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LENGTH AND RELATIVE LENGTH OF CROWNS IN 88−YEAR OLD PINES AND ITS RELATIONSHIP WITH VOLUME INCREMENT

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Summary

The study presents fluctuations in length and relative length of crowns in 88-year old pines depending on the social class of tree position and relationships with 5-year current volume increment of trees. Current volume increment of 50 randomly selected pines was determined by section analyses conducted after felling selected mean sample trees.

Keywords and phrases: volume increment, stepwise regression, Scots pine (*Pinus sylvestris* L.)

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1. Introduction

The size of tree crown is an indicator of growth energy of trees. Pioneering extensive studies on crown structure and shape were conducted by Burger and Badoux (Borowski, 1974), while in Poland - by Lemke (1966). Crown size may be described by different dimension traits, including length and relative length of the crown.

Crown length in a tree indicates its viability and is considered when assessing its photosynthetic potential (Daniels and Burkhart, 1975). Since shoot growth and cambium growth occur in the crown and root growth is initiated in the crown, relative crown length may be a good indicator of increment potential of a tree (Monserud, 1975). Both traits of the crown – its length and relative length – are indicators of competition for the potential growing space of a tree (e.g. Monserud, 1975; Daniels and Burkhart, 1975).

The aim of the study was to describe fluctuations in length and relative length of crowns in 88-year old pines depending on their social class of tree position in the stand and their relationship with volume increments determined by section analyses.

2. Experimental material and methods

The experimental material was collected in an 88-year old pure pine stand growing on the fresh coniferous forest site in the Zielonka Experimental Forest Division. A total of 50 trees were randomly selected from the stand. The social class of tree position in the stand according to Kraft's classification was determined for each tree before felling. Kraft's classification is based on tree position in the stand social structure and its crown development and extent. The social class reflects a position of a tree in a stand, and through this, its growth potential (Assmann, 1970). Outside diameter at breast height was measured on standing trees in two directions, N-S and W-E, accurate to 0.1 cm and the arithmetic mean of these measurements was assumed as diameter at breast height of the tree ($d_{1.3}$). Moreover, crown width and the degree of crown spread were also determined. Crown width d_k measured in m was obtained from the crown projection area assumed as the area of a circle. Crown projection area was established based on projections of characteristic points of tree crowns. The degree of crown spread was calculated as a ratio of crown diameter to tree height d_k/h.

After felling among other things length was determined accurate to 0.01 m and it was assumed as tree height (h), as well as crown position height to the first live branch constituting the base of compact crown. Crown length l_k was calculated as the difference between total tree height and crown position height, while relative crown length l_k/h was the ratio of crown length and tree height. Current volume increment in m^3 for the last 5 years (Zv_5) was determined by section analysis for each felled tree. Tree slenderness was calculated as a ratio of tree height to diameter at breast height $h/d_{1.3}$. Slenderness is an important characteristic of a tree indicating its stability. Colinearity does not occur between diameter at breast height and tree height.

Regression was performed using the backward elimination method at the level of significance of 0.05 with the help of the STATISTICA 10.

3. Results

Absolute and relative mean crown length in analysed pines decreases with the deterioration of social class of tree position (Table 1). The arithmetic mean recorded for all analysed trees is similar to the mean for trees of Kraft's class II, which in the selected sample comprised the most numerous group.

Crown length in 88-year old pines increased with an increase in diameter at breast height and tree height, an increase in current volume increment of the tree, crown width and the degree of crown spread, while it decreased with the slenderness. A similar ordering of the power of relationships was found in relation to relative crown length, although the power of the dependence was weaker than in the case of crown length. The strongest correlation was observed for crown length and relative length (Table 2).

Table 1. Statistical characteristic of tree crown traits in biosocial classes

Statistical traits	All trees	Kraft's class		
		I	II	III
Number of trees	50	10	23	17
Crown length l_k [m]				
minimum	3.00	5.40	3.05	3.00
maximum	8.83	8.83	7.75	6.20
arithmetic mean	**5.88**	**7.26**	**5.90**	**5.04**
standard deviation	1.36	1.16	1.30	0.82
coefficient of variation	23.17	15.93	21.94	16.37
Crown ratio l_k/h				
minimum	0.16	0.26	0.16	0.18
maximum	0.41	0.40	0.41	0.33
arithmetic mean	**0.29**	**0.33**	**0.29**	**0.26**
standard deviation	0.06	0.05	0.06	0.04
coefficient of variation	19.47	14.86	20.92	14.69

