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Provenance experiment with pedunculate (*Quercus robur* L.) and sessile (*Q. petraea* [Matt.] Liebl.) oaks established in 1968

Abstract

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Review of literature on European provenance experiments suggests that there are substantial differences between oak races not only in terms of growth but also in phenological traits, stem characteristics and other factors. In 1966 the Institute of Dendrology in Kórnik near Poznań established an experiment with Polish populations of pedunculate and sessile oaks, because these species are of economic interest in Poland. Seed used in this study was collected in the autumn of 1966 from seven oak reserves and two seed stands. A field trial located in Kórnik with 7 provenances of *Q. robur* and 2 of *Q. petraea* was established in spring 1968 in a randomised complete block design with 8 replications.

After 28-years the best growing provenances are the local one from Kórnik, from Dębina, and from Radziądz, all from western Poland, and from Białowieża from eastern Poland. Stem slenderness (tree height to breast height diameter ratio) varies with the provenances. Tree stems of Kórnik provenance are very robust, while the slow growing trees from Lipiny are slender. Among the studied provenances the most straight stems are characteristic for trees of provenance Białowieża. In spite of significant differences among provenances in all the studied traits the important for silviculture good stem form, does not go parallel with height growth and volume production.

The results indicate that sessile oaks grew less than the pedunculate oaks. There is a lack of any geographical pattern in the studied traits. Provenance differences concern stands rather than regions, which confirms the hypothesis about the existence of local ecotypes.

Additional key words: height, DBH, basal area, volume, stem slenderness, stem straightness, correlation.

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INTRODUCTION

Pedunculate and sessile oaks represent a very important component of forest in our country. The share of the two species in the whole forest area is but a few percent, however it is on the increase. It is necessary to improve genetically our oak populations and to select best genotypes to take advantage of the potential and possibilities

