Beech (*Fagus sylvatica* L.) forests of a selection structure in the Bieszczady Mountains (southeastern Poland)

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ABSTRACT: The characteristics of two beech (*Fagus sylvatica* L.) stands are presented in this paper. One, the Tarnicki stand, situated in the Bieszczadzki National Park, represents the growing up stage and selection phase of a forest of primeval character. The other one, the Otryt stand, is situated in managed forests of the Lutowiska Forest District. In each stand two sample plots were established. The distribution of the number of trees in each sample plot agreed with de Liocourt sequence and Meyer curve. Both stands were characterized by the structure of many generations. The Otryt stand, with respective volumes of 238 and 324 m³/ha in two sample plots, was characterized by a lack of large diameter trees and a high percent of trees of the smallest diameters, while the Tarnicki stand, with volumes of 442 and 517 m³/ha, was characterized by the presence of large diameter trees ($d_{1.3} \geq 72$ cm). The phase of the selection forest in the Tarnicki stand is of temporary character because, due to natural processes, a two-storied structure may develop there, and with time, a one-storied structure in the optimal stage. In the Otryt stand, representing a managed forest, the maintenance of the selection structure may be expected due to selection cuttings. It has to be acknowledged that managed stands of characteristics similar to those presented in this paper makes it possible to carry out selection cutting, especially in the protection zone surrounding the Bieszczadzki National Park.

Keywords: selection forest; primeval forest; development stages; Liocourt and Mayer distributions

Beech (*Fagus sylvatica* L.) in the Polish part of the Carpathians is one of the major forest tree species, and it covers 25.3% of the forest area of this region, while the remaining major tree species – fir (*Abies alba* Mill.), spruce (*Picea abies* [L.] Karst.), and pine (*Pinus sylvestris* L.) take up 25%, 21.7%, and 17%, respectively (TRAMPLER et al. 1990).

The beech stands in the Carpathians between 1950 and 1990 were regenerated using the uniform shelterwood system, the most popular cutting method in the mountainous area of the Polish Carpathians. In the early 1980s this type of cutting was used on about 85% of the area of regenerated stands. Generally, the results of this method, with a 15–25-year regeneration period, were satisfactory. Undergrowth of good structure and stocking was obtained permitting beech stands of good quality to form. However, this created even-aged, one-storied stands where a large amount of small products (SCHÜTZ 2001) was harvested during costly tending operations, lowering the economic efficiency of forest management (AMMON 1995). The uniform shelterwood system, due to natural regeneration, decreased silvicultural risk. However, it did not eliminate such a risk (BERNADZKI 1995) due to a short regeneration period and large regenerated areas.

These shortcomings do not occur in the case of the Swiss irregular shelterwood system[1] (Swiss femel coupe[1]), and especially in the case of selection cutting.

The Swiss irregular shelterwood system is increasingly used in Carpathian pure fir stands and in stands composed of fir, beech, and spruce (FABIJANOWSKI, JAWORSKI 1996; PRZYBYLSKA, ZIĘBA 2003). The idea to "ecologize the forest management", obligatory in Polish forestry since 1995, encourages the use of selection cutting, mainly in fir forests, especially in mountain forests where a protection function of the forest dominates (BERNADZKI 1971; GRANICZNY 1971; JAWORSKI 1979; FABIJANOWSKI, JAWORSKI 1996). The possibility of using selection cutting in beech forests is also taken into consideration, seeking examples in managed stands and forests of primeval character (reserves, national parks). There is a question whether beech forests of primeval character, known in the Eastern Carpathians of Slovakia and Poland and frequently having a complex structure in the growing up stage (KORPEĽ 1995; JAWORSKI et al. 2000), may become the model for selection beech forests.

Therefore, the purpose of these investigations was to study the characteristics of beech forests of primeval character being in the selection phase of the growing up stage, and also the characteristics of a managed stand of many-storied structure, as well as to determine whether

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[1] According to the dictionary edited by J. Weck: Wörter der Forstwirtschaft. BLV, München 1966.

the forests of such a structure may serve as models in using selection cutting in beech forests of southern Poland.

Study area and sample plots

The Western Bieszczady Mountains, where the Bieszczadzki National Park is situated, are the most westerly range of the northeastern Carpathians. They are of medium height with Tarnica as their highest mountain of 1,348 m in elevation. They are situated within the flysch outer Carpathians (ZARZYCKI 1963).

Brown soils prevail in this area, and among 10 natural forest associations large complexes of old beech, beech-sycamore maple, and beech-fir stands (*Dentario glandulosae-Fagetum* and *Luzulo nemorosae-Fagetum typicum*) dominate (MICHALIK, SZARY 1997).

The sample plots are situated in a belt 600–920 m in elevation (Table 1) where the climate is moderately cool with mean annual temperature from +4 to +6°C and annual total precipitation from 900 to 1,200 mm, depending on the elevation. The growing season in this area lasts for 192–199 days, and the snow cover persists for 107 to 114 days (NOWOSAD 1995).

The investigations were carried out in 1998 and 2002 in four stand fragments where a many-storied stand structure was present in a relatively small area.

Two plots, Tarnicki 1 and Tarnicki 2, each 0.25 ha in size, are situated in the Tarnicki forest complex of the Bieszczadzki National Park (compartment 260a, 48.51 ha in area), where no forest management activities have been carried out since 1973. The stand makes a mosaic of development stages of a primeval forest, with the optimum and growing up stages prevailing. The plots are situated in stand fragments representing the growing up stage. The old growth is formed of beech (*Fagus sylvatica* L.) with admixture of sycamore maple (*Acer pseudoplatanus* L.), mountain elm (*Ulmus glabra* Huds.), and fir (*Abies alba* Mill.), while the beech undergrowth, covering about 5% of the area, occurs in the

form of single trees, and less frequently in the form of small groups, 0.5–2 ares in size.

The remaining two plots, Otryt 1 and Otryt 2, 0.20 and 0.25 ha respectively, are situated in managed beech forests of the Otryt forest complex of the Lutowiska Forest District (compartment 145Ab – 21.45 ha in area). These forests adjoin the Bieszczadzki National Park. The plots represent the most frequently occurring stand fragments. Cuttings similar to the Bavarian group cutting were carried out in this stand till the mid-nineties of the last century. They promoted the development of a storied and complex age structure (see the results). Presently selection cutting is practiced in this stand.

METHODS

Field work

The field work included the measurement of height (Vertex type hypsometer) and diameter ($d_{1.3} \geq 6$ cm) of all trees as well as the classification of tree development generations (A, B, C) according to ŘEHÁK (1964) (see the results). In order to determine tree age, increment cores were taken from 2–4 trees of each development generation. The determination of age at the ground level was impossible in the case of some cores because the annual increments were difficult to read. In plots Otryt 1 and Tarnicki 1, where studies were carried out in 1998 during investigations concerning the primeval forests (Otryt 1 was a control plot), after determination of the tree age, the average age was computed for a given development generation. In the case of plots Otryt 2 and Tarnicki 2 a more detailed method was used giving the age of each tree as well as its characteristics (see the results). The investigations in these two plots were carried out in 2002 in order to get more detailed data on the stand structure.

