DENDROBIOLOGY
2004, vol. 51, Supplement 81–86

Stanisław Orzeł, Marcin Forgiel

Biometric characterisation of selected seed stands of *Picea abies* (L.) Karst. of Istebna

Abstract: The paper assesses the growth of nine seed stands of *Picea abies* (L.) Karst. of Istebna. The stands were selected on the basis of the dynamic height growth and good adaptation of their progeny under different site conditions. The d.b.h. increment of trees during the entire lifespan of stands is analysed in detail, especially its magnitude and dynamics during the last twenty years, i.e. from 1982 to 2001.

Additional key words: stand taxation characteristics, crown length, d.b.h. increment, merchantable wood volume increment

Address: S. Orzeł*, M. Forgiel, Agricultural University of Kraków, Department of Forest Mensuration, al. 29 Listopada 46, 31-425 Kraków, Poland
* Corresponding author: e-mail: rlorzel@cyf-kr.edu.pl

Introduction

Proper management is of great importance to Carpathian forests because they perform multiple functions, serving social purposes (protection, recreation, etc.) and economic aims (production of valuable raw material). Their present species composition is largely the result of forestry activities pursued during the second half of the 19th century and early years of the 20th century. The introduction of pure spruce (*Picea abies* (L.) Karst.) stands in the lower mountain vegetation belt in place of natural mixed stands created and still creates, many protection-related problems not only in the Western Beskids, but also in other mountain ranges (Capecki 1981; Król 1988). This does not mean that there is a lack of healthy, highly productive spruce stands in this belt (Rieger 1968, 1972; Orzeł 1993; Orzeł et al. 1999). Spruce, due to its site requirements, is a natural tree species of mountain forests. Thus, the problem lies not in its presence in mountain stands, but in its optimal proportion in their structure and the need for conversion. From the point of view of forest management, the planting stock should be produced from seeds collected in stands having, i.a., a high productivity.

The study was aimed to evaluate tree increment in the seed stands of Istebna spruce, selected on the basis of the genetic and silvicultural value of their progeny.

Material and methods

The study was conducted in nine seed stands of *Picea abies* (L.) Karst. situated in the Wisła Forest District. The stands were selected according to the criteria suggested by Sabor (2000), i.e. the good adaptability and dynamic height growth of their progeny grown under different conditions. In the early spring of 2002, permanent sample plots were established in the stands. The size of plots depended on the area occupied by a stand. Wherever possible, 0.5-ha plots were used. All trees occurring on a plot were permanently marked and their d.b.h. was measured. The measurements of tree height, bark thickness, crown length and d.b.h. increment were based on a sample of over 30 trees selected at random. From each sample tree, two icrement cores were taken: one, reaching the pith, on the tree side facing the slope, and the other, perpendicular to the first one, including the last 20 years of tree life. This method made it possible to examine the radial increment changes taking place during the entire lifespan of a tree as well as to determine the magnitude of d.b.h. increment during the period from 1982 to 2001.

The results of the measurements enabled determination of the following:

– the basic taxation characteristics of stands and the parameters of distribution of such dendrometric characteristics as d.b.h. (d), height (h), volume of merchantable wood (v_g), crown length (l_k), slenderness (s) and double bark thickness (k),
– d.b.h. increment and volume increment of merchantable wood for two 10-year periods: 1982–1991 (Zd1, Zv1) and 1992–2001 (Zd2, Zv2),
– pattern of the mean radial increment at breast height during the entire lifespan of trees in the investigated stands.

