Tree volume increment and crown volume

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This study describes the development of the selected features of pine crowns (d_k width, l_k length and degree of its spread d_k/h) depending on the biosocial position of a tree in a stand. Impact of a crown volume on tree volume increment of 35-year-old pines is also considered.

Crown spread, crown volume, crown length, pine

Introduction

Crown of the tree, its size and structure affect the efficiency of assimilation processes. These, in turn, determine tree growth and increment. Assimilation efficiency helps to reduce the amount of CO_2 in the atmosphere.

Burger and Badoux (after Borowski 1974) were conducting pioneering research on the tree crowns. Dubravac T., Krejci V. (1993), Dubravac T. (1998, 1999, 2003, 2004), Hemery et al. (2005) were testing the dependence of the crown size on different tree features. Lemke (1966) was studying the size of tree crown in Polish pine stands. Dudek (1969) was making research on the dependence of DBH increase from crown projection area and crown volume of pines, where Zajączkowski (1973) evaluated the relationship between the crown projection area and the current volume increment of that species.

The aim of this study is to describe the evolution of the crown size of 35-year-old pines, depending on the vertical position occupied by a tree in the stand, and its impact on the tree volume increment. Tree crown was characterized by its width (d_k m), length (l_k m) and the degree of its spread (d_k/h).

Materials and methods

The research material was collected from 35-year-old pine stand growing on fresh coniferous forest (FCF) in Zielonka Experimental Forest District. There were 50 trees randomly selected from the stand. Biosocial position according to Kraft classification was established for each tree before harvesting. In addition, the following measurements were done:

1. breast height diameter with bark of standing trees was measured in two directions - NS and EC (accurate within 0,1m), and the arithmetic mean of these measurements was taken as the tree diameter at breast height ($d_{1,3}$).
2. tree length, accurate within 0,01m and adopted as tree height (h), measured after cutting,
3. the height of the crown base with an accuracy of 0.01 m was set after felling trees,
4. crown projection area p_k (m^2) based on projected characteristic points of the crown,
5. current volume increment (m^3) for the last five years Iv_5 was measured with section method.

Other crown features were established based on the collected measurements. Crown width - d_k (in meters) was obtained from the crown projection area adopted from area of a circle. Crown length l_k was calculated as the difference between the total height of the tree and the height of the crown base. The relative crown length l_k/h was calculated as the ratio of crown length to the tree height. Crown deflection coefficient was calculated as the ratio of the crown diameter to the tree height d_k/h. Slenderness was calculated as the ratio of the tree height and its diameter at breast height.

Results

Arithmetic means of all studied crown traits (width, length and degree of spread) substantially decrease with the deterioration of the position of the tree in a stand (Table 1, Fig. 1). The arithmetic average, obtained for all analyzed trees, is similar to the mean calculated for trees from III[rd] Kraft class (codominant trees) which constitute the most numerous group of randomly selected sample.

Table 1. Statistical characteristics of tree crown traits in the biosocial classes

Statistical traits	All trees	Kraft's class					
		I	II	III	IVa	IVb	Va
Number of trees	50	9	10	16	8	3	4
Crown diameter d_k [m]							
The minimum	0,62	2,26	1,89	0,94	1,10	1,16	0,62
The maximum	3,30	3,30	2,99	2,57	2,31	1,99	1,29
The arithmetic mean	**1,96**	**2,72**	**2,24**	**1,88**	**1,54**	**1,59**	**0,97**
The standard deviation	0,62	0,32	0,37	0,44	0,42	0,42	0,30
The coefficient of variation	31,50	11,57	16,31	23,55	27,09	26,23	30,83
Crown length l_k [m]							
The minimum	2,80	5,39	4,57	3,68	2,95	3,09	2,80
The maximum	9,01	9,01	7,25	5,75	5,05	5,07	3,69
The arithmetic mean	**4,92**	**6,62**	**5,59**	**4,64**	**4,03**	**3,88**	**3,15**
The standard deviation	1,31	1,16	0,89	0,62	0,73	1,05	0,38
The coefficient of variation	26,59	17,50	15,99	13,28	18,10	27,03	12,19
Degree of crown spread d_k/h							
The minimum	0,05	0,16	0,14	0,07	0,09	0,11	0,05
The maximum	0,24	0,20	0,24	0,21	0,20	0,14	0,11
The arithmetic mean	**0,15**	**0,18**	**0,16**	**0,14**	**0,13**	**0,13**	**0,09**
The standard deviation	0,04	0,02	0,03	0,04	0,04	0,02	0,03
The coefficient of variation	27,18	9,05	20,64	24,77	32,17	11,76	30,94