All trees with $d_{1.3} \geq 8$ cm were considered to make up the main stand, while trees with $d_{1.3}$ 6.0–7.9 cm were included in the advanced undergrowth and classified to three classes

Table 1. Location of sample plots and their site and stand characteristics

Plot	Tarnicki 1	Tarnicki 2	Otryt 1	Otryt 2
Location (forest range, compartment)	Bieszczadzki National Park (Suche Rzeki, 260a)		Lutowiska Forest District (Sękowiec 145Ab)	
Size of sample plot (ha)	0.25	0.25	0.20	0.25
Elevation (m)	900	920	600	610
Plant association	*Dentario glandulosae-Fagetum typicum*			
Species composition* (volume percentage) (%)	Fg – 98.0 Ab – 2.0	Fg – 88.7 Ac – 11.0 Ul – 0.3	Fg – 96.5 Ab – 3.0 Cp – 0.5	Fg – 97.4 Ab – 2.5 Cp – 0.1
No. of trees ($d_{1.3} \geq 8$ cm) (N/ha)	356	392	570	504
Advanced undergrowth ($d_{1.3}$ = 6–7.9 cm) (trees/ha)	124	44	165	40
Basal area (G) (m²/ha)	33.16	41.13	24.42	27.55
Volume (V) (m³/ha)	442.29	517.04	238.19	323.69

Description of abbreviations: Fg – *Fagus sylvatica*, Ab – *Abies alba*, Cp – *Carpinus betulus*, Ac – *Acer pseudoplatanus*, Ul – *Ulmus glabra*

$(D_1, D_2,$ and $D_3)$ on the basis of their vitality and growth tendency (see the results).

Principles of data analysis

For trees of $d_{1.3} \geq 8$ cm the parameters of theoretical distribution of the number of trees were computed according to the de Liocourt geometric sequence

$$A, A \cdot q^{-1}, A \cdot q^{-2}, \dots\dots A \cdot q^{-n}$$

where: A – number of trees in the lowest size gradation,
q – parameter,
n – number of size gradations

and the MEYER function (1933)

$$N_d = k \cdot e^{-ad}$$

where: N_d – number of trees in the size gradation d,
k, a – parameters.

The method proposed by RUTKOWSKI (1968) was used for computations. It ensures the equality between the number of trees and mean $d_{1.3}$ in the existing stand (diameter distribution) and the theoretical stand. It should be stressed that this method makes it possible to compute not the Liocourt quotient but its reverse $1/q$ indicated here as q_R.

The following formulas in following table were used (table).

On the basis of computed parameters the theoretical diameter distributions were made for four investigated stands (per 1 ha). The theoretical and real distributions in 4-cm size gradations (based on the number of trees determined in sample plots) were compared using the chi-squared test at the significance level $\alpha = 0.05$.

In this study the Liocourt formula as well as the Meyer formula were used in spite of the identity of theoretical distributions of the number of trees obtained (MEYER

Table 2. Percentage of trees in individual stand layers (according to IUFRO classification)

Plot	Layer			Total
	100	200	300	
Tarnicki 1 (*N*/ha)	108	136	112	356
(%)	30.3	38.2	31.5	100.0
Tarnicki 2 (*N*/ha)	144	164	84	392
(%)	36.7	41.9	21.4	100.0
Otryt 1 (*N*/ha)	110	400	60	570
(%)	19.3	70.2	10.5	100.0
Otryt 2 (*N*/ha)	120	288	96	504
(%)	23.8	57.1	19.1	100.0

1933) because in the publications concerning selection beech forests the authors presented parameters of one of these two formulas (GROSSMANN 1959; GEROLD, BIEHL 1992; SANIGA 1998a,b; SANIGA, SZANYI 1998).

The stand volume was computed using the "Zasoby" computer program based on the GRUNDNER-SCHWAPPACH tables (1952).

RESULTS

The stands in sample plots differed in volume (Tarnicki 1 and 2 – 442 and 517 m³/ha; Otryt 1 and 2 – 238 and 324 m³/ha), basal area (Tarnicki 1 and 2 – 33.16 and 41.13 m²/ha; Otryt 1 and 2 – 24.42 and 27,55 m²/ ha), and the number of trees (Tarnicki 1 and 2 – 356 and 392 trees/ha; Otryt 1 and 2 – 570 and 504 trees/ha) – Table 1. They also differed with respect to the distribution of the number of trees and volume in individual diameter classes (Figs. 1–3).

The investigated stands had a diversified storied structure (Table 2, Fig. 4). There were uneven-aged stands ranging in

| Formulas	Denotations
	Meyer function
$a = \dfrac{1}{\bar{d} - b}$	a, k – parameters $\bar{d}$ – mean stand $d_{1.3}$ b – $d_{1.3}$ measurement threshold
$k = \dfrac{N_1}{e^{-ad_1}}$	N_1 – theoretical number of trees in the first size gradation e – base of a natural logarithm ε – range of size gradation (4 cm) d_1 – middle value of the first size gradation (10 cm)
$N_1 = N\,(1 - e^{-a(d_1 + 0.5\,\varepsilon - b)})$	N – number of trees in a stand (No./ha)
	Liocourt sequence
$q_R = e^{-a\varepsilon}$	
	q_R – quotient of the Liocourt geometric sequence according to Rutkowski; $0 < q_R < 1$
$q = \dfrac{1}{q_R}$	q – parameter ε – as in Meyer function A – theoretical number of trees in the first size gradation
$A = N \cdot (1 - q_R)$	N – as in Meyer function
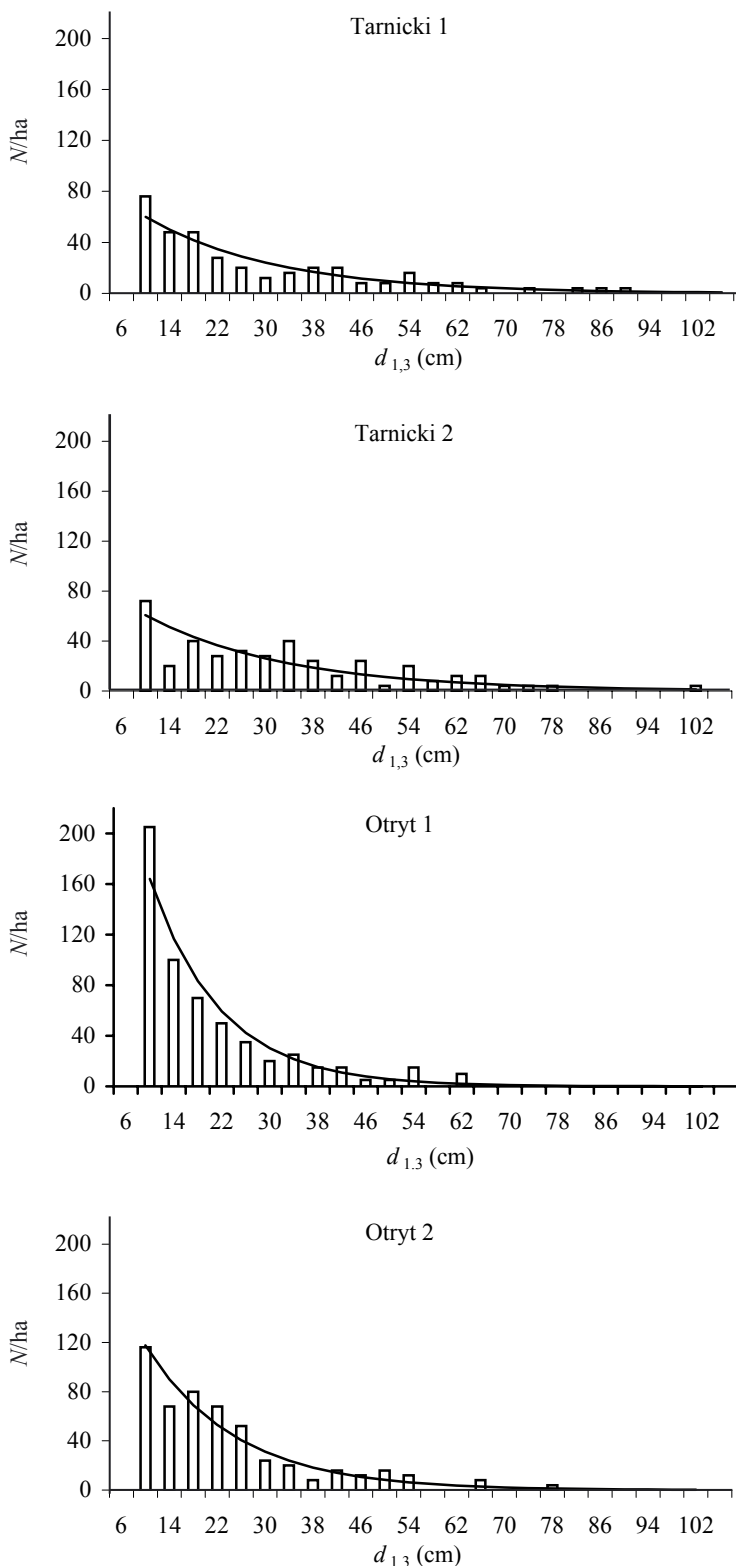
Fig. 1. Diameter ($d_{1.3}$) distribution compared to the Liocourt and Meyer curve