The volume of merchantable wood of individual trees (v_g) was computed according to the formula:

$$v_g = \frac{\pi}{4} d^2 \cdot h \cdot f_g$$

where:

d – tree d.b.h.,

h – tree height determined from Näslund's curve in a general form (Bruchwald and Rymer-Dudzińska 1981):

$$h = 1.3 + \left(\frac{d}{a + b \cdot d}\right)^2$$

f_g – d.b.h. form factor of merchantable spruce wood, computed using an empirical formula worked out by Bruchwald and Rymer-Dudzińska (1996):

$$f_g = \left(0.34 + 0.684 \cdot d^{-0.5}\right) \cdot \left[1 - 225.73 \cdot (d-1)^{-3.2542}\right]$$

Results and discussion

Characteristics of stands

The stands under study were mature stands growing in most cases on the mixed mountain forest site (Table 1). Five of them (22t, 91g, 108f, 109f and 149h) constituted approved seed stands (Cieślar 2001). The youngest stand (88b) was 100 years old, and the oldest one (95f) was 175. Stands 91g and 95f had a very low stocking. They were composed of spruce trees of older generation, growing at large distances from one another. In stand 95f, regeneration made up of the progeny of spruce growing there occurred in most plots, while stand 91g was in the process of stand conversion. Therefore, the results concerning these two stands required a separate interpretation. From among the remaining stands, three were pure spruce stands without any admixture tree species (Table 1).

The data provided in Table 1 show that the average values of d.b.h. and height were generally related to stand age. Slightly lower values for the stand 15h resulted most likely from poorer site conditions (mixed mountain coniferous forest site). The impressive d.b.h. and height, and consequently the volume of trees (Table 2), as well as their relatively high number per area unit caused that their basal area and stand volume, especially those of stands 149h and 108f (Table 1), were distinctly superior to the model values given in the stand volume and increment tables for spruce of quality class I at full stocking (Szymkiewicz 1961).

It follows from the data shown in Table 2 that the investigated stands were stable since the mean coefficient of slenderness ranged from 0.654 to 0.910. Only some single trees exhibited lower stability and the ratio between their height and d.b.h. exceeded 1.0. The stability of a tree also depends greatly on the length of its crown.

Table 1. Selected taxation characteristics of seed stands of *Picea abies* (L.) Karst

Management unit	Stand	Forest site type*	Size of sample plot (ha)	Stand age (years)	N (trees ha^{-1})	Dg (cm)	HL (m)	G ($m^2 ha^{-1}$)	V ($m^3 ha^{-1}$)
Istebna	109f	LMG	0.50	115	294	44.2	39.0	45.12	775.0
	108f	LMG	0.50	125	324	45.0	39.8	51.45	901.7
	45f	LMG	0.50	140	214	49.9	39.3	41.76	712.8
	149h	LMG	0.50	162	258	51.4	46.6	53.60[1]	1081.0
Wisła	88b	LMG	0.50	100	224	41.5	35.1	30.26[2]	470.4
	22t	LMG	0.50	135	266	46.6	40.9	45.02[3]	808.6
	15h	BMG	0.35	160	211	44.7	33.1	33.12[4]	481.5
	91g	LMG	0.25	155	80	53.4	39.1	17.90[5]	302.1
	95f	BMG	0.50	175	64	53.8	35.8	14.52[6]	222.4

* LMG – mixed mountain forest, BMG – mixed mountain coniferous forest ; 1 – fir (*Abies alba* Mill.) 0.91 $m^2 ha^{-1}$ + beech (*Fagus sylvatica* L.) upgrowth; 2 – beech 4.86 $m^2 ha^{-1}$; 3 – fir 2.36 $m^2 ha^{-1}$; 4 – larch (*Larix decidua* Mill.) $m^2 ha^{-1}$, beech 0.24 $m^2 ha^{-1}$; 5 – fir 6.08 $m^2 ha^{-1}$ + beech understorey 12.20 $m^2 ha^{-1}$; 6 – fir 1.64 $m^2 ha^{-1}$, beech 2.87 $m^2 ha^{-1}$ + spruce (*Picea abies* (L.) Karst.) upgrowth

Table 2. Statistics of dendrometric characteristics of trees in seed stands of *Picea abies* (L.) Karst