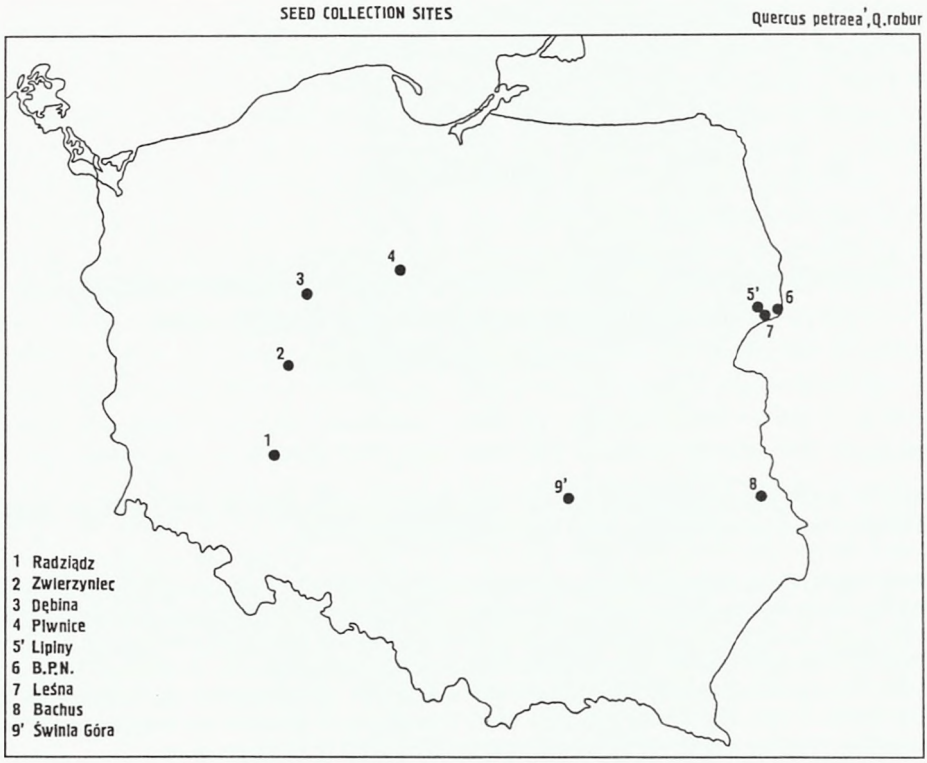

Fig. 1. A map of seed collection sites

of forest sites and to conduct a sensible management. In comparative experiments, in which various provenances grow in the same place and on the same site, we can compare the genetic value of several populations. Great interest in oak races throughout Europe results in the establishment of numerous provenance experiments with pedunculate and sessile oaks, from early nineteenth century till today (Kleinschmit 1993, Fober 1994a). The first oak plantations have been established from 1790 to 1920 at Černý Kostelec from indigenous seeds and from acorns transferred from Bohemia, Moravia, Silesia, Croatia and Vienna (Pokorný 1958). In Germany in 1877 Kienitz started studying oak races (Krahl-Urban 1957). Since the beginning of this century provenance experiments were established in Belgium, Austria, Denmark, Bulgaria, Switzerland, Czechoslovakia, Ukraine, Romania and former Yugoslavia. Great interest in oak races from numerous countries, led to scientific research, in Poland also, with indigenous oak populations. Basing on a good crop of acorns in the 1966 year, seed collection has been done for this experiment. Till then Polish forest management had not differentiated in practice the species variation of oaks, often both species were growing with a common silvicultural designation as oak. In order to take advantage in forest management of a better knowledge about the pro-

duction potential of Polish oak races a trial was established by me to test the most valuable provenances characterized by best height growth and also other variable qualitative traits of stem and wood as well as resistance to diseases.

MATERIALS AND METHODS

Acorns were collected in the autumn of 1966 from seven oak reserves and two seed stands (Fig. 1). The list of provenances with general information about locality and geographic coordinates of seed collection sites is given in Table 1. In October

Table 1

Origin of seeds used in the experiment

Provenance designation	Species	For. District For. Range Comp. "Reserve"	Long.	Lat.	Alt. (m)
1	2	3	4	5	6
Dębina S-08-192	*Q. robur*	Durowo Dębina 147c „Dębina"	17°09′	52°48′	80
Piwnice S-14-193	*Q. robur*	Olek Piwnice 231b „Piwnice"	18°33′	53°05′	70
Lipiny S-01-194	*Q. petraea*	Hajnówka Lipiny 272d „Lipiny"	23°39′	52°45′	180
Leśna S-01-195	*Q. robur*	Leśna Nieznany Bór 488d –	23°40′	52°41′	160
Białowieża S-01-196	*Q. robur*	399 „Białowieża National Park"	23°51′	52°43′	160
Bachus S-05-197	*Q. robur*	Stańków Sawin 46 „Bachus"	23°25′	51°19′	210
Świnia Góra S-10-198	*Q. petraea*	Bliżyn Świnia Góra 137 „Świnia Góra"	20°42	51°03′	350

Table 1 continued

1	2	3	4	5	6
Radziądz S-15-199	*Q. robur*	Żmigród Radziądz 229n –	16°57′	51°30′	90
Kórnik S-08-233	*Q. robur*	– Exp. Forest Zwierzyniec	17°05′	52°15′	80

1966, just after collection, the acorns were sown in the nursery with two replications. The seedlings were grown in the nursery until the spring of 1968. Heights were measured in the autumn of 1967. A field trial with 7 provenances of *Q. robur* and 2 of *Q. petraea* was established in the spring of 1968 in a randomised complete block design with 8 replications (Fig. 2). Spacings were 0.75 m × 1.20 m. 104 (13 × 8) oak seedlings were planted per plot. The experiment is located in Kórnik near Poznań, in the Zwierzyniec Forest of the Institute of Dendrology. The trial area is flat with a proper brown soil, loamy sand, tough, mainly deep on light sandy clay. Site type is defined as rich moist broadleaf.

Heights of all trees were recorded in the autumn of 1975 and 1977 as 9- and 11-year-old trees respectively, and on three trees per plot in the autumn of 1994 on 28-year-old trees. Breast height diameters were measured in the autumn of 1986,