age from about approximately 20 to 170 years (Tarnicki), and from approximately 50 to 120 years (Otryt) (no regeneration was taken into account) (Tables 3 and 4).

Trees of the growing up generation of normal vitality (C_2) were the most abundant in all plots (Fig. 5). Trees

of the generation of optimal growth, luxuriant (B_1) and of normal vitality (B_2) were more abundant in the Tarnicki 1 and 2 plots than in the Otryt 1 and 2 plots. Trees of the generation B_3 (weakened and dying) occurred only in the Tarnicki 1 and 2 plots, and they were not numerous there (Fig. 5).

There were no trees of the old age generation (A) in the Otryt 1 plot, while in the Otryt 2 plot they were not numerous.

The parameters of theoretical diameter ($d_{1.3}$) distributions computed for the Liocourt geometric sequence and Meyer function are shown in Table 5, and the diameter distribution in Fig. 1. The results of the chi-squared test showed that real (empirical) distributions of the number of trees were in agreement with the Liocourt-Meyer theoretical distribution in all plots investigated (Fig. 1).

The advanced undergrowth (D), from which the recruitment to the lower story takes place, showed a considerable variability in density in the Otryt 1 and 2 plots (165 and 40 trees/ha) as well as in Tarnicki 1 and 2 plots (124 and 44 trees/ha). In both stands vital beech under-growth (D_2) dominated (Table 6).

DISCUSSION

The stands investigated during this study differed with respect to the number of trees per hectare, diameter ($d_{1.3}$) structure, height structure, age, and volume per hectare. It is unlikely that differences in volume resulted from site variability because both stands are situated in a belt 600–920 m in elevation where the Carpathian beech forests (*Dentario glandulosae-Fagetum*) occurring between about 500 and 1,150 m in elevation grow under optimal conditions (ZARZYCKI 1963; MICHALIK, SZARY 1997).

The different origin of these two stands is the main factor responsible for these differences. The Tarnicki stand is situated in a zone of inaccessible stands. It developed as a result of spontaneous natural processes and is of primeval character with many large trees with $d_{1.3} \geq 52$ cm (Figs. 1 and 2). The Otryt stand was formed by intentional silvicultural activities, i.e. the cutting system similar to the Bavarian group cutting with a very long regeneration period.

The maximum age of beech trees was distinctly different in the two stands under discussion. In the Otryt stand it was about 120 years, while in the Tarnicki stand approximately from 150 to 170 years (Tables 3 and 4). This maximum age is much different from the age re-ported in the Keula selection forest, where it was 300 years
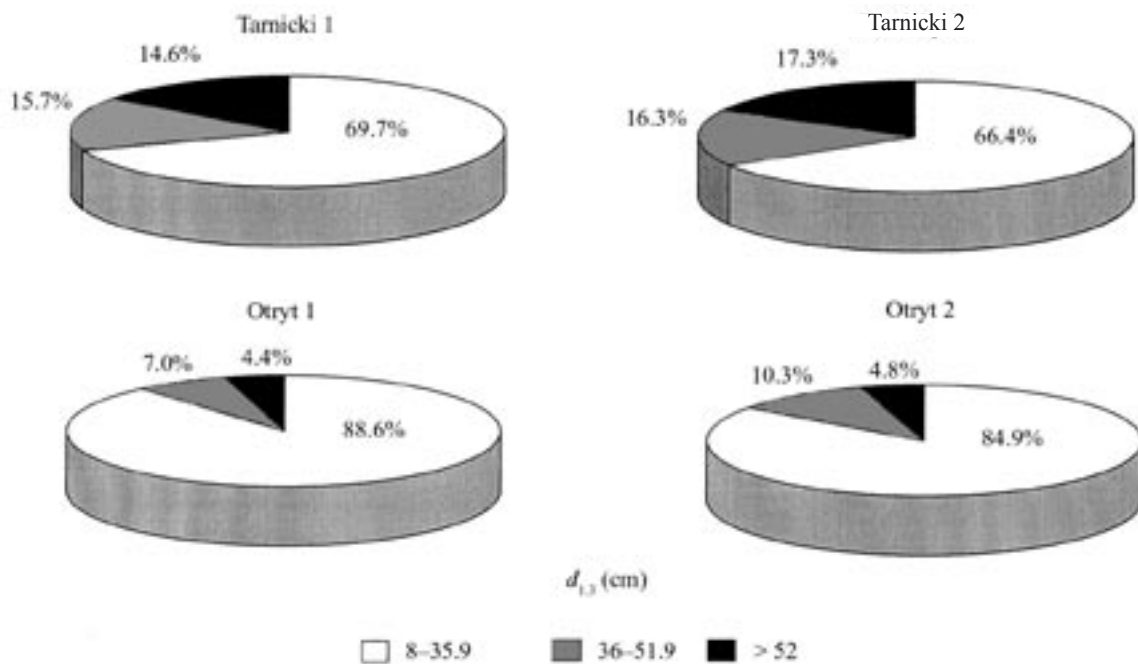
Fig. 2. Percentage of the number of trees in three diameter classes

($d_{1.3}$ over 80 cm) (LANDBECK 1952). It should be pointed out that the oldest beech trees measured in the Carpathian Mountains are not more than 250 years old (KORPEĽ 1995).

