AGRONOMY SCIENCE
wcześniej – formerly
Annales UMCS sectio E Agricultura

VOL. LXXIII (3) 2018

 http://dx.doi.org/10.24326/asx.2018.3.4

[1] Department of Forest Management, University of Life Sciences in Lublin,
Akademicka 15, 20-950 Lublin, Poland
[2] Institute of Genetics, Plant Breeding and Biotechnology, University of Life Sciences in Lublin,
Akademicka15, 20-950 Lublin, Poland
e-mail: zdzislaw.kaczmarski@up.lublin.pl

ZDZISŁAW KACZMARSKI[1], KATARZYNA MASTERNAK[2],
MATEUSZ JARMUŁ[1]

Slenderness of pedunculate oak (*Quercus robur* L.) according to biosocial position

Smukłość dębu szypułkowego (*Quercus robur* L.) w zależności od stanowiska biosocjalnego

Summary. The paper presents results of an analysis of pedunculate oak slenderness. The dependence between slenderness of the oak tree and dimensions of the trunk and the crown dimensions of a single tree were examined. The biosocial position of each tree was determined based on the Kraft's classification criteria. Following dimensions were measured for each tree: height, height of base of live crown, crown radius, diameter at breast height. The following crown parameters related to the growth space of a single tree were determined: crown length, crown width, crown projection area, space of a single tree, Seebach's growth space number, crown projection area to basal area ratio, crown spread. Based on the obtained results, the following was found: biosocial position of the oak tree in vertical structure of the stand has significant impact on the size of the tree slenderness; the slenderness increases with deterioration of the biosocial position of the tree, but it decreases with the increase in the value of the tree's measurement characteristics and the measures of its crown.

Key words: Kraft class, tree growth space, Seebach growth space

INTRODUCTION

Slenderness calculated as the quotient of tree height expressed in meters and its diameter in centimeters, is one of the features of the trunk longitudinal section shape [Grochowski 1973, Bruchwald 1999, Jaworski 2004]. The slenderness ratio of a tree is a number, the average value of which can be considered an index of a forest stand stability [Burschel and Huss 1997, Jelonek et al. 2014]. The tree slenderness is also accepted as a measure of their resistance to damage caused by snowfall and wind [Zajączkowski 1991]. Schütz et al. [2006], using the slenderness ratio of trees, determine the threat to stands due to the action of strong winds and hurricanes. Bruchwald and Dmyterko [2010, 2011, 2012], using the inverse of the slenderness ratio, determine the risk of tree stand damages by strong wind. According to the authors of the research, factors that have a crucial influence on the slenderness of trees are: species, age, density, habitat conditions and their biosocial position in the forest stand. In Poland, studies referring to the slenderness ratio were carried out for pine [Rymer-Dudzińska 1992a, 1992b, Kaźmierczak 2012], spruce [Orzeł and Socha 1999, Kaźmierczak et al. 2008b, Korzeniewicz et al. 2017], European larch [Kaźmierczak et al. 2012], oak [Rymer-Dudzińska and Tomusiak 2000, Kaźmierczak et al. 2008a, 2009], beech [Rymer-Dudzińska and Tomusiak 2000] and birch [Korzeniewicz et al. 2016]. Research on the slenderness of various tree species from the Niepołomice Forest was also conducted by Orzeł [2007].

The aim of the present study is to analyze the slenderness of oak depending on the biosocial position of trees in the stand. In addition, the work assessed the strength of correlation between slenderness and other features of tree growth and crown parameters.

MATERIAL AND METHODS

The research object consisted of pedunculate oak (*Quercus robur* L.), growing in 86-year-old stand under conditions of the Lśw habitat, in Chełm Forest District (RDLP Lublin). Geographical location of the tested object is 51°15'N and 23°40'E. In the studied stand, the oak was present as the main species with its share fluctuating from 60% to 90%, while hornbeam was the admixture.