Table 2. The Pearson correlation diagram

Tree traits	l_k/h	$d_{1.3}$	h	Zv_5	d_k	d_k/h	$h/d_{1.3}$
l_k	0.964*	0.692*	0.675*	**0.659***	0.592*	0.492*	-0.569*
l_k/h		0.558*	0.462*	**0.539***	0.484*	0.433*	-0.515*
$d_{1.3}$			0.760*	**0.756***	0.761*	0.651*	-0.915*
h				**0.693***	0.609*	0.415*	-0.476*
Zv_5					**0.649***	**0.547***	**-0.648***
d_k						0.972*	-0.700*
d_k/h							-0.669*

*The correlation coefficient significant at the level $\alpha = 0.05$

Since the measurement of current volume increment (Zv_5) requires tree felling and is both time-consuming and costly, it was attempted to describe this tree characteristic using traits which could be determined on standing trees and describing energy and photosynthetic potential of the tree (dimensional characteristics of the crown). Diameter at breast height ($d_{1.3}$), tree height (h), crown width (d_k) and the degree of crown spread (d_k/h), length (l_k) and relative length of the crown (l_k/h) as well as tree slenderness ratio ($h/d_{1.3}$) were assumed to be explanatory variables. Multiple backward regression was applied. As a result of estimation an equation was produced, which took the form:

$$Zv_5 = 0.0950 + 0.0275 \cdot l_k - 0.4887 \cdot l_k / h - 0.0839 \cdot h / d_{1.3}$$

The estimated equation describes 64.12% variation in current volume increment by the variation in length, relative length of the crown and tree slenderness ratio (Table 3).

Table 3. Multiple and partial correlation coefficients for the volume increment dependence on crown length l_k, relative crown length l_k/h and tree slenderness ratio $h/d_{1.3}$

$R_{multiple}$	$100R^2$	$R_{partial}$		
		l_k	l_k/h	$h/d_{1.3}$
0.8007	64.12	0.5598	-0.4611	-0.4252

4. Discussion

Results recorded in the above mentioned analyses confirm earlier studies conducted by other authors. Investigations by Turski et al. (2012) showed that mean crown length decreased with the deterioration of Kraft's class and it increased with tree age. Mean crown length in a 92−year old dominant stand was 1.2 times greater than that recorded in a 77-year old stand and 1.3 times greater than in a 47−year old stand, respectively. Moreover, in each of the three investigated stands (Turski et al. 2012) a distinct trend was observed for the relative crown length to decrease with the deterioration of social class of tree position in the stand.

Skrzyszewski (1995) in 11 out of 15 pine stands showed a relationship of crown length with current 10-year increment in breast height basal area. Relative crown length has a statistically significant effect on this type of tree increment in 9 out of 15 stands. The relationship of the above mentioned traits was also observed by that author in larch. Crown length and width were significantly related with the increment in breast height basal area in 6 out of 7 analysed stands, while relative crown length – in 4 out of 6 stands. The dependence between these traits was stronger in larch than in spruce (Skrzyszewski, 1995).

Jaworski et al. (1988, 1995) showed a dependence between relative crown length and increment in annual rings in firs in younger stands at the correlation coefficient of 0.579, while in older stands it was at the correlation coefficient of 0.515.

Relative crown length was successfully used in estimations of tree increments. Monserud and Sterba (1996) showed a strong significant effect of relative crown length on the increment of breast height basal area in all forest tree species in Austria. Monserud (1975) found a significant effect of relative crown length on increment in height in 11 out of 12 investigated species, while on increment in diameter at breast height - in 9 out of 12, respectively. Wykoff (1990) showed that this trait had a highly significant effect on the increment in breast height basal area in all the 11 investigated coniferous stands. Daniels and Burkhart (1975) used the value of relative crown length to determine increment in diameter at breast height in pine plantations in the south-eastern regions of the USA.

Investigations by Svensson (1998) conducted on the extensive material of mean sample trees in relation to pine and spruce showed the need to consider crown traits (relative crown length) when determining volume increment.

Interesting conclusions were drawn by researchers analysing larch in China (Jiang and Liu 2011). Relative crown length was used to develop a model of longitudinal section of a tree. An equation based on this trait had the coefficient of determination of 98%. These investigations confirm results of studies on the effect of crown dimensions on longitudinal tree section (Muhairwe, 1994; Sharma and Zhang, 2004; Jiang et al., 2007).

5. Conclusions

(i) Mean absolute and relative crown lengths in pines decrease with the deterioration of social class of tree position in the stand.

(ii) Crown length is correlated the strongest with crown relative length.

(iii) Crown length in pines increased with an increase in diameter at breast height and tree height.

(iv) Crown length increases also with an increase in crown width and the degree of crown spread.

(v) Crown length and relative crown length are correlated with current volume increment.

(vi) Current volume increment of 88-year old pines may be estimated with 64.12% accuracy based on measured crown length and relative crown length and tree slenderness ratio.

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