The Tarnicki stand is not the only stand that is in the selection phase of the growing up stage known in the Bieszczadzki National Park. Also in the neighboring compartments there are other beech stands in the growing up stage with structures close to a selection structure (JAWORSKI et al. 2000). However, the diameter distribution of two known stands, i.e. Beskidnik (67.10 ha in area) and Solinka (25.63 ha), does not agree (according to the chi-square test) with the Liocourt and Meyer distributions, as shown by the following comparison:

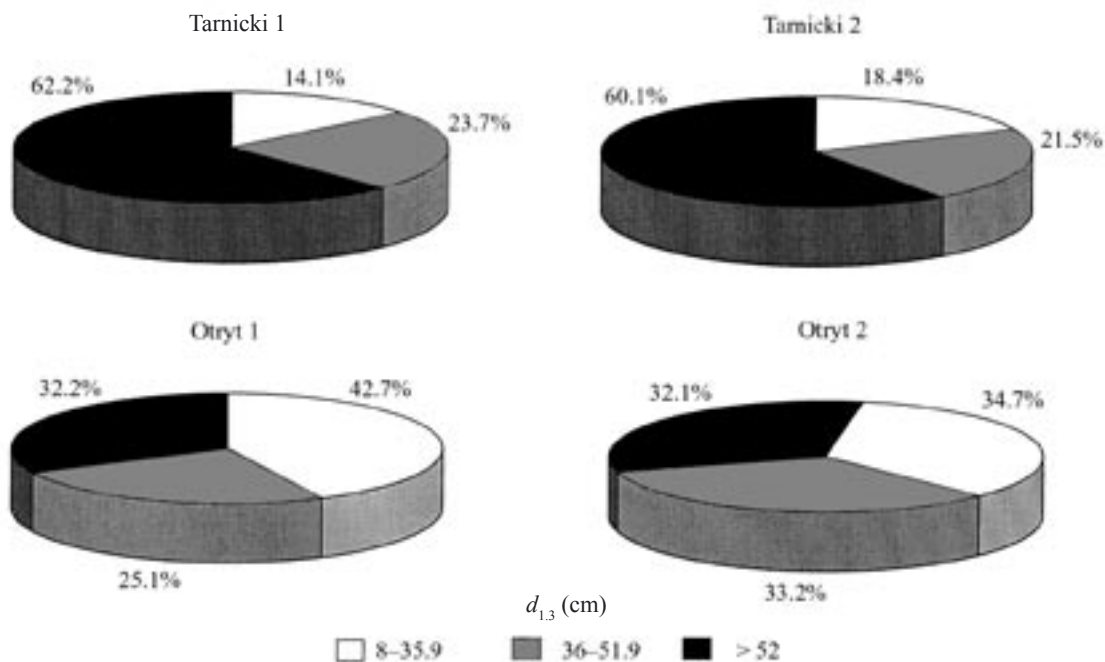| Stand	V	G	N	Parameters of Liocourt geometric sequence	
	(m³/ha)	(m²/ha)	(trees/ha)	A	q
Beskidnik	226.35	25.17	552	158	1.40
Solinka	529.29	40.49	450	85	1.23

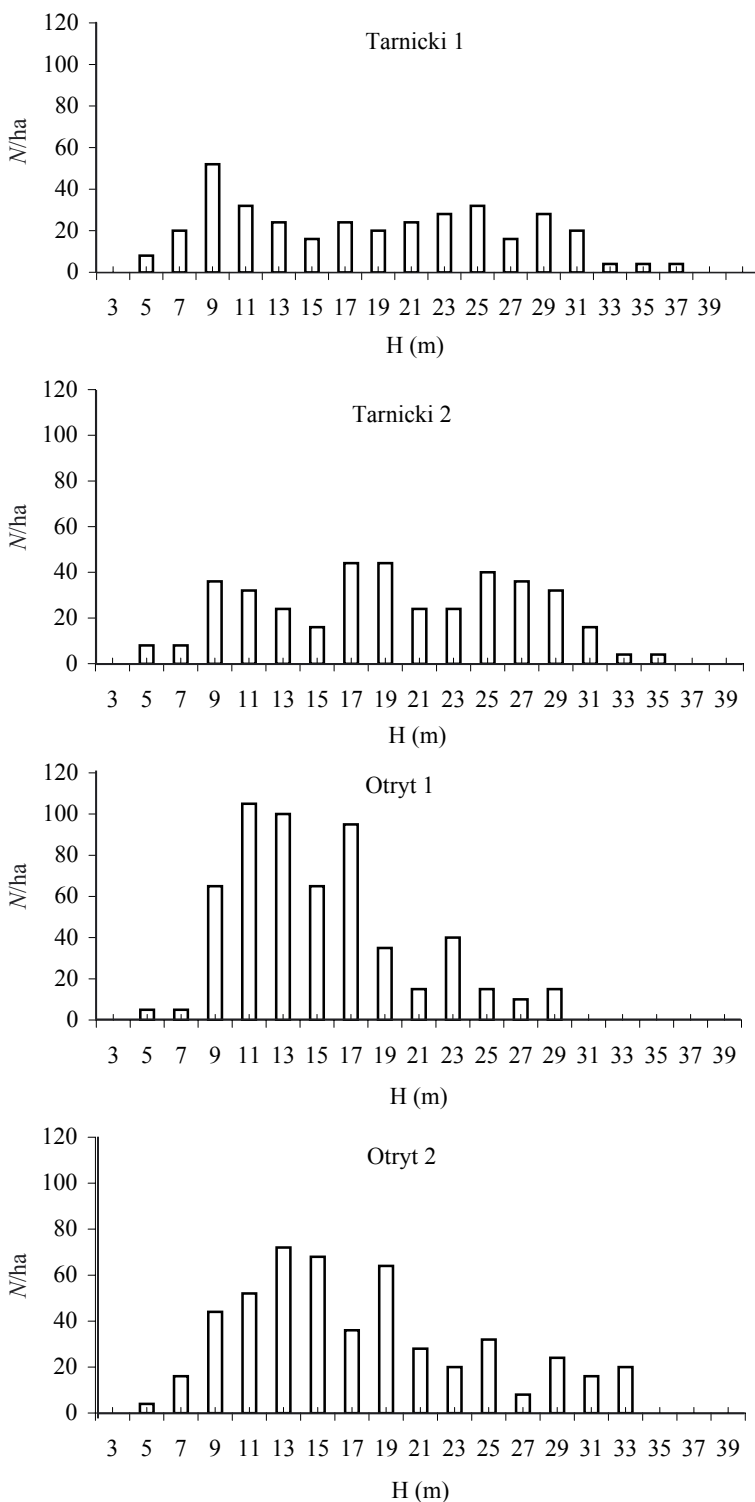Fig. 3. Percentage of tree volume in three diameter classes

Fig. 4. Distribution of tree height

The selection phase of a primeval forest is associated with the growing up and break-up stages (KORPEĽ 1995). The stands present in Tarnicki 1 and 2 plots are in the selection phase of the growing up stage because of the domination of trees of the growing up generation, the small number of trees of the old age generation (A) (Fig. 5) and volume per hectare (Table 1). The selection phase lasts for about 30 years, i.e. one-tenth of the entire

cycle (KORPEĽ, SANIGA 1993), which in beech forests is about 230–250 years (KORPEĽ 1995). As a result of subsequent development a diversified storied structure begins to disappear (KORPEĽ 1995).