In four selected research areas (each of 25 a), all trees were measured to determine the following characteristics:

1. $d_{1,3}$ – diameter of breast in the bark by measuring the tree in two directions perpendicular to one another with an accuracy of 0.1 cm; the arithmetic mean of two measurements was taken as the diameter of the tree breast,
2. h – tree height with an accuracy of 0.1 m, using a Nikon Forestry Pro altimeter,
3. h_{pk} – the height of the crown base from the first living branch of the crown, with an accuracy of 0.1 m, by means of the Nikon Forestry Pro altimeter,
4. r_k – radius of the crown by measuring, to the nearest 0.1 m, four projected points of the crown of tree located on two perpendicular lines. The average distance of these points to the trunk axis was assumed as the radius of the tree crown.

Based on the measurements, the following characteristics were calculated:

1. s – slenderness calculated as the quotient of tree height (in m) and its breast diameter (in cm),
2. l_k – crown length (in m) calculated as the difference between the tree height (h) and the height of the crown base (h_{pk}),
3. d_k – crown diameter (in m) calculated as the double crown radius value (r_k),
4. l_k/h – relative length of the crown (in m) calculated as the ratio of the crown length (l_k) to the tree height (h),
5. p_k – crown projection area (in m^2) calculated based on the crown diameter (d_k) using a formula for the circle area,

6. $d_k/d_{1,3}$ – the number of Seebach growth space calculated as the ratio of the crown diameter (d_k) to tree breast diameter ($d_{1,3}$),
7. $d_k^2/d_{1,3}^2$ – quotient of the crown area projection,
8. d_k/h – degree of the crown spread calculated as the quotient of the crown diameter (d_k) and tree height (h),
9. p_{pd} – space of a single tree (in m^3) calculated from the formula: $p_{pd} = p_k \times h$.

For each tree, a biosocial position was determined in accordance with the Kraft classification criteria. In order to determine the dependence between slenderness and selected tree features as well as measures of tree growth, Pearson's correlation coefficient was used. An analysis of variance of slenderness was performed due to the biosocial position of a tree in the forest stand applying the nonparametric Kruskal-Walis ANOVA test. Calculations were performed with the help of statistical software Statistica ver. 13.1 [2017].

RESULTS

Relationship between the trees belonging to particular Kraft classes and their slenderness was analyzed. The average ratio of oak slenderness increases with the deterioration of the tree's position in the biosocial structure of the stand (Fig. 1). The Kruskal-Walis test showed statistically significant effect of the biosocial position on the slenderness of trees in the forest stand. Trees constituting the main stand were characterized by lower slenderness ratio as compared to those forming a sub-stand.

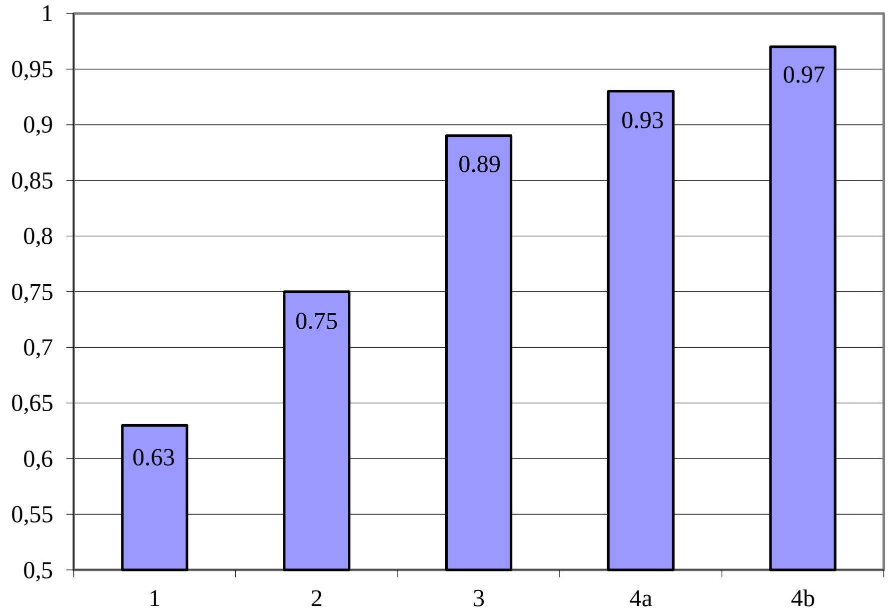

Fig. 1. Slenderness of oak trees in Kraft's classes

The mean value of the slenderness of trees belonging to the first Kraft class was lower than the average slenderness of the stand, and trees belonging to the second class of Kraft showed slenderness equal to the average slenderness of the stand. Variability of the tree slenderness was quite large. The slenderness variability coefficient determined for all examined trees was slightly over 25% (Table 1).

