skewness (–0.03). In 2 out

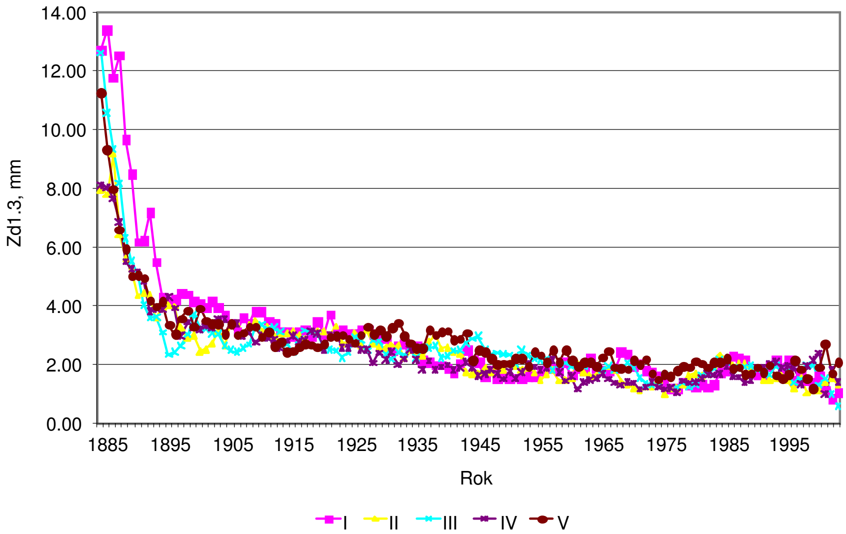

Fig. 6. Increment of breast height diameter
Rys. 6. Przyrost pierśnicy

of 5 plots the W Shapiro-Wilk test of the distribution of the absolute crown length confirmed it was consistent with the normal distribution. Only in 2 out of 5 cases differences between means for absolute crown length were found to be significant. A downward trend was observed for the absolute crown length with a deterioration of the social class of tree position in the stand.

Relative crown length was calculated by dividing the absolute crown length (h_k) by tree height (h). The range of values and the means for this trait in individual plots were as follows:

I: from 0.10 to 0.40 – mean 0.23,
II: from 0.12 to 0.32 – mean 0.24,
III: from 0.17 to 0.36 – mean 0.23,
IV: from 0.11 to 0.35 – mean 0.21,
V: from 0.17 to 0.31 – mean 0.23.

The variation of this trait (from 14.7 to 25.3%) was lower than that of the absolute crown length, which results from the relationship of this trait with tree height, exhibiting much smaller variability.

Slenderness (s), as a trait of the shape of a tree, was established from the ratio of height (h) to diameter at breast height ($d_{1,3}$). It is a measure of the resistance of a tree to damage caused by wind or snow. The critical value was adopted to be 1.00, over which value of the trait a given tree is characterized by poor stability. The percentages of trees in the analysed plots with slenderness values were below 1.00 ranged from 92.6% to 100%. The mean for this index was from 0.71 to 0.83.

All analysed stands exhibited higher yield levels (from 464.6 to 614.1 $m^3 \cdot ha^{-1}$) than model values from yield tables by Szymkiewicz [1966], which was confirmed by the stocking rate of 1.0-1.3.

Interdependencies of basic mensuration characteristics were investigated in the analysed stands (Table 4). The most significant relationship was found for diameter at breast height and slenderness (–0.71 to –0.913), height and absolute crown length (0.619-0.715) and diameter at breast height and height (0.161-0.708).

Among increment parameters, current diameter breast height increment was an object of analysis in the conducted investigations. Changes in this trait in calendar years for individual stands are presented in Figure 6. When analysing the graphs it may be observed that after the peak current diameter breast height increment, for the period of approx. 15 years the increment decreased rapidly, followed by a gradual decrease, with locally found slight deviations from the downward trend.

DISCUSSION

As a result of investigations it was found that stands in all experimental plots exhibited good health condition. The biggest numbers, i.e. 2/3 all trees, represented damage rate 1 and mean defoliation of 20.3% classified a given stand to the slight damage class. The structure of the social class of tree position in the stand exhibited an appropriate share of the dominant stand (81.2-95.1%) and second storey (4.9-18.8%). This is consistent with studies by Borowski [1974] and Beker [2003], in stands of older age classes, the upper storey amounts to over 90%, while the second storey 10% all trees. In turn, the higher share (in four out of five plots) of trees from Kraft's class III in relation to class II was not typical. Mean values of analysed traits, i.e. diameter at breast height, height and crown length, decreased with a deterioration of the social class of tree position in the stand. An opposite trend was observed for slenderness, which is a confirmation of earlier studies by Rymer-Dudzińska [1992]. Slenderness is an important index, as a measure of tree resistance to damage caused by wind and snow, to ensure appropriate stand tending. The mean value from this trait ranging from 0.71 to 0.83 confirmed good stand stability. The biggest values of slenderness were recorded for plots with higher numbers of trees. As a result of stronger growth competition trees were characterized by lower tapering and a higher artificial form ratio $q_2 = d_{h/2}/d_{1,3}$. Additionally, the mean in those cases was influenced by a higher share of pines from the second storey. When analysing current annual diameter breast height increment, local fluctuations were observed in increments, caused by different factors. A distinct and biggest effect was found in this respect for the gradation of the nun moth (*Lymantria monacha* L.). Drops in values of diameter breast height increment were recorded in the years 1977--1983, 1969-1974, 1962-1967, 1956-1960 and 1949-1952. Those periods coincided with periods of gradation given by Śliwa (1989). The observed decrease in the late 1980s might have been connected with the effect of weather conditions (long-term drought), which was confirmed by observations reported by Zielski and Krąpiec [2004] and by the levels of industrial emissions [Beker 1996]. It also needs to be stressed that the volume of diameter breast height increment was connected with defoliation of pine crowns [Beker 2001].