In the primeval forests of the Eastern Carpathians the growing up stage develops under a wide range of stand volume per hectare (see the comparison on the next page), and this volume is often larger than the volume in the optimum stage.

It may be expected that the diversified structure in the Otryt stand will be maintained thanks to selection cuttings presently being carried out. The lack of data concerning the tree increment, rate of tree mortality (Tarnicki 1 and 2, Otryt 1 and 2), and also the extent of cutting (Otryt 1 and 2) does not allow to determine whether the permanent maintenance of a complex structure of these stands is possible. It is possible that in order to reach this goal it may be necessary to lower stand volume per hectare (mainly it concerns the Tarnicki 1 and 2 plots).

Since site conditions are similar, the stands investigated during this study may be compared to selection beech forests in Slovakia (SANIGA 1998 a,b; SANIGA, SZANYI 1998) (Table 5, Fig. 6).

The stand in the Otryt 1 plot and stands in Slovakia (Zvolen and Čergovska Mts. – SANIGA 1988a,b) are characterized by the same theoretical diameter distribution curve (Fig. 6). Such a curve in the stand in the Otryt 2 plot indicates a smaller number of trees in small and medium size gradations than is present in selection forests of Slovakia (Zvolen and Čergovska Mts.), but a larger number than in Keula (GROSSMAN 1959) (Fig. 6). The diameter distribution curves for stands in the Tarnicki 1 and Tarnicki 2 plots are very similar (Fig. 6, Table 5). However, these distributions are flatter than in selection stands of Langula (GEROLD, BIEHL 1992) and Nižna Jablonka (Slovakia) (SANIGA, SZANYI 1998) (Fig. 6). It should be pointed out that in the case of the Langula stand the authors gave parameters of Meyer distribution ($k = 160$, $a = 0.055$) which are replaced in the graph by the parameters q and A of the Liocourt sequence.

The maintenance of the structure characteristic of a selection forest requires, among other things, the continuity of the regeneration process. In the stands under study of the Bieszczady Mountains the number of the advanced undergrowth ($d_{1.3}$ 6–7.9 cm) from which the recruitment to the lower stand story takes place was 44 and 124 trees per hectare (Tarnicki 1 and 2), and

Stand	Volume (m³/ha)	Stage and phase	Author
Stužica	564	growing up stage	KORPEĽ (1995)
Stužica*	710	selection phase	
Vihorlat	400-600	optimal stage	REH (1993)
Popričny	700		REH (1993)
Havešová	720		KORPEĽ (1989)

*Fir participation 20%

Table 3. Mean age of beech trees in the Tarnicki 1 and Otryt 1 plots (1998 data)

Plot	Class of development generation*	Age at ground level (years)
Tarnicki 1	C_1	70
	C_2	20
	B_1	110
	A_2	150–160
Otryt 1	C_1	50
	C_2	50
	B_2	80–90

*Development classes of trees:
A – generation of old age
B – generation of optimal growth
C – generation of growing up

Vitality:
1 – luxuriant
2 – normal
3 – weakened

40 and 165 trees per hectare (Otryt 1 and 2) (Tables 1 and 6).

It is worth pointing out that the number of advanced undergrowth does not show the expected relationship with stand volume. This suggests that volume, even when site conditions are comparable, may only be one of many factors affecting the amount of regeneration.

SCHÜTZ (1989), quoting the results of DUC, reported that in order to secure recruitment in fir selection forests there should be 160–350 trees, 4–8 cm in $d_{1.3}$ per hectare in the undergrowth. Data concerning beech undergrowth may be found in the paper of SANIGA and SZANYI (1998). There the number of trees ($d_{1.3}$ 2–7 cm) in the undergrowth was 156 per hectare. It may therefore be assumed that the number of trees in the advanced undergrowth is satisfactory in the Tarnicki 1 and Otryt 1 plots (Table 6), while in the Tarnicki 2 and Otryt 2 plots it is too small.

SCHÜTZ (2001) stressed that a satisfactory number of trees in the regeneration and the lower stand layer is a basic problem in beech selection forests. Moreover, these trees should be of good vitality and growth, which guarantees their constant transfer to higher size gradations. He also concluded that at a stand volume above 300 m³/ha and basal area above 27 m²/ha these requirements were impossible to fulfill. These values are considerably higher in the Tarnicki stands 1 and 2 (Table 1).

Table 4. Age of beech trees in the Tarnicki 2 and Otryt 2 plots (2002 data)

| Tree No.	Class of development generation*	Diameter ($d_{1.3}$) (cm)	Height (m)	Age at ground level (year)	Age at $d_{1.3}$ (years)
		Tarnicki 2			
37	C_1	30.0	21.0	168	146
49	C_1	24.0	18.5	–	85
44	C_2	14.0	15.2	79	68
54	C_2	16.0	18.0	135	124
90	C_2	8.0	7.8	45	30
87	B_1	55.0	27.5	–	142
7	B_2	46.0	27.5	–	156
52	B_2	43.0	25.4	–	89
		Otryt 2			
32	C_1	26.0	21.0	–	47
54	C_1	28.0	21.5	–	71
115	C_1	25.0	22.0	120	112
25	C_2	17.0	15.7	69	62
72	C_2	9.0	10.7	68	60
1	B_1	66.0	32.0	–	79
110	B_1	50.0	28.2	–	74
66	B_2	53.0	30.0	–	85
87	B_2	47.0	32.5	–	105