Table 1. Statistical characteristics for oak trees features and parameters of crown

Tree feature	N	Mean	Minimum	Maximum	Standard deviation	Coefficient of variation (%)
h (m)	284	21.51	10.8	26.5	2.71	12.62
$d_{1,3}$ (cm)	284	29.13	11.6	50.2	6.69	22.99
s	284	0.76	0.46	1.14	0.12	25.02
p_k (m^2)	284	28.03	2.93	106.84	17.47	62.34
l_k/h	284	0.47	0.2	0.73	0.08	18.15
$d_k/d_{1,3}$	284	19.64	11.35	32.76	3.87	19.72
$d_k^2/d_{1,3}^2$	284	400.93	128.85	1073.51	160.96	40.14
p_{pd} (m^3)	284	625.41	44.18	2671.18	429.02	68.59
d_k/h	284	0.26	0.13	0.47	0.07	26.10

An analysis of the dependence of slenderness on the measurement characteristics of trees and the size of measures related to their growth space was also carried out. The strongest negative correlation of slenderness with crown diameter was found, a bit weaker with the crown projection area, space of a single tree and the crown spread. As the diameter of the crown increases, the slenderness of trees decreases. Relatively small negative correlation with slenderness was shown by the height and breast diameter of trees. However, both the number of Seebach growth space and the quotient of the tree crown projection area did not show statistically significant correlation (Table 2).

Table 2. Dependence between oak trees slenderness, tree's features and parameters of crown

Tree feature	Correlation coefficient
h (m)	-0.3946^{***}
$d_{1,3}$ (cm)	-0.1816^{**}
d_k	-0.7017^{***}
p_k (m^2)	-0.6719^{***}
l_k/h	-0.1269^{*}
$d_k/d_{1,3}$	-0.0269
$d_k^2/d_{1,3}^2$	-0.0069
p_{pd} (m^3)	-0.6547^{***}
d_k/h	-0.6373^{***}

Significance at the levels of: *0.05, **0.01, ***0.001

DISCUSSION

Results of the present study showed the relationship between biosocial position of ak and its slenderness. Along with the deterioration of the tree's position in the stand structure, the slenderness ratio increased. Research carried out by Rymer-Dudzińska [1992b] in pine stands showed an increase in the pine slenderness ratio along with the deterioration of the biosocial class of trees. Rymer-Dudzińska [1992a] also reported a decrease in slenderness with an increase in the average diameter of breast and height of the stand. However, the increase in the slenderness ratio took place with the growing class of bonitation and trees density. Similar results were presented by Kazimierczak et al. [2008b], who examined spruces from Central Sudetes and showed a decrease in the slenderness ratio with age and breast diameter, height and thickness of trees increase. Orzeł and Socha [1999], when studying spruce from Western Sudetes proved that slenderness also depends on the position of the tree above sea level. Spruce growing in the upper parts of mountains showed lower slenderness ratio.

Rymer-Dudzińska and Tomusiak [2000], when examining beech tree stands, showed a relationship between slenderness of trees and their age, average breast diameter, height and bark thickness. There was no significant dependence between slenderness and the length of the crown. Results obtained by investigating the oak stands were similar. Analysis of the oak slenderness showed significant changes in this characteristic in association with biosocial position of the tree [Kaźmierczak et al. 2009]. Strong dependence of slenderness with breast diameter in the bark and without bark was also demonstrated, with the cross section of breast diameter and double thickness of bark on the breast height. However, weaker relationship was found between slenderness and age, thickness and Kraft class. The lowest correlation coefficient was found for the relationship between the slenderness of tree and its height. Along with the increase of all features, except from the Kraft class and the breast shape number, value of the slenderness ratio for oaks decreased. Results of other studies carried out by Kaźmierczak et al. [2008a], which showed a decrease in slenderness of oaks with an increase in breast diameter, breast gain, thickness, thickness gains and age, were similar.