Tree characteristic	Statistics	Stand								
		109f	108f	45f	149h	88b	22t	15h	91g	95f
d.b.h. (d) in cm	mean	43.6	44.3	49.1	50.4	40.8	45.6	44.1	52.5	51.6
	min	27.9	30.4	31.1	28.0	16.5	30.1	28.8	35.1	30.3
	max	62.2	64.6	67.5	78.7	63.0	76.0	65.4	68.1	99.4
	cv	16.3	16.8	17.2	20.0	19.0	20.4	16.4	20.5	29.4
Height (h) in m	mean	38.8	39.6	39.1	45.9	34.5	39.1	32.4	37.8	32.7
	min	33.3	32.6	32.3	37.0	28.2	29.3	28.6	30.0	18.4
	max	45.0	44.9	43.2	50.5	39.3	47.5	38.9	44.6	46.3
	cv	6.9	7.5	7.9	7.6	8.0	9.7	8.0	11.6	18.3
Volume of merchantable wood (v_g) in m^3	mean	2.636	2.783	3.331	4.190	2.100	3.040	2.282	3.776	3.475
	min	0.926	1.135	1.117	1.062	0.211	1.075	0.825	1.397	0.687
	max	5.533	6.150	6.474	10.393	5.356	9.007	5.278	6.557	14.672
	cv	36.1	37.3	37.6	42.0	42.3	49.0	31.2	46.7	78.2
Slenderness (s)	mean	0.872	0.874	0.773	0.910	0.862	0.900	0.751	0.732	0.654
	min	0.670	0.674	0.638	0.663	0.623	0.671	0.611	0.538	0.466
	max	1.094	1.099	1.038	1.322	1.127	1.090	1.005	0.906	0.848
	cv	12.6	13.2	13.0	16.0	13.3	12.2	11.7	13.2	14.2
Crown length (l_k) in m	mean	12.0	11.9	14.2	13.9	13.5	12.6	13.9	15.2	16.5
	min	6.4	6.7	6.7	3.8	7.3	4.5	8.5	7.8	5.4
	max	17.6	17.0	21.2	21.2	20.0	20.8	21.7	24.5	28.2
	cv	23.4	23.2	25.0	27.5	24.1	30.0	23.0	25.5	32.0
Relative crown length ($l_{k\%}$)	mean	30.9	29.8	36.2	30.0	38.7	31.7	42.5	39.8	50.5
	min	17.3	17.7	20.7	10.3	24.9	15.4	29.6	23.6	16.7
	max	45.8	41.2	49.9	43.0	53.9	47.9	59.1	55.3	73.2
	cv	20.9	17.6	20.7	22.7	18.9	23.0	17.3	17.5	25.0
Double bark thickness ($_k$) in cm	mean	2.35	2.54	2.22	2.17	2.18	2.17	2.39	2.42	2.61
	min	1.70	1.80	1.50	1.10	1.40	1.50	1.20	1.70	1.70
	max	3.40	4.00	3.00	3.40	2.90	3.70	3.40	2.90	4.00
	cv	15.5	17.3	16.4	25.3	17.5	18.0	17.5	16.7	20.3
Percentage of bark thickness ($p_{k\%}$)	mean	5.76	6.24	4.75	4.49	5.57	4.88	5.80	4.68	5.52
	min	3.91	4.36	3.22	2.63	4.04	3.15	3.53	3.64	3.54
	max	8.02	8.57	6.87	5.57	7.65	6.38	7.84	5.89	7.80
	cv	14.7	16.4	14.8	14.4	14.7	13.6	16.0	15.8	16.7

c_v – coefficient of variation (in %)

The mean absolute crown length of spruce trees in the analysed stands ranged from 11.9 to 14.2 m (29.8–42.5%).

Spruce belongs to the group of trees having thin bark evenly distributed along the entire trunk. For practical reasons, bark thickness is usually measured at a height of 1.3 m above the ground (b.h.). The investigated stands did not differ fundamentally in respect of this characteristic as the average value of double bark thickness at b.h. varied from 2.17 to 2.54 cm. Generally, bark thickness increases with tree age. However, trees in stand 108f, a relatively young one (125 years), had significantly thicker bark than trees in the remaining stands which were most often older. In the first case the bark made on average over 6.2% of tree d.b.h., while in the other stands it accounted for 4.5% (149h) to 5.8% (15h). Provenance studies of *Pinus sylvestris* L. (Orzeł and Sabor 1994) and *Larix decidua* Mill. (Orzeł and Kulej 1999) showed that this characteristic may be of great diagnostic importance.