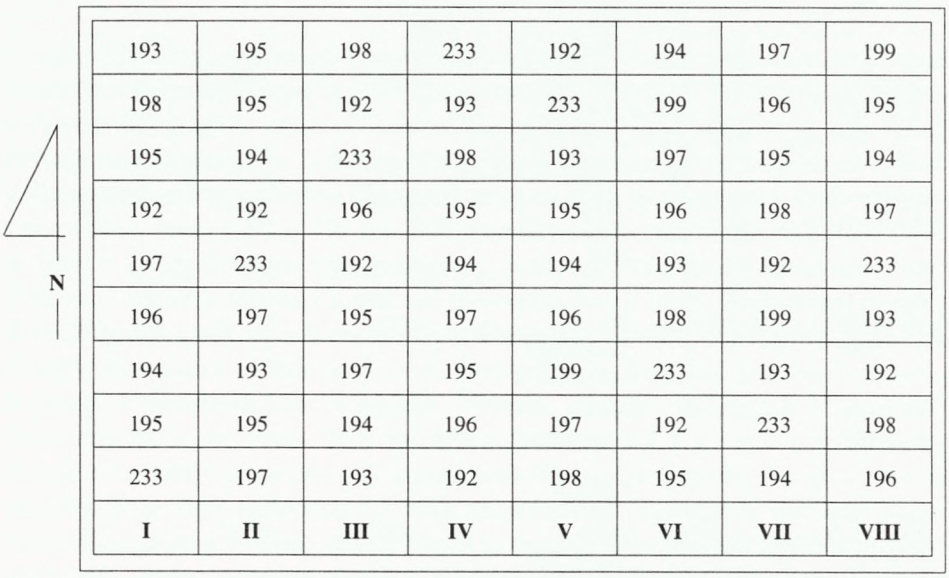

Fig. 2. Randomized design of the experiment. The number of the plot indicates the last number of the provenance designation according to Table 1

1990 and 1994. In 1994 also stem straightness was assessed according to a three point scale: 1 – straight, 2 – medium, 3 – crooked. Stem slenderness, i.e. tree height to breast height diameter ratio, was estimated. All data were submitted to analyses of variance. Linear correlation coefficients were estimated between provenance means for traits.

RESULTS

Height

The mean heights of 1-year-old seedlings in the nursery for different provenances varied between 11.5 cm and 19.8 cm (Table 2). The best growing provenances were Dębina, Kórnik, Białowieża, Piwnice and Leśna, all belong to pedunculate oak. Slow growing provenances were Radziądz and Bachus. Among all provenances, sessile oaks, Lipiny and Świnia Góra had the lowest height. In the field pedunculate oak provenances: Kórnik, and then Piwnice, Radziądz, Dębina, Białowieża achieved the best average heights at 9 and 11 years (Table 2). The slow growth of sessile oak provenances, Lipiny and Świnia Góra continued. The mean heights for different provenances varied between 1.43 m and 2.26 m in 1975, and between 1.71 m and 2.98 m in 1977. Duncan's test demonstrated that differences between provenances were small but statistically significant.

Among the pedunculate oak provenances, there were considerable differences in ranking between the nursery and field results at ages 9-11. This concerns primarily provenance Radziądz growing very poorly in the nursery, and very well in the field when 9-11 years old.

Height measurement of test trees aged 28 years showed great differences between provenances (Table 2). The best growing were Kórnik (11.9 m) and Białowieża (11.8 m), and also Dębina (11.6 m), Radziądz (11.3 m), and Bachus (11.1 m). The shortest were trees of provenance Lipiny (8.6 m). The other sessile oak provenance, Świnia Góra, was of middle tree height (10.6 m).

DBH

For stem thickness (Table 2), significant differences among provenances were obtained. The values at 20 years varied between 4.9 cm (Lipiny) and 8.4 cm (Kórnik). At 25 and 28 years provenance Kórnik was also first in ranking with diameters 10.6 cm and 12.4 cm, respectively. On the other end of the scale there was always Lipiny with diameter 7.5 cm at 25 and 9.1 cm at 28 years, and Świnia Góra, both belonging to sessile oak. Among pedunculate oak provenances the lowest diameter was demonstrated by Leśna at all measurements.

Table 2

Mean values of characters for provenances and species. Values with the same letter are not significantly different at 0.05 level