Orzeł [2007], who examined the slenderness of main tree species in the Niepołomice Forest, determined that the average slenderness of eight species was 0.817 m/cm and showed significant relationship between its coefficient and age of the tree. The older the trees, the slenderness decreases. In addition, the author showed that deciduous trees showed greater slenderness than pine and larch. Studies upon larch revealed that age and position of the tree in vertical structure of the stand have significant impact on the slenderness ratio. However, there was no significant impact of the habitat fertility on slenderness [Kaźmierczak et al. 2011].

Research by Kaźmierczak [2012] conducted on pine stands showed that both the age and biosocial position of the tree affect the value of the slenderness ratio. The tree's slenderness decreased with the increase of every pine feature considered in the study; it only increased with the deterioration of the tree's position in the forest stand. Slenderness is most strongly linked to tree breast diameter, thick thickness, biosocial class and current 10-year thickness gain. There was also a strong association between slenderness and crown parameters associated with the growth space. Only the correlation coefficients with the number of Seebach growth space in the 35- and 88-year-old stand as well as the quotient of the crown projection area in all stands were statistically insignificant.

Based on the conducted research it was also shown that when diameter of the crown increases, the slenderness of trees decreases. The reason for this may be the fact that trees with broader crowns are less slender, because they are characterized by larger breast diameter (they achieved higher breast diameter gains). The increase in breast diameter of oak and other species is closely correlated with the size of crown [Spiecker 1991]. Moreover, results of the present study showed that trees constituting the main stand were characterized by lower slenderness ratio and therefore were more stable compared to those forming the sub-stand. Slenderness is an indicator of tree's resistance to damage caused by snow and wind, and thus it is one of the tree stability measures, and its average value is considered as a measure of stand stability [Zajączkowski 1991].

CONCLUSIONS

1. Biosocial position of oak in vertical structure of the stand has significant impact on value of tree slenderness.

2. Tree slenderness increases with the deterioration of tree biosocial position, while it decreases with the increase in the value of tree's measurement characteristics and crown parameters related to its growth space.

3. It was found that the strongest association with slenderness is shown by: crown diameter, crown projection area and space of a single tree. The weakest relationship with slenderness is revealed by the relative length of crown.

4. There was no statistically significant association between slenderness and the quotient of the crown projection area and the measure of Seebach growth space.

REFERENCES

Bruchwald A., 1999. Dendrometria. Wyd. SGGW, Warszawa.

Bruchwald A., Dmyterko E., 2010. Metoda określania ryzyka uszkodzenia drzewostanu przez wiatr. Leś. Pr. Bad. 71(2), 165–173.

Bruchwald A., Dmyterko E., 2011. Zastosowanie modeli ryzyka uszkodzenia drzewostanu przez wiatr do oceny zagrożenia lasów nadleśnictwa. Sylwan 155(7), 459–471.

Bruchwald A., Dmyterko E., 2012. Ryzyko powstawania szkód w drzewostanach poszczególnych nadleśnictw Polski. Sylwan 155(7), 472–481.

Burschel P., Huss J., 1997. Grundriss des Waldbaus. Parey Buchverlag, Berlin.

Grochowski J., 1973. Dendrometria. PWRiL, Warszawa.

Jaworski A., 2004. Podstawy przyrostowe i ekologiczne odnawiania oraz pielęgnacji drzewostanów. PWRiL, Warszawa.

Jelonek T., Tomczak A., Pazdrowski W., 2014. Wybrane wskaźniki stabilności drzew w drzewostanach sosnowych narażonych na wiatr. Stud. Mater. CEPL Rogów 39, 35–45.

Kaźmierczak K., 2012. Smukłość sosen w klasach biosocjalnych. Forestry Lett. 103, 33–39.

Kaźmierczak K., Nawrot M., Pazdrowski W., Najgrakowski T., Jędraszak A., 2012. Kształtowanie się smukłości modrzewia europejskiego (*Larix decidua* Mill.) w zależności od siedliska, wieku i pozycji biosocjalnej. Sylwan, 156(2), 83–88.