Using increment cores reaching the pith made it possible not only to measure the d.b.h. increment of trees from the moment they attained the height of 1.3 m to the year 2001, but also to determine the percentage of trees attacked by rot. In five stands, i.e. 15h, 22t, 88b, 108f and 109f, the proportion of diseased trees was below 3%, in two, i.e. 45f and 95f, it was 6.3 and 7.4%, respectively, while in stand 91g it reached even 22.2%. The highest number of trees with internal rot was found in stand 149h (36.3%), commonly recognised as the leading seed stand of *P. abies*.

Increments of d.b.h. and stand volume

Increment is a measurable expression of the vitality of trees and stands (Assmann 1968). In standing trees, one usually measures the diameter increment at a height of 1.3 m above the ground. This is the only increment characteristic of a standing tree that can be measured directly. The diameter increment investigated (taking into account the age of the stands) may be considered as high (Table 3). Its mean value for the period 1982–1991 (Zd1) was from 1.47 cm (149h) to 3.05 cm (88b), while for the period 1992–2001 (Zd2), from 1.43 cm (149h) to 2.99 cm (95f). The data shown in Table 3 indicate that the d.b.h. increment during the 20-year study period remained at a similar level. In individual stands its value for the period 1992–2001 was only slightly smaller than the value for the period 1982–1991. In stands 22t and 95f, Zd2 was even greater than Zd1.

Stand volume increment is a measurable effect of the increment patterns of trees making a stand. The stands under study exhibited a high volume increment, from 6.7 to 11.5 $m^3 \cdot ha^{-1} \cdot year^{-1}$, and in no case its value for the period 1992–2001 was lower than for the years 1982–1991. It should be stressed that the increment value for spruce was computed only on the basis of trees present in a stand at the moment of measurement, which means that its actual value was even higher.

Pattern of the mean diameter increment during the entire lifespan of trees

The pattern of the diameter increment of trees growing under undisturbed conditions shows a definite regularity: after the culmination during the young age of trees, the diameter increment usually decreases from period to period (Assmann 1968).

The measurements of the cores reaching the pith made it possible to trace the diameter increment of individual trees during their entire lifespan. Figure 1 shows that the course of the mean radial increment curves of trees, especially in the case of younger stands, generally followed the pattern mentioned above. Its remaining on a similar level over the last few decades reflects the high growth dynamics of the stands.

Due to the substantial differences in age between the stands under study it was impossible to make a direct comparison between the absolute values of mean diameter increment for individual calendar years. After making necessary shifts on the time axis it became possible to compare the growth rings produced during the same years of tree life (Fig. 2). Although the results of such a comparison should be treated with some caution due to the changing weather conditions, considerable differences in the values of mean diameter increment between individ-

Table 3. D.b.h. increment and stand volume increment of seed stands of *Picea abies* (L.) Karst

Management unit	Stand	Zd1 (cm)	Zd2 (cm)	Zd2 $Zd1^{-1}$	Zv1 (m^3 ha^{-1})	Zv2 (m^3 ha^{-1})	Zv2 $Zv1^{-1}$
Istebna	109f	2.08 0.59–5.24	1.93 0.65–4.34	0.968 0.625–1.645	9.20	9.30	1.01
	108f	2.16 0.68–3.93	2.00 0.60–4.11	0.956 0.601–1.254	11.22	11.50	1.02
	45f	2.09 0.55–3.67	2.08 0.49–3.64	1.038 0.673–2.516	7.42	8.06	1.09
	149h	1.47 0.35–2.78	1.43 0.32–4.16	0.992 0.475–2.010	8.12	9.07	1.12
Wisła	88b	3.05 1.13–8.33	2.80 0.75–5.68	0.933 0.665–1.289	8.79	9.69	1.10
	22t	1.70 0.49–3.14	1.91 0.39–3.37	1.197 0.734–2.606	7.49	10.06	1.34
	15h	2.16 0.53–6.53	2.09 0.37–4.20	1.042 0.407–2.310	6.33	6.71	1.06
	91g	2.01 0.85–3.73	1.72 0.69–2.71	0.880 0.326–1.374	–	–	–
	95f	2.80 0.86–4.78	2.99 0.60–6.08	1.066 0.501–2.033	–	–	–