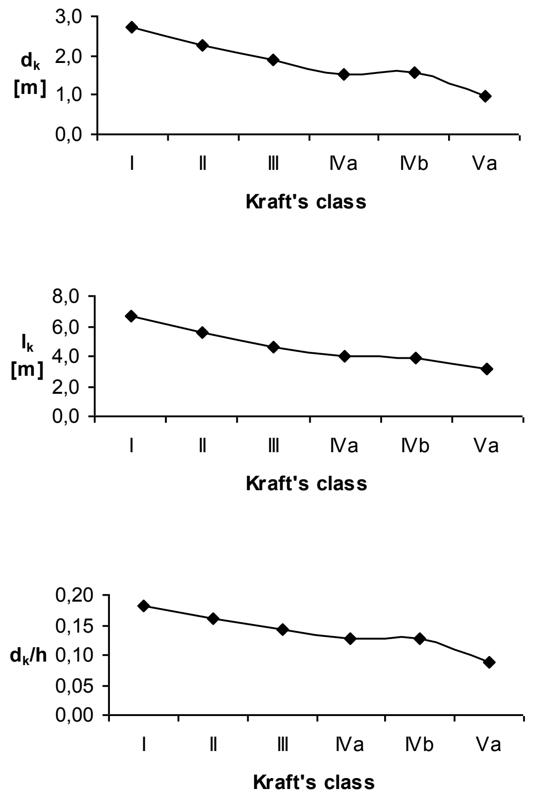

Fig. 1. The arithmetic mean of pine trees crown traits in the biosocial classes

The influence of crown features, DBH, height and slenderness of analyzed pines on the five-year volume increment was determined using section method. The connection between tree biosocial position and its volume increment was also calculated. The correlation coefficients, with significant relationships at the level of α = 0.05, are given in Table 2. Tree DBH is the strongest correlated to the tree volume increment, then crown height and its length. Slightly weaker relationship was found between volume increment and crown slenderness and width, then with Kraft class, and the lowest with a degree of crown deflection. The volume increment increases with increasing diameter at breast height, height, length, width, and the degree of crown deflection, but decreases with increasing slenderness and decreasing tree biosocial class (Table 2).

Table 2. The correlation diagram

Tree traits	*Kraft's class*	$d_{1.3}$	h	l_k	d_k	d_k/h	s
Zv5	-0.684	0.935	0.842	0.846	0.771	0.567	-0.797
Kraft's class		-0.785	-0.728	-0.670	-0.682	-0.553	0.805
$d_{1.3}$			0.845	0.800	0.780	0.594	-0.937
h				0.802	0.652	0.387	-0.685
l_k					0.673	0.483	-0.676
d_k						0.948	-0.756
d_k/h							-0.640

Due to the strong relationships between pine volume increment and its other traits the equation for estimating the current increment depending on the diameter at breast height, height, width, degree of crown deflection and slenderness was established. The function takes the form:

$$Zv_5 = -0.0149 + 0.0050 \cdot d_{1.3} - 0.0058 \cdot h + 0.0442 \cdot d_k - 0{,}5215 \cdot d_k / h + 0.0322 \cdot s$$

The size of multiple correlation coefficient and partial correlation coefficients describing the estimated equation are shown in Table 3. All correlation coefficients are significant at α = 0.05. The regression function obtained describes the variation of current pine increment at a high level of accuracy - over 95% (Table 3). Excluding the impact of other characteristics, correlation coefficient between the volume increase and height assumes a negative value. This can be justified by greater intensity of a trees breast height increase, compared with an increase in their height.

Table 3. Multiple and partial correlation coefficients for the tree increment of volume dependence on the selected characteristics of trees

$R_{multiple}$	$100R^2$	$R_{partial}$				
		$d_{1.3}$	h	d_k	d_k/h	s
0.9764	95.34	0.7176	-0.5282	0.5425	-0.5149	0.5218

Discussion

Retrospective analysis of growth and increase in 50-year-old pine trees showed that the curves of current volume increment in individual tree Kraft classes formed an increasing sequence of those classes (Lemke 1972). Similar results were obtained by Zajączkowski (1973) in relation to the dominant stand of pine trees. Analogous results were also found for beech and spruce (Šmelko 1982). Żółciak (1963), while analyzing the development of the growth of pine trees in various life stages, claimed that even when trees temporarily change their position in the stand they usually maintain a permanent one.

Lemke (1968) found significant relationships between elements of the crowns and the volume increment of pine trees. According to the results of Borowski (1968) increments of trees depends not only on the crown size and the occupied space, but mostly on tree biosocial position. That was clearly visible in the stand with an average age of 44 years. Volume increment per square meter of crown projection decreased with the increase of crown projection area in each of Kraft classes. It decreased rapidly with a small crown projection area, while more slowly with the large crown projection area. Zajączkowski (1973) showed an increase of volume increment with an increase in crown projection area in Kraft classes. Trees with higher Kraft class were characterized by a greater increase in volume than trees from lower classes but having crowns of similar size. Dudek (1969) found that younger trees of similar crown projection area had a greater increase in DBH and larger volume increment per unit of cross-sectional area (greater factor of volume increment intensity) than older trees.

Conclusions

1. All tested crown features of 35-year-old pines - the width, length and spread degree - substantially decrease with deterioration of tree position in the stand.
2. DBH ($d_{1.3}$) and tree height (h) are the most correlated with the current volume increment.
3. Crown length (l_k) and its width (d_k) are the most correlated with tree volume increment, while degree of crown spread (d_k/h) is much less correlated.
4. Volume increase decreases with lowering of Kraft biosocial class.
5. Current volume increment of 35-year-old pine trees can be estimated with over 95% accuracy by the equation:

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Summary

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