Kaźmierczak K., Pazdrowski W., Mańka K., Szymański M., Nawrot M., 2008a. Kształtowanie się smukłości pni dębu szypułkowego (*Quercus robur* L.) w zależności od wieku drzew. Sylwan 7, 39–45.

Kaźmierczak K., Pazdrowski W., Paraniak P., Szymański M., Nawrot M., 2008b. Smukłość jako miara stabilności świerka pospolitego (*Picea abies* (L.) Karst.) na przykładzie drzewostanów Sudetów Środkowych. Conf. Mat. Human and nature safety 3, 228–230.

Kaźmierczak K., Pazdrowski W., Szymański M., Nawrot M., Mańka K., 2009. Slenderness of stems of common oak (*Quercus robur* L.) and selected biometric traits of trees. Conf. Mat. Human and nature safety 2, 53–56.

Korzeniewicz R., Borzyszkowski W., Szmyt J., Kaźmierczak K., 2016. Smukłość 30-letniego niepielęgnowanego drzewostanu brzozy brodawkowatej (*Betula pendula* Roth.). Acta Sci. Pol. Silv. Colendar. Ratio Ind. Lignar 15(2), 79–86.

Korzeniewicz R., Jakubowski M., Jelonek T., Kaźmierczak K., Tomczak A., 2017. Smukłość świerków (*Picea abies* (L.) H. Karst) w 30-letnim niepielęgnowanym drzewostanie i jej związek z wybranymi cechami biometrycznymi. Acta Sci. Pol. Silv. Colendar. Ratio Ind. Lignar. 16(2), 131–140.

Orzeł S., 2007. A comparative analysis of slenderness of the main tree species of the Niepołomice Forest. EJPAU, Forestry 10(2), http://www.ejpau.media.pl/forestry/index.html.

Orzeł S., Socha J., 1999. Smukłość świerka w sześćdziesięcioletnich drzewostanach Beskidów Zachodnich. Sylwan 4, 35–43.

Rymer-Dudzińska T., 1992a. Smukłość drzew w drzewostanach sosnowych. Sylwan 11, 35–44.

Rymer-Dudzińska T., 1992b. Zależność średniej smukłości drzew w drzewostanach od różnych cech taksacyjnych drzewostanu. Sylwan 12, 19–25.

Rymer-Dudzińska T., Tomusiak R., 2000. Porównanie smukłości drzewostanów bukowych i dębowych. Sylwan 9, 45–52.

Schütz J.-P., Götz M., Schmid W., Mandallaz D., 2006. Vulnerability of spruce (*Picea abies*) and beech (*Fagus silvatica*) forest stands to storms and consequences for silviculture. Eur. J. For. Res., 125, 291–302.

Spiecker H., 1991. Zur Dynamik des Wachstums von Tannen und Fichten auf Plenterwald-Versuchsflächen im Schwarzwald. Allg. Forstz. 21, 1076–1080.

Zajączkowski J., 1991. Odporność lasu na szkodliwe działanie wiatru i śniegu. Świat, Warszawa.

Streszczenie. W pracy przedstawiono wyniki analizy smukłości dębu szypułkowego (*Quercus robur* L.), która została przeprowadzona w 86-letnim drzewostanie o położeniu geograficznym 51°15’N i 23°40’E, w warunkach siedliska Lśw, na terenie Nadleśnictwa Chełm (RDLP Lublin). Na podstawie pomiarów wszystkich drzew w drzewostanie zbadano zależność smukłości dębu od wymiarów pnia i parametrów korony związanych z przestrzenią wzrostu pojedynczego drzewa. Pozycja biosocjalna każdego drzewa została określona na podstawie kryteriów klasyfikacji Krafta. Stwierdzono, że pozycja biosocjalna dębu w strukturze pionowej drzewostanu ma istotny wpływ na wielkość współczynnika smukłości drzewa oraz że smukłość drzewa rośnie wraz z pogarszaniem się pozycji biosocjalnej drzewa, natomiast maleje wraz ze wzrostem wartości cech pomiarowych drzewa oraz parametrów korony.

Słowa kluczowe: klasy Krafta, przestrzeń wzrostu drzewa, przestrzeń wzrostowa Seebacha

Received: 14.06.2018
Accepted: 14.09.2018