	Tree height				DBH			Basal area	Volume/tree	Volume/ha	Stem slenderness	S. straightness
At age:	1 (cm)	9 (m)	11 (m)	28 (m)	20 (cm)	25 (cm)	28 years (cm)	28 m^2/ha	28 m^3	28 m^3	28 years old	28 years old
Provenance												
Dębina	19.8 a	2.04 ab	2.64 a	11.6 ab	7.9 ab	10.1 a	11.7 ab	35.7 a	0.0380 abc	116 a	100.2 a	2.13 ab
Piwnice	17.9 a	2.19 a	2.94 a	9.7 e	7.8 ab	9.8 a	11.3 ab	30.8 a	0.0351 abc	99 a	102.0 a	2.33 b
Lipiny	11.5 b	1.43 b	1.71 b	8.6 f	4.9 d	7.5 c	9.1 c	18.0 b	0.0208 d	52 b	113.9 b	2.04 ab
Leśna	17.7 a	1.80 ab	2.34 ab	10.6 d	6.9 bc	9.0 b	11.0 b	30.1 a	0.0315 bc	100 a	99.0 a	1.89 ab
Białowieża	18.6 a	1.99 ab	2.56 ab	11.8 a	7.6 ab	9.8 a	11.8 ab	32.5 a	0.0384 abc	112 a	98.2 a	1.76 a
Bachus	14.1 b	1.93 ab	2.38 ab	11.1 c	7.6 ab	9.8 a	11.7 ab	31.3 a	0.0374 abc	95 a	98.0 a	2.01 ab
Świnia Góra	12.2 b	1.69 ab	2.12 ab	10.6 d	6.3 c	8.9 b	10.7 b	19.7 b	0.0302 c	60 b	102.2 a	2.19 ab
Radziądz	12.4 b	2.06 ab	2.75 a	11.3 bc	7.9 ab	9.8 a	11.9 ab	21.8 b	0.0401 ab	92 a	101.2 a	1.95 ab
Kórnik	19.2 a	2.26 a	2.98 a	11.9 a	8.4 a	10.6 a	12.4 a	35.9 a	0.0414 a	118 a	92.9 a	2.20 ab
Species												
Q. robur	17.1	2.04	2.66	11.1	7.7	9.8	11.7	31.2	0.0374	105	98.8	2.04
Q. petraea	11.9	1.56	1.92	9.6	5.6	8.2	9.9	18.9	0.0255	56	108.1	2.12

Basal area at breast height

On the basis of diameter measurements of all trees on each plot at the age of 28 years, the basal area per ha was calculated for all provenances (Table 2). The highest value was obtained for the local provenance Kórnik, nearly 36 m^2/ha. A similar value was obtained for Dębina, and to this same group according to Duncan's test with values 30-33 m^2/ha belong all provenances of *Q. robur*, except provenance Radziądz. This last provenance together with both provenances of *Q. petraea*, Świnia Góra and Lipiny form a separate group with smallest values, 22 m^2, 20 m^2 and 18 m^2, respectively.

Volume

Mean volume/tree or volume/ha production at the age of 28 years significantly differentiates the studied provenances. The value for different provenances varies between 0.0208 m^3 and 0.0414 m^3/tree or between 52 m^3/ha and 118 m^3/ha, respectively (Table 2). In both cases the *Q. petraea* provenances, Lipiny and Świnia Góra had the smallest volume production. Kórnik provenance followed by all the other *Q. robur* provenances were superior in volume production. Values above 100 m^3/ha were demonstrated by provenances Kórnik (118 m^3/ha), Dębina (116 m^3/ha) and Białowieża (112 m^3/ha).

Stem slenderness

Stem slenderness (tree height in m to breast height diameter in cm ratio) was calculated on the basis of the test trees measured at the age of 28 years. The values for provenances varied between 92 and 114 (Table 2). Lipiny provenance with the highest value differs significantly from all the others. The second sessile oak provenance, Świnia Góra also had a great value of this ratio. Tree stems of the Kórnik provenance with a value of 92, are very robust.

Stem straightness

Stem straightness was assessed on all trees at the age of 28 years (Table 2). Among the studied provenances the most straight stems are characteristic for trees of provenance Białowieża (lowest percent of crooked stems). At the other end of the scale, with a high percent of crooked stems one finds provenance Piwnice, followed by Kórnik. Above average proportion of crooked stems was also found in provenances Dębina and both the *Q. petraea* provenances, Świnia Góra and Lipiny.

Correlation

In Table 3 are shown values of correlation coefficients between heights of trees and stem diameter at provenance level. Height of 1-year-old seedlings from the nursery correlates slightly with tree height at the age of 9 years on the field area and with diameter of stem at the age of 20 and 25 years. There was no correlation between height at 1 year (nursery stage) and that at 11 or 28 years. All values of growth traits measured in the field area were strongly positively correlated.