*Explanation see Table 3
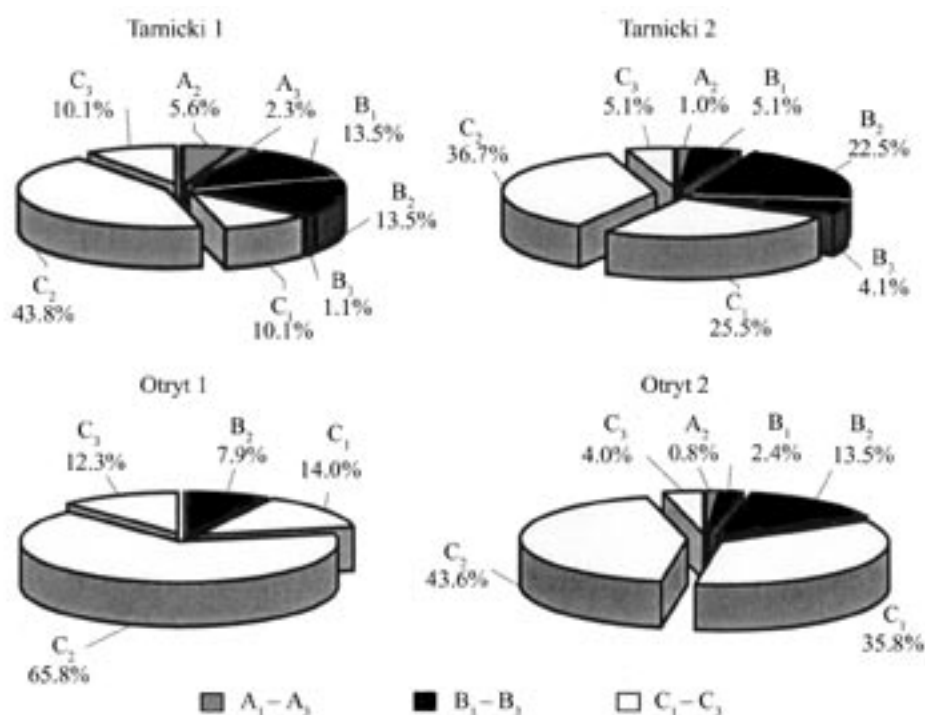
Fig. 5. Percentage of trees in individual classes of Rehak's development generations

However, constant transfer of trees into the higher stories is indicated in these stands by satisfactory vitality of beech trees in the lower layer (generation C) and in the undergrowth (D) (Fig. 5, Table 6).

In selection forests the continuity of processes of regeneration and tree transfer to higher height classes is associated, among others, with the optimal stand volume per hectare (Der optimale Gleichgewichtsvorrat). There is a question of how the volumes of the four investigated plots compare with the volume of beech selection forests assumed to be the optimal.

According to SCHÜTZ (1992), who quoted Schaffer, a stand volume below 250 m³/ha is required in order to keep the rule of the biological automation of production

Table 5. Parameters of the Meyer distribution and Liocourt sequence of investigated sample plots

Sample plot	Meyer function		Liocourt sequence		
	a	k	A	q_R	$q = \dfrac{1}{q_R}$
Tarnicki 1	0.0490	103	63	0.8222	1.22
Tarnicki 2	0.0420	93	61	0.8454	1.18
Otryt 1	0.0848	383	164	0.7123	1.40
Otryt 2	0.0664	229	118	0.7667	1.30

Table 6. Characteristics of beech undergrowth in the investigated plots

Plot	Classes of beech undergrowth*							
	D_1		D_2		D_3		Total	
	(N/ha)	(%)	(N/ha)	(%)	(N/ha)	(%)	(N/ha)	(%)
Tarnicki 1	16	12.9	96	77.4	12	9.7	124	100
Tarnicki 2	–	–	28	63.6	16	36.4	44	100
Otryt 1	10	6.0	125	75.8	30	18.2	165	100
Otryt 2	8	20.0	32	80.0	–	–	40	100

*D_1 – luxuriant undergrowth with increased rate of growth showing tendency to enter the lower stand story, D_2 – vital undergrowth but waiting for favourable conditions to advance to class D_1 (however it may drop to class D_3), D_3 – suppressed individuals of low vitality
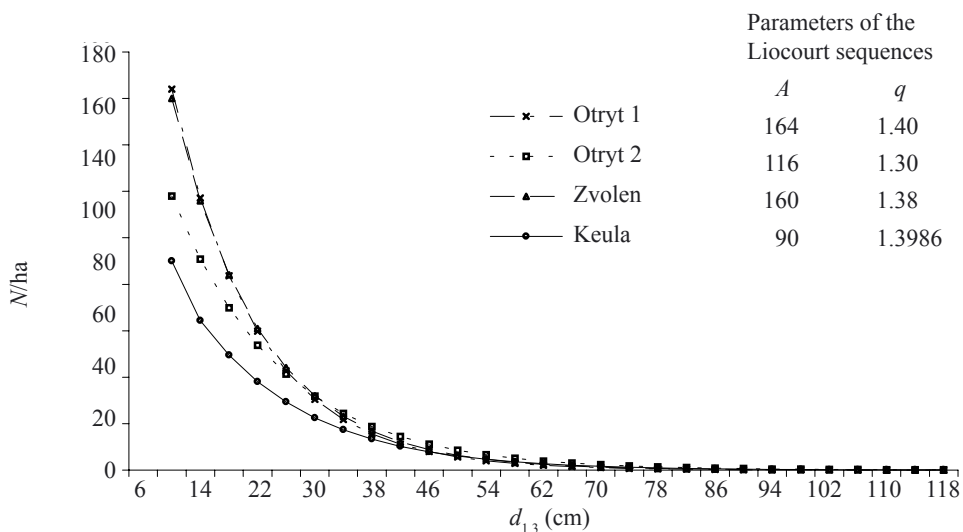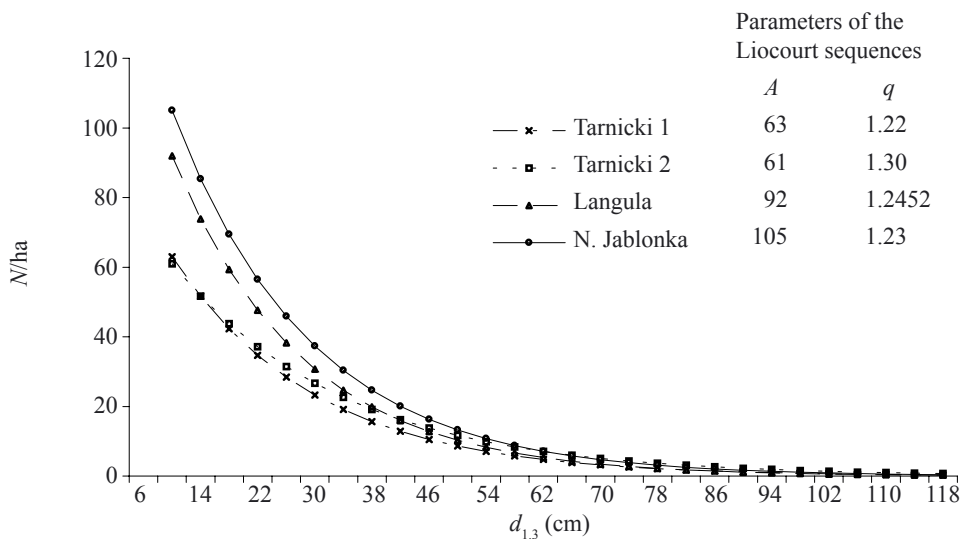
Fig. 6. Theoretical diameter ($d_{1.3}$) Liocourt and Meyer distributions of stands in the Bieszczady Mts. (Tarnicki 1, Tarnicki 2, Otryt 1, Otryt 2), Slovakia (Zvolen and Nižna Jablonka), and Germany (Keula and Langula)

(permanent dynamic regeneration and transfer of trees in diameter and height classes). On the basis of studies in Langula GEROLD and BIEHL (1992) also indicated the necessity to maintain a low stand volume (180–240 m³/ha) at poorer sites (Oberhohenleistungklasse 3). For the Langula beech selection forest SCHÜTZ (2001) assumed an optimal volume of 220 m³/ha. The Otryt stand has a volume (238 m³/ha) close to the volume cited above, but smaller than that assumed by SANIGA (1998a,b) (260 and 280 m³ per ha). Thus it is similar to a selection forest formed as a result of using the modified selection cutting (SCHÜTZ 1981) aimed at the production of medium size products. The maintenance of such stands requires active promotion of regeneration, higher number of trees in the lowest size gradations and distinctly lower stand volume. The Otryt 2 stand has a volume (324 m³/ha) close to the average volume in the Keula stand (280–315 m³/ha), but much lower than in the Keula sample plot 19/20 (410 m³/ha) – DITTMAR (1990).

