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Original article

Variation of growth in Danish provenance trials with oak (*Quercus robur* L and *Quercus petraea* Mattuschka Liebl)

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Summary — In 1990 an evaluation was made of all 29 Danish provenance trials with oak. For the most part, north-European provenances have been used in these trials. The paper presents results from 2 provenance trials with respectively 20 and 25 provenances 25 years of age raised from seed. From these trials it can be seen that the provenances are divided into many distinctive ecotypes, and differ with regard to the time of flushing, volume yield, morphological characteristics, etc. High heritability values have been found for straightness, tree height and volume yield as well as for flushing, epicormics and axis formation.

***Q robur* / *Q petraea* / provenance / stem form / epicormic shoot**

Résumé — Variabilité intraspécifique de la croissance du chêne pédonculé (*Q robur* L) et sessile (*Q petraea* [Matt] Liebl) au Danemark. *Les 29 tests de provenance de chênes installés au Danemark ont été étudiés en 1990. Ces tests comprenaient essentiellement des provenances d'Europe du Nord. Les résultats présentés ici concernent 2 tests regroupant 20 et 25 provenances et âgés de 25 ans. Ils montrent que les provenances se répartissent en différents écotypes. Des variations importantes ont été observées pour le débourrement, la production en volume, la forme. Des valeurs élevées d'héritabilité ont été trouvées pour la rectitude du tronc, la hauteur, le volume, le débourrement, les pousses épicormiques, et la formation de la tige principale.*

Q robur / Q petraea / *provenance / forme du tronc / pousse épicormique*

INTRODUCTION

Due to a lack of sufficient seed sources in Denmark, there has always been a fairly large importation of acorns from different countries. Although the foreign provenances often showed good form and production qualities, they frequently had frost dieback and mildew *(Microsphaera alphitoides).* Understanding this provenance problem led to the establishment of provenance trials at the beginning of this century (Helms, 1909; Hauch, 1914).

Cieslar (1923) described the existence of different climate-conditioned oak species. He also pointed out the presumably high maternal inheritance for stem straightness. This was strongly supported by demonstration trials carried out by Oppermann (1932). Oppermann very carefully described the existence of various races and form types in Denmark. Later on, other genetic properties of oak were described by Schreiber (1952), Krahl-Urban (1959) and Kleinschmit (1977).

Due to lack of statistical knowledge, most of the early provenance trials were made without replications with insufficient possibilities of estimating genetic gain of phenotypic observations.

The importance of oak for production of high quality wood and as a stabilizing and esthetic element of forests and landscapes has in recent years increased interest in the different properties of the oak races used in Denmark.

In 1990, all Danish oak provenance trials were evaluated. In this paper, results are presented mainly from 2 young and large trials with almost identical provenance compositions. Due to replications, these trials have formed a basis for estimating genetic gains.

MATERIALS

The 1990 evaluation included 29 provenance trials of different experimental value. Only 6 of these trials include replicate treatments. All trials are randomly distributed throughout Denmark.

Two of these are described here in more detail. In 1967, 2 provenance trials were established in eastern Denmark, including 15/20 provenances of presumably Danish origin, 4 of Dutch origin and 1 of German origin. All of them are *Quercus robur,* except F232 which is a *Quercus petraea* of German origin. Most of the acorns for the provenance trials were collected from selected stands in Denmark. Each trial was designed as a complete 4-block experiment, each block with 20/25 provenances. Each plot included 20–30 trees, 25 years of age. Both trials were established on moist loamy–clayey soils which often exhibited pseudogley tendencies.

METHODS

All Danish oak provenance trials were evaluated in 1990 and most of the trials have been measured several times in the past. The yield parameters: height, diameter and standing volume/ha were measured, and in 3 trials the volume production could be quantified. The evaluations of qualitative parameters included: stem straightness, epicormic formation, branch angle, stem axis, fork formation and flushing. Contrary to the metric measurements of production, the estimation of qualitative parameters includes the use of a non-continuous scale.

The data were analyzed using a statistical software package, partly developed by the Research Institute for corresponding tasks. Due to the nature of qualitative values, which often showed a non-normal statistical distribution, only plotwise mean values were used for statistical analyses.

MAJOR RESULTS FROM 2 LARGE PROVENANCE TRIALS

The major results are shown in table I. Concerning stem straightness, the percentage of "acceptable" possible future trees in the stand has been estimated. In the last column the average number of epicormics per tree and plot is shown.

The results reflect the common knowledge in Denmark about the relationship between oaks *(Q robur)* of Danish and Dutch origins. The yield level is generally higher for Dutch oak than for Danish, but straightness is the most important character for recommending Dutch oak. The straightness of Danish oak is often very poor. The parameter "formation of epicor-

Table I. Measurement of yield and qualitative factors. The provenance Zevenaar is a Dutch export; the other provenances are either Danish or domestic provenances. The frequency of acceptable future trees due to straightness factor is estimated and the number of epicormics/pole is given. Evaluation from 2 oak provenance trials each with 4 blocks and 20/25 and 25 provenances, respectively.