Table 3

Correlation coefficients (r) between tree characters

	Height			DBH		
at age:	9	11	28	20	25	28-years
Height						
at age: 1-year	0,676*	0,656	0,419	0,671*	0,681*	0,609
9		0,992**	0,838**	0,966**	0,950**	0,903**
11			0,823**	0,945**	0,916**	0,872**
28				0,898**	0,867**	0,875**
DBH						
at age: 20					0,986**	0,974**
25						0,977**

* significant at 0,1 level

** significant at 0,05 level

DISCUSSION

The results obtained in this experiment confirm the previous opinions about provenance diversity in oaks. Because only few provenances have been used in this experiment, the variability obtained is not impressive, however statistically significant with regard to the many characters. Populations represent various regions of Poland and seed collections were made in old reserves or seed stands growing in similar site conditions.

Considerable provenance differences in tree height, which in juvenile stage approached 37 percent for pedunculate oak and 18 percent at the age of 28 years, obtained in this experiment, confirm data from literature. For example, Jovančević (1968) revealed differences in germinative energy and seedling growth between *Q. robur* provenances. In the international experiment with 19 provenances of *Q. petraea*, representing the whole European range of this species, there was a 3-fold difference in seedling height between best growing and poorest growing populations after 1-year and 2.5-fold after 2 years (Fober 1994b). Also for the older trees differ-

ences between provenances were confirmed. On a 6-year-old oak plantation, at which 16 provenances from Krasnodar region were compared, the best growing local one was 30 percent taller than the poorest (Budjanskij 1963). In another experiment with pedunculate oaks in the Ukraine, the provenance differences observed at the age of 10 years approached 62 percent (Patlaj and Gajda 1988). However, 36-year-old trees of pedunculate oak from 21 different origins in southern European Russia obtained a range of heights only from 8.7 m to 11.5 m in the group of late-flushing oaks or from 8.0 m to 10.1 m in early-flushing ones (Šutjaev and Terterjan 1980).

With time, differences in mean height between provenances diminish, but remain statistically significant, which proves the strongly differentiated dynamics of growth. In the present experiment provenance differences in height growth at the juvenile stage in the nursery were greater than at nine or eleven years. However, the Duncan's test of height values on trial trees at the age of 28 years confirmed the largest partition of the studied provenances into groups.

With provenance differences in height and diameter, we observe also differences in wood volume. Differences between provenances in volume production can reach 100 percent in 30-40 year old stands (Patlaj et al. 1975, Kleinschmit 1993). In this experiment, the best growing provenance Kórnik achieved 30 percent greater volume/tree than slowly growing provenance Leśna. This is similar to the data of Šutjaev and Pozdorovkina (1983). They consider that differences in volumes between edaphotypes reach 29 percent. However with regard to the current number of trees on plot, there are no differences in volume/ha at provenance level within the same species. The Duncan's test divided all provenances into two groups in accordance with species affiliation.

It is very interesting that ranking of provenances in the nursery differed strongly from that in the field area at the age of 9 years. In particular this concerns Radziądz provenance which grew very poorly in the nursery and very well in the field. An opposite response was demonstrated by provenance Leśna. This behaviour can affect $G \times E$ interaction suggesting existence of soil races (edaphotypes). Also very important can be the influence of acorn size on tree growth, in particular in the juvenile stage. According to Barzdajn (1993) acorn diameter was correlated with height of the seedlings in the nursery, but not with height of 5-year-old plants in field conditions. The weight of acorns of sessile oak correlates with the height of 1-year-old seedlings on provenance level. This correlation was no longer significant in the second year (Fober 1994b). Kleinschmit and Svolba (1979) confirmed a strong correlation between acorns' weight and height increment in the first 3 years, however this correlation is manifest rather on individual than on provenance level. According to Cieślar (1923), the influence of seed weight only disappears after 12-15 years.

Another reason for different growth of seedling in the nursery is susceptibility of young oaks to late spring frost. Hence provenance differences can follow their phenology.

Generally, the results obtained indicate heavy and statistically significant differences between the studied species, pedunculate and sessile oak. From the measurements it follows clearly that both provenances of sessile oak, Lipiny and Świnia Góra, were growing more slowly, at the juvenile stage in the nursery, as well as in the field area. At the age of 1 year seedlings of sessile oak were 30 percent smaller than those of pedunculate oak and at the age of 28 years, 14 percent smaller. The stem diameters of *Q. petraea* provenances at the age of 20, 25 and 28 years were 27, 16 and 15 percent smaller, respectively, and volume of wood at the age of 28 years, 47 percent smaller. Tree stems of sessile oak provenances are robust, in particular those from Lipiny.