The stands in the Tarnicki 1 and 2 plots are characterized by a considerably higher volume (442 and 517 m³ per ha) and large percent of very large diameter trees, and also a relatively small number of trees in the lowest size gradation (Figs. 1 and 2). These characteristics correspond to characteristics typical of a forest managed by the classical selection cutting aiming at the production of large diameter products during longer periods of time, which is particularly useful in fir stands (SCHÜTZ 1981). A considerably higher stand volume in the Tarnicki 2 plot (Table 1) may, however, hinder the regeneration process, as indicated by a lack of generation D_1 trees (Table 6).

In the Tarnicki 1 and 2 plots the volume per hectare is higher than that assumed by GEROLD and BIEHL (1992) as the optimal volume for beech stands at the best sites (300–360 m³/ha) where trees at the most grow to 32 m in height (Oberhohenleistungklasse 1). According to these authors a selection structure disappears at a stand

volume below 100 m^3/ha and above 500 m^3/ha. In the Eastern Carpathians (Slovakia) the selection forests with fir (40%) and beech (60%) are in equilibrium at an optimal stand volume of 470–500 m^3/ha (SANIGA, SZANYI 1998). Under conditions of the Bieszczady Mountains beech reaches the highest stand quality (JAWORSKI et al. 1991), which made it possible in the primeval forest to form the selection phase in the growing up stage at a relatively high stand volume. Under strict protection, i.e. without human interference in the growth and development of stands, this phase will be maintained for about 30 years (KORPEĽ, SANIGA 1993), and in the next period with an increasing stand volume per hectare the phase of a two-storied structure will begin to form, and probably with time a one-storied structure in the optimum stage. This has been indicated by other fragments of the Tarnicki stand (compartment 260a), and other stands of the primeval beech forests in the Bieszczadzki National Park (JAWORSKI et al. 2002). It may be supposed that in the case of managed forests growing at such rich sites the formation of beech selection forests of about 440 m^3/ha per hectare is possible as was indicated by the results of SANIGA and SZANYI (1998) cited above.

The stands, investigated during this study, confirm the suppositions of Mitscherlich (ASSMANN 1961) that there are many states of equilibrium in a selection management system depending the on site and production goal. To determine how close the actual stand volume per hectare is to the optimal one requires control studies and also the determination of the rate of tree transfer within diameter classes.

CONCLUSIONS

This study carried out in beech forests of the Bieszczady Mountains showed that the selection structure may develop in forests of primeval character (Tarnicki) as well as in managed forests (Otryt).

The managed Otryt stand, characterized by a high number of trees, considerable percent of small diameter trees and small stand volume (238 and 324 m^3/ha) may be recommended in the case of production of medium-sized products in forests where protection and recreation functions dominate. The Tarnicki 1 stand of primeval character, characterized by a larger stand volume (442 m^3/ha) and a smaller number of trees in the selection phase of the growing up stage, makes it possible to obtain large size products during longer production periods at full maintenance of protection functions. The Tarnicki 2 stand shows a selection structure at high volume (517 m^3/ha), which probably hindered the regeneration. At the same time the stands in the Tarnicki 1 and 2 sample plots show a possibility of the formation of the selection phase in the growing up stage in forests of primeval character.

References

AMMON W., 1995. Das Plenterprinzip in der Waldwirtschaft. Bern, Verlag Paul Haupt: 172.

ASSMANN E., 1961. Waldertragskunde. München, BLV: 490.

BERNADZKI E., 1971. Problem zagospodarowania drzewostanów jodłowych. Sylwan, *130* (8): 19–30.

BERNADZKI E., 1995. Gospodarka leśna w obliczu zmian klimatu. Sylwan, *13* (1): 19–32.

DITTMAR O., 1990. Untersuchungen im Buchen-Plenterwald Keula. Forst u. Holz, *45* (15): 419–423.

FABIJANOWSKI J., JAWORSKI A., 1996. Kierunki postępowania hodowlanego w lasach karpackich wobec zmieniających się warunków środowiska. Sylwan, *140* (8): 75–98.

GEROLD D., BIEHL R., 1992. Vergleich zwischen Buchenplenterwald und Buchenbetriebsklasse. Allg. Forstz., *47* (2): 91–94.

GRANICZNY S., 1971. Niektóre problemy sposobów zagospodarowania lasu w drzewostanach jodłowych i jodłowo-mieszanych na Roztoczu w świetle badań. Sylwan, *130* (8): 9–17.

GROSSMANN H., 1959. Ergebnisse der im Jahre 1957 durchgeführten Holzvorrats- und Zuwachsinventur im Plenterwald Keula. Arch. Forstw., *8* (6/7): 666–689.

GRUNDNER F., SCHWAPPACH A., 1952. Massentafeln. Berlin, Verlag Paul Parey: 216.

JAWORSKI A., 1979. Charakterystyka hodowlana wybranych drzewostanów z udziałem jodły (*Abies alba* Mill.) w Karpatach i Sudetach. Acta Agr. et Silv. ser. Silv., *18*: 19–60.

JAWORSKI A., SKRZYSZEWSKI J., ŚWIĄTKOWSKI W., KARCZMARSKI J., 1991. Budowa i struktura dolnoreglowych drzewostanów o charakterze pierwotnym na wybranych powierzchniach w Bieszczadach Zachodnich. Zesz. Nauk. AR w Krakowie 254, Leśnictwo, *20*: 17–43.

JAWORSKI A., KOŁODZIEJ ZB., OPYD ZB., 2000. Bukowe lasy o charakterze pierwotnym jako model lasów przerębowych. Acta Agr. et Silv. ser. Silv., *38*: 3–31.

JAWORSKI A., KOŁODZIEJ ZB., PORADA K., 2002. Structure and dynamics of stands of primeval character in selected areas of the Bieszczady National Park. J. For. Sci., *48* (5): 185–201.

KORPEĽ Š., 1989. Pralesy Slovenska. Bratislava, Veda: 329.

KORPEĽ Š., 1995. Die Urwälder der Westkarpaten. Stuttgart, Gustav Fischer: 310.