Zd1 – diameter (d.b.h.) increment for the period 1982–1991; Zd2 – diameter (d.b.h.) increment for the period 1992–2001; Zv1 – volume increment for the period 1982–1991; Zv2 – volume increment for the period 1992–2001

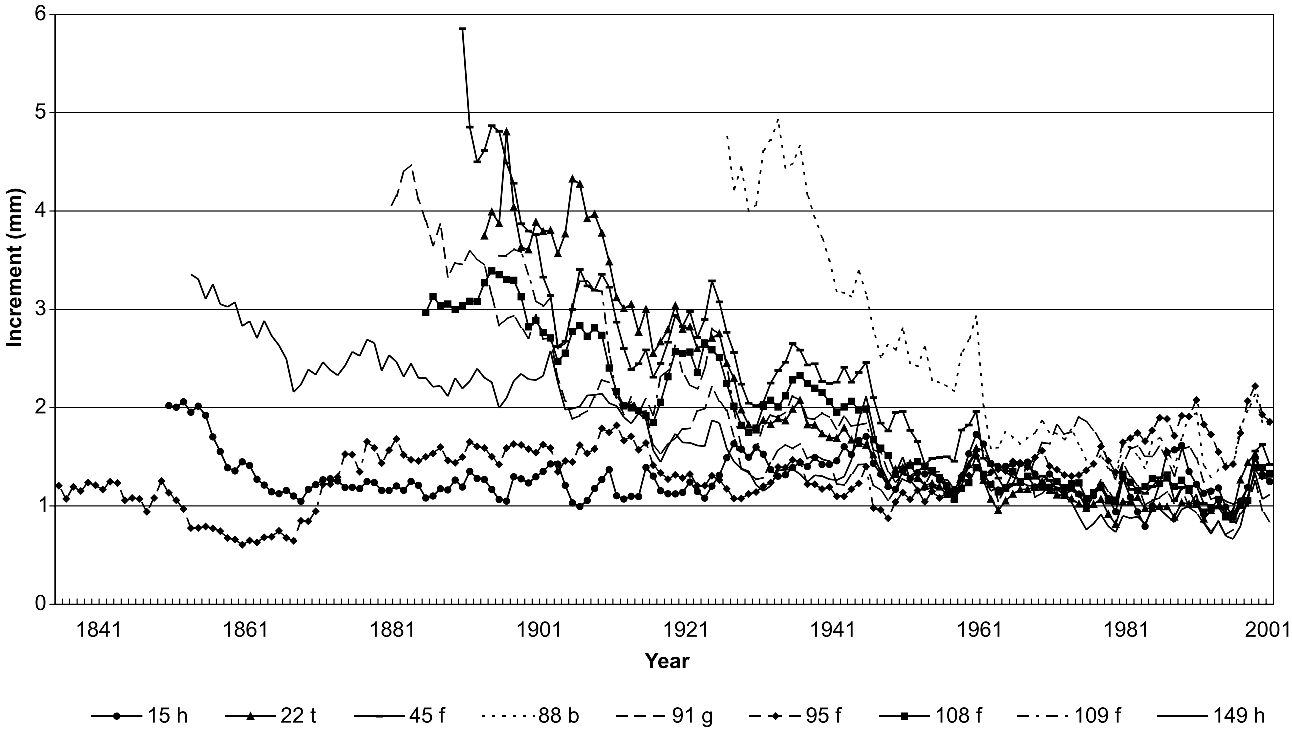

Fig. 1. Mean radial increment at b.h. of trees in seed stands of Picea abies (L.) Karst. as dependent on calendar year