The results obtained, pertaining to differences between species confirm the data from literature. Burger (1949) informed, that on any given site, trees of *Q. robur* grow more rapidly than of *Q. petraea*, particularly during the early years. Only at 20-30 years of age were the two species equal. Better early growth of *Q. robur* may result from greater acorns. Morphological characteristics of *Q. petraea* indicate reaching smaller dimensions than *Q. robur* at later ages, too.

The results obtained indicate, that testing various provenances to select the most valuable ones and best growing genotypes is needed. High heritability of morphological traits, particularly height growth and volume yield, as well as stem form and phenological characteristics (Jensen 1993), guarantee success of selection. On the other hand, the high values of correlation coefficients between growth measurements indicate the possibility for this selection at earlier developmental stages.

From the results it follows, that the most recommended provenance is the local one, Kórnik, and Białowieża and Dębina. These were the best growing in the nursery and in the field, and they have the greatest volume yield at the age of 28 years. However, the Kórnik provenance has very slender and crooked tree stems.

CONCLUSIONS

The results obtained indicate existence of differences between Polish oak populations. Growth differences stay with time, suggesting that the suitable selection of provenances may be very important in the economic success of plantations.

High values of correlation coefficients between measurements indicate the possibility for early selection.

In all growth traits provenances of sessile oaks grew less than the pedunculate oaks.

There is lack of any geographical pattern in the traits studied. Provenance differences concern stands rather than regions, which confirms the hypothesis about the existence of ecotypes.

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Doświadczenie proweniencyjne z dębem szypułkowym (*Quercus robur* L.) i bezszypułkowym (*Q. petraea* [Matt.] Liebl.) założone w 1968 roku

Streszczenie

Duże zainteresowanie rasami dębów w różnych krajach zrodziło potrzebę badań proweniencyjnych w Polsce z krajowymi rodzimymi populacjami rosnącymi w licznych rezerwatach i drzewostanach nasiennych na terenie całego kraju. Korzystając z dobrego urodzaju żołędzi, jesienią 1966 roku, zebrano nasiona dębu szypułkowego lub bezszypułkowego w dziewięciu nadleśnictwach (tab. 1). Wiosną 1968 roku założono terenową powierzchnię doświadczalną zlokalizowaną w Kórniku k. Poznania w Lesie Doświadczalnym Instytutu Dendrologii. Doświadczenie w układzie zrandomizowanych bloków z 8 powtó-

rzeniami (ryc. 2) obejmuje siedem proweniencji dębu szypułkowego i 2 – dębu bezszypułkowego. W tabeli 2 przedstawiono średnie dla proweniencji i obu gatunków pomiary wysokości drzew w szkółce po pierwszym sezonie wegetacyjnym oraz na powierzchni terenowej w wieku 9, 11 i 28 lat, a także pomiary pierśnicy drzew w wieku 20, 25 i 28 lat oraz wyliczone powierzchnie przekroju, miąższość grubizny, zbieżystość pni (stosunek wysokości drzewa do pierśnicy) oraz ocenę prostości pni. Uzyskane wyniki wykazują różnice między polskimi populacjami dębów. Utrzymujące się w czasie różnice wzrostowe mogą świadczyć o ekonomicznym pożytku z selekcji. Wysokie wartości współczynników korelacji między kolejnymi pomiarami wskazują na możliwość wczesnej selekcji. Pod względem cech wzrostowych dąb bezszypułkowy wyraźnie ustępuje dębowi szypułkowemu. Wyraźna zmienność drzewostanowa, przy równoczesnym braku geografizmu zmienności potwierdza hipotezę o istnieniu ekotypów.

Z dotychczasowych obserwacji wynika, że najbardziej godne polecenia są proweniencje Kórnik, Białowieża i Dębina wykazujące najlepszy wzrost wysokości zarówno w szkółce, jak i na powierzchni terenowej oraz najwyższą masę w wieku 28 lat. Jednak lokalna proweniencja Kórnik ustępuje miejsca dwóm pozostałym ze względu na krzywiznę i zbieżystość pni.