CONCLUSIONS

1. Mean defoliation in tree crowns was 20.3% (below the warning level of 25%), which corresponds to damage rate of 1.14. A vast majority, i.e. 67% out of the 176 analysed trees, represented damage rate 1. In view of the age of the stand (127 years) and its provenance (it was established on former farmland) the health condition may be considered to be good.

2. The structure of the social class of tree position in the stand exhibits an appropriate share of the upper storey (81.2-95.1%) and the second storey (4.9-18.8%).

3. Mean values of the analysed traits: diameter at breast height, height and crown length decreased with a deterioration of the social class of tree position in the stand, while an opposite trend was observed for slenderness.

4. Slenderness, defining resistance of a tree to damage caused by wind and snow, took mean values below 1.0 (from 0.71 to 0.83). This shows good stability of the analysed stands.

5. Analysed stands exhibited high yields ranging from 465 m^3 to 614 m^3 large timber per 1 ha and stocking rate between 1.0 and 1.3.

6. The fluctuations in the current diameter breast height increment showed the highest drops in the years 1977-1983, 1969-1974, 1962-1967, 1956-1960 and 1949-1952. Those periods coincided with gradations of the nun moth and adverse weather conditions.

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STAN ZDROWOTNY I STRUKTURA DRZEWOSTANÓW SOSNOWYCH NA STAŁYCH POWIERZCHNIACH DOŚWIADCZALNYCH W NADLEŚNICTWIE KWIDZYN

Streszczenie. Praca przedstawia stan zdrowotny i strukturę drzewostanów sosnowych na stałych powierzchniach doświadczalnych w Nadleśnictwie Kwidzyn, obręb Ryjewo, leśnictwo Lisewo. Wykonano badania dendrometryczne w 127-letnim drzewostanie sosnowym (oddział 214), na pięciu działkach o powierzchni 0,26 ha każda. Stan zdrowotny drzewostanu został określony na podstawie ubytku aparatu asymilacyjnego. Średnia defoliacja koron drzew wyniosła 20,3% (poniżej wielkości ostrzegawczej), co odpowiada stopniowi uszkodzenia 1,14. Zdecydowana większość, bo 67% ze 176 ocenianych drzew, reprezentowała 1 stopień uszkodzenia (tab. 2). Biorąc pod uwagę wiek drzewostanu (127 lat) oraz pochodzenie (założony na gruncie porolnym), stan zdrowotny można ocenić jako dobry. Struktura biosocjalna drzew wykazuje prawidłowy udział drzewostanu panującego (81,2-95,1%) i opanowanego (4,9-18,8%). Analizując podstawowe cechy struktury drzewostanu, stwierdzono, że największą zmienność wykazuje długość korony (od 17% do 30%), natomiast najmniejszą wysokość (od 6% do 9%). Średnia względna długość korony drzewostanów waha się od 0,21 do 0,24. Smukłość drzew, określająca odporność drzew na uszkodzenia powodowane przez wiatry i śnieg, przyjmuje średnie wartości poniżej 1,0 (od 0,71 do 0,83). Świadczy to o stabilności badanych drzewostanów. Analizowane drzewostany charakteryzują się dużą zasobnością – od 465 m^3 do 614 m^3 grubizny na hektar i zadrzewieniem od 1,0 do 1,3. W wyniku badania współzależności podstawowych cech dendrometrycznych stwierdzono najistotniejszy związek dla pierśnicy i smukłości (od –0,718 do –0,913), wysokości i absolutnej długości korony (0,619-0,715) oraz pierśnicy i wysokości (0,161-0,708; tab. 4). Przebieg bieżącego przyrostu pierśnicy wykazywał największe spadki w latach 1977-1983, 1969-1974, 1962-1967, 1956-1960 i 1949-1952 (rys. 6). Okresy te pokrywają się z gradacjami brudnicy mniszki oraz niekorzystnymi warunkami meteorologicznymi.

Słowa kluczowe: drzewostany sosnowe (*Pinus sylvestris* L.), stan zdrowotny, struktura, przyrost pierśnicy

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