Seed-stand No	*Origin*	*Height (dm)*	*Diameter (mm)*	*Volume/tree (dm^3/tree)*	*Straightness*	*Epicormics*	
					% trees with acceptable form	*No/tree*	*Relative (%)*
F148	Dutch ?	93.6	97.5	97.6	64.8	6.26	–19
F286	Dutch	93.3	97.6	92.1	49.0	8.59	11
F369	Dutch	93.4	100.0	102.5	54.5	8.75	13
Zevenaar	Dutch (E)	89.4	96.7	89.1	53.5	6.33	–19
F51	Danish	86.3	95.1	87.1	20.0	8.48	9
F96	Danish	86.2	95.8	87.7	22.2	8.67	12
F315/16	Danish	88.3	97.5	91.8	31.0	9.13	18
Various	Danish	86.0	96.3	87.6	18.0	7.16	– 8
F232*	German	98.4	106.4	120.3	31.6	4.50	–42
Average		87.8	96.6	95.1	28.9	7.76	0

* *Quercus petraea*

mics" is more complex; within Dutch and Danish provenances we find provenances producing more or fewer epicorms.

Provenance F232 of German origin *(Q petraea)* showed a very high yield, its straightness is moderate, and most importantly: epicormic formation is very low. This result is surprising and has been verified in other provenance trials.

At an even younger age, the trials had provided useful results. At 13 years of age, the differences in height and stem straightness between provenances were statistically significant at a 5% level. Another important parameter, the total volume production, showed a very low, but significant effect of provenance at 18 years of age; however, the effect of block variation (site condition) was very high. At the age of 25 years, this relationship had changed. The effect of provenance at 25 years was high, but the effect of block was reduced.

In conclusion, at the age of 10–15 years, it should be possible to make rough positive or negative selections. At the age of 20–25 years, the optimum time has presumably been reached for deducing information from these mid-sized trials.

There was no correlation between the height at 2 years (nursery stage) and that at 13 years. Furthermore, there was no correlation between acorn dimension and the height at nursery stage. These results diverge from those reported in the literature, but they could be caused by less than optimal treatments of acorns and nursery plants. However, other newly established Danish trials also confirm the difficulties in predicting future growth at the nursery stage.

ESTIMATION OF HERITABILITY

The 2 Danish provenance trials have been a powerful tool to quantify the heritability (repeatability). The results shown in table II are based on the 80–100 mean plot values from the quality evaluation and production measurement. The values for heritability should be interpreted with care and are only valid for estimations made under the same conditions (same provenance, location, age, treatment, etc). Heritability ranking for various characters is probably of prime interest (Nanson, 1989).

The broad-sense heritability values for height, straightness, epicormic formation and flushing seem to be strongly controlled by genetic factors. The heritabilities of diameter and volume are high too, but these production parameters are also sensitive to thinning strength.

Table II. Values for broad-sense heritability (h^2_G), and statistical significance between provenances. Factors concern production and quality. Evaluation from 2 oak provenance trials each with 2 blocks and 20/25 provenances respectively.

Parameters	h^2_G
Height	0.871***
Diameter	0.606***
Mass volume/tree	0.719***
Volume/ha	0.773***
Straightness	0.946***
Epicormics	0.797***
Forks	0.231 NS
Axis	0.831***
Branch angle	0.542**
Flushing	0.870***

** Significant at the 1% level; *** significant at the 0.1% level; NS: non significant at the 5% level.

ECOTYPES AND CLINAL VARIATION OF OAK IN THE REMAINING TRIALS

Some other traits have been observed in the other provenance trials. In general, provenances of *Q robur* imported into Denmark from countries southwest of Denmark flush late, and their defoliation is also late too (compared to Danish provenances). Oak from Norway and Sweden flush early and their defoliation is also early.

Concerning the provenances of foreign origin, the length of the yearly period of growth and the production level seem to increase as the latitude of the origin decreases and *vice versa*.

Even though Denmark is considered a very limited area, provenances originating from the western part (on sandy, poor soil near the North Sea) have a short period of growth compared to provenances from the eastern parts of Denmark.

In harsh wind- or frost-exposed areas, we have observed extreme differences in yield and lethality corresponding to provenance variation. For example, Dutch and even Swedish provenances suffer from severe defoliation, when they are suddenly exposed to the wind. In such localities, only very distinct local ecotypes should be recommended.

DISCUSSION

Even if there is an evident overall clinal variation in growth, flushing, defoliation, wind-resistance etc, oak is a pioneer species. Even within limited regions, there may be deviation from the clinal variation and several ecotypes may exhibit considerable variation. Such factors should be taken into consideration in choosing oak provenances, whether the goals are quality of wood and/or landscape ornamental trees, for example.

The results of heritability are promising in relation to influencing the quantitative and qualitative genetic properties by genetic improvement. In particular, improvement of stem straightness in original Danish genetic materials could be important, as the oak stands of Danish origin mostly have very poor stem quality due to the human devastation of forests over several hundred years.

The use of *Q petraea* in Denmark should be taken more carefully into consideration. The phenotypic appearances, at least in younger stands, are surprisingly good even on more or less clayey soils. This contrasts with earlier assumptions where *Q petraea* only were recommended on sandy soils (Krahl-Urban, 1959; Jahn, 1988). The growth of *Q petraea* during the nursery stage is often much smaller than that of *Q robur* and this could hypothetically be a very important negative factor for *Q petraea* in the competition with different weeds, at least under certain soil conditions. Before general recommendations can be made, more investigations on older stands of *Q petraea* should be carried out, including observations of quantitative and qualitative factors ("cracks" and "shakes" for example).

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