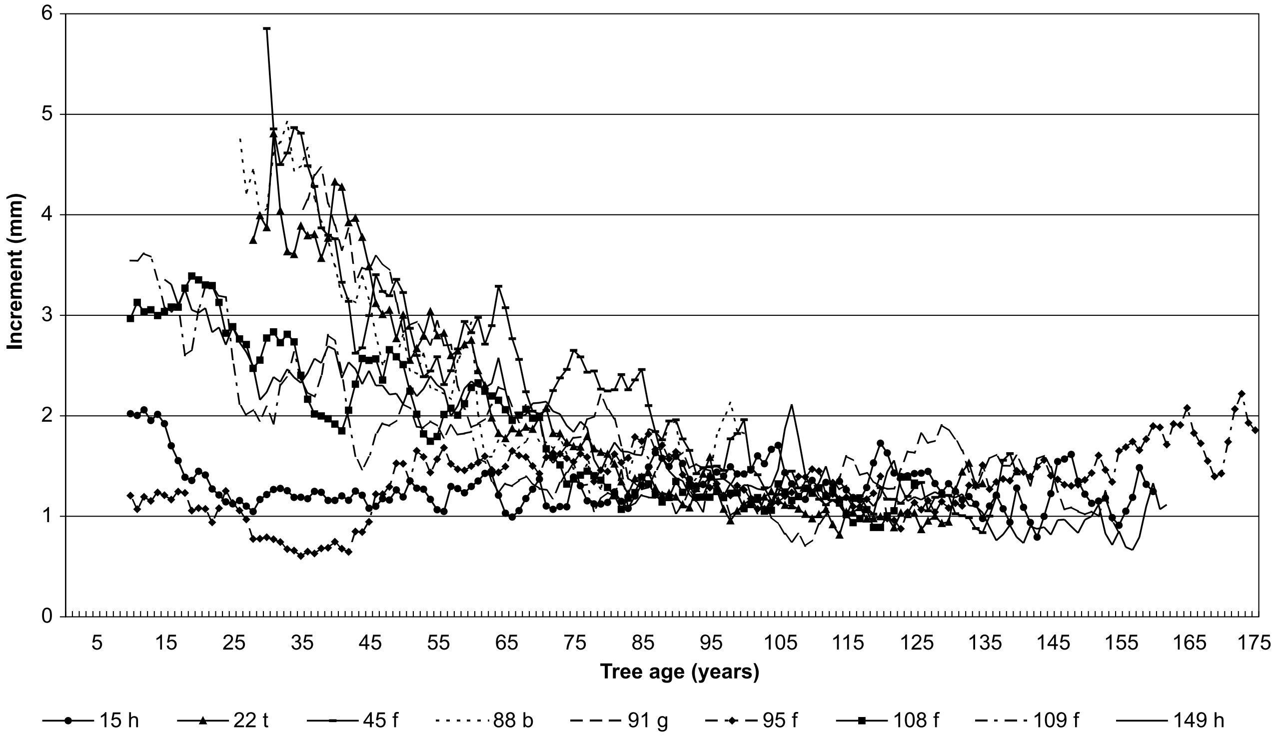

Fig. 2. Mean radial increment at b.h. of trees in seed stands of Picea abies (L.) Karst. as dependent on tree age

ual stands may be noticed. Figure 2 shows that stand 149h, considered to be the best seed stand of *P. abies* in Poland, may rank as average in respect of that characteristic.

Conclusions

1. The seed stands of Istebna spruce, investigated during this study, are stable and exhibit high vol-

ume and good growth parameters. A large number of the trees have impressive dimensions.
2. The diameter increment, remaining at a constant level during the last few decades, permits one to expect that most of the investigated stands will continue to considerably increase in volume.
3. Taking into account the age, present volume and health condition of trees as well as their increment patterns, stand 108f, and not stand 149h commonly believed to be the leader, should be considered the best in productivity terms.
4. A considerable number of trees with internal rot, growing in stand 91g, and especially 149h, may cause serious management problems in the near future.

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