KORPEĽ Š., SANIGA M., 1993. Výberný hospodársky spôsob. Praha, VŠZ a Písek, Matice lesnická: 127.

LANDBECK H., 1952. Über die Buchenplenterwälder in Nordthüringen. Der Wald, *2* (8): 244–247; (9): 279–282.

MEYER H., 1933. Eine mathematisch-statistische Untersuchung über den Aufbau des Plenterwaldes. Schweiz. Z. Forstwes., *84* (3): 33–46; (4): 88–103, (5): 124–131.

MICHALIK ST., SZARY A., 1997. Zbiorowiska leśne Bieszczadzkiego Parku Narodowego. Monografie Bieszczadzkie, *1*: 1–175.

NOWOSAD M., 1995. Zarys klimatu Bieszczadzkiego Parku Narodowego i jego otuliny w świetle dotychczasowych badań. Roczniki Bieszczadzkie, *4*: 163–183.

PRZYBYLSKA K., ZIĘBA ST., 2003. Rezultaty wdrożenia rębni stopniowej udoskonalonej w Leśnym Zakładzie Doświadczalnym w Krynicy. Sylwan, *147* (2): 20–29.

REH J., 1993. Structure, development and yield conditions of beech virgin forests in the Popricny Mts. In: KORPEĽ Š., SANIGA M. (eds.), Symposium über die Urwälder. Zvolen, Forstliche Fakultät der Technischen Universität: 23–25.

ŘEHÁK J., 1964. Vývoj stromů a porostních útvarů v přirozených lesích. Ochr. Přír., *19* (7): 105–113.

RUTKOWSKI B.,1968. Rozkład pierśnic według krzywej frekwencji Liocourta i Meyera. Zesz. Nauk. WSR w Krakowie, 38, Leśnictwo, *3*: 1–19.

SANIGA M.,1998a. Optimalizácia štruktúry a regeneračných procesov bukového výberkového lesa. Zvolen, Acta Fac. For., *40*: 17–27.

SANIGA M., 1998b. Štruktúra a regeneračné procesy bukového výberkového lesa. Lesnictví, *44* (6): 241–249.

SANIGA M., SZANYI O., 1998. Modely výberkových lesov vo vybraných lesných typoch a geografických celkoch Slovenska. Ved. Štúd., Zvolen, Technická Univerzita, *4/A*: 1–50.

SCHÜTZ J. PH., 1981. Que peut apporter le jardinage a notre sylviculture. Schweiz. Z. Forstwes., *132* (4): 219–241.

SCHÜTZ J. PH., 1989. Der Plenterbetrieb. Zürich, ETH: 54.

SCHÜTZ J. PH., 1992. Die Waldbauliche Formen und die Grenzen der Plenterung mit Laubbaumarten. Schweiz. Z. Forstwes., *143* (6): 442–460.

SCHÜTZ J. PH., 2001. Der Plenterwald. Berlin, Parey Buchverlag: 207.

TRAMPLER T., MĄKOSA K., GIRŻDA A., BĄKOWSKI J., DMYTERKO E., 1990. Siedliskowe podstawy hodowli lasu. Warszawa, PWRiL: 197.

ZARZYCKI K., 1963. Lasy Bieszczadów Zachodnich. Acta Agr. et. Silv. ser. Silv., *3*: 3–132.

Bukové lesy se strukturou výběrného lesa v pohoří Bieszczady (jihovýchodní Polsko)

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ABSTRAKT: Příspěvek pojednává o porostních charakteristikách dvou bukových (*Fagus sylvatica* L.) porostů. První, nazývaný Tarnicki, nacházející se v Národním parku Bieszczady, představuje stadium dorůstání v porostu s výběrnou strukturou a pralesovitým charakterem. Druhý porost se jmenuje Otryt. Nachází se v hospodářském lese na Lesní správě Lutowiska. V každém z porostů byly založeny dvě zkusné plochy. Rozdělení četností stromů na zkusných plochách odpovídá Liocourtovu pořadí a Meyerově křivce. Oba porosty jsou charakteristické strukturou mnoha generací. Porost Otryt se zásobami zkusných ploch 238 a 324 m³/ha byl charakteristický nedostatkem silných stromů a vysokým procentem nejtenčích jedinců, zatímco porost Tarnicki se zásobami zkusných ploch 442 a 517 m³/ha byl charakteristický zastoupením silných ($d_{1,3} \geq 72$ cm) stromů. Výběrná fáze porostu Tarnicki má dočasný charakter, protože zde vzhledem k přírodním procesům může dojít k vytvoření dvouetážové a později ve stadiu optima jednoetážové struktury. V porostu Otryt reprezentujícím hospodářský les lze udržení výběrné struktury očekávat vzhledem k aplikaci výběrné seče. Z toho tedy vyplývá, že v podobně strukturovaných obhospodařovaných porostech je možné pokračovat s aplikací výběrné seče, zvláště v ochranné zóně obklopující Bieszczadský národní park.

Klíčová slova: výběrný les; prales; vývojová stadia; Liocourtovo a Mayerovo rozdělení

Cílem práce je zjistit, jaké jsou porostní charakteristiky bukových lesů pralesovitého charakteru ve výběrné fázi stadia dorůstání (porost Tarnicki, oddělení 260a – dvě zkusné plochy) a hospodářských bukových lesů s mnohovrstevnou strukturou (Otryt – dvě zkusné plochy). Dále pak určit, zda porosty s touto strukturou mohou sloužit jako model k užití výběrné seče v bukových lesích jihovýchodního Polska. Porost Otryt se zásobami zkusných ploch 238 a 324 m³/ha byl charakteristický nedostatkem silných stromů ($d_{1,3}$ < 52 cm) a vysokým procentem nejtenčích jedinců (8,0–15,9 cm), zatímco v porostu Tarnicki se zásobami zkusných ploch 442 a 517 m³/ha byl počet slabých stromů výrazně menší a procento silných stromů zase vyšší. Sledované porosty jsou charakteristické diverzifikovanou víceetážovou strukturou a různověkou strukturou zastoupenou na malém území (Tarnicki 20–170 let, Otryt 50–120 let). Tyto porosty jsou zřetelně rozdílné s ohledem na rozdělení počtu stromů a zásoby v jednotlivých tloušťkových a výškových třídách. Výsledky testu chí-kvadrát ukázaly, že skutečné (empirické) rozdělení počtu stromů na sledovaných plochách odpovídají v obou porostech teoretickému Liocourtovu a Meyerovu rozdělení (α = 0,05).

Analýza vitality a růstové tendence obnovy a ovšem i stromů v nižších i vyšších stromových etážích ukázala trvalý přesun stromů do vyšších porostních vrstev.

Výběrná fáze v porostu Tarnicki je dočasná vzhledem k přírodním procesům, časem se zde může vyvinout méně

diverzifikovaná struktura. Naopak u obhospodařovaného porostu Otryt je možné očekávat udržení dosavadní struktury vzhledem k současné aplikaci výběrné seče. Lze předpokládat, že obhospodařované porosty s podobnými porostními charakteristikami umožňují použití výběrné seče.

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