Ann Sci For (1993) 50, Suppl 1, 228s-232s

Original article

Morphological variability of oak stands (*Quercus petraea* and *Quercus robur*) in northern Germany

G Elsner

Niedersächsische Forstliche Versuchsanstalt, Abt C, Abteilung Forstpflanzenzüchtung, 3513 Staufenberg OT Escherode, Germany

Summary — According to the German law concerning forest reproductive material, purity of species is required for the admission of *Quercus robur* and *Q petraea* as seed crop stands. A method for species identification was devised by the Lower Saxony Research Institute. It is based on leaf morphology and calculates a discriminant score for every leaf by the means of discriminant analysis in comparison with 2 pure reference stands. In this way, the species relationship and the degree of expression of characters are assessed. Leaf samples were collected in 733 oak stands in Lower Saxony and evaluated for every stand. Mixed stands and stands with a high degree of intermediate forms, which may have arisen from hybridization, occur besides stands of pure species.

Quercus robur / Quercus petraea **/ morphological variability / discriminant analysis**

Résumé — Variabilité morphologique des peuplements de chêne (*Quercus petraea* et *Quercus robur*) en Allemagne du Nord. *La loi allemande exige un contrôle de la pureté spécifique des chênaies préalable à leur classement en peuplements porte-graines. Dans ce but, nous avons mis au point une méthode de reconnaissance des chênes sessile et pédonculé basée sur la morphologie foliaire. Cent-cinquante feuilles sont récoltées au sol dans chaque peuplement. Une fonction statistique discriminante a été établie à partir de 2 peuplements purs de référence. L'étude de 733 peuplements de Basse-Saxe montre la présence de 49% de peuplements pédonculés, 40% de sessiles et 11% d'hybrides. Même les peuplements dominés par une seule espèce possèdent souvent des feuilles de forme intermédiaire. La part respective de l'hybridation et de la variabilité intra-arbre dans l'interprétation de ces résultats est discutée.*

Quercus robur / Quercus petraea ***/ variabilité morphologique / analyse discriminante***

INTRODUCTION

Quercus petraea (Mattuschka) Liebl and *Quercus robur* L are native to Lower Saxony. Both species are targeted by the law concerning forest reproductive material (Anonymous, 1979). According to this law, only stands of pure species can be classified as seed crop stands or, in exceptional cases, stands that exhibit minor transition forms may be accepted. In the past, this law was not always followed. As a consequence of this situation, the Forest Research Institute developed a method for the determination of purity of oak species.

This task is difficult because of the variety of forms within the species and the possibility of hybridization between species (Schwarz, 1936; Cousens, 1965; Rushton, 1974, 1978, 1983; Olsson, 1975; Wigston, 1975; Dupouey, 1983; Aas, 1988, 1990; Ietswaart and Feij, 1989). With reference to Rushton's analysis (1983), Spethmann (1986) developed a method for identification of species composition in stands.

MATERIALS AND METHODS

In 1986, Spethmann collected 150 leaves each from presumed pure *Q petraea* and pure *Q robur* stands. Eleven leaf characters were measured or estimated and 6 additional ratios and sums were calculated (table I). The characters were defined according to Rushton (1983), who gave a detailed description. The auricle development and basal shape of lamina were scored according to an index ranging from 0 to 4 ('0' for a strong auricle or a cordate base and '4' for no auricle or a cuneate base). Some of the measurements are explained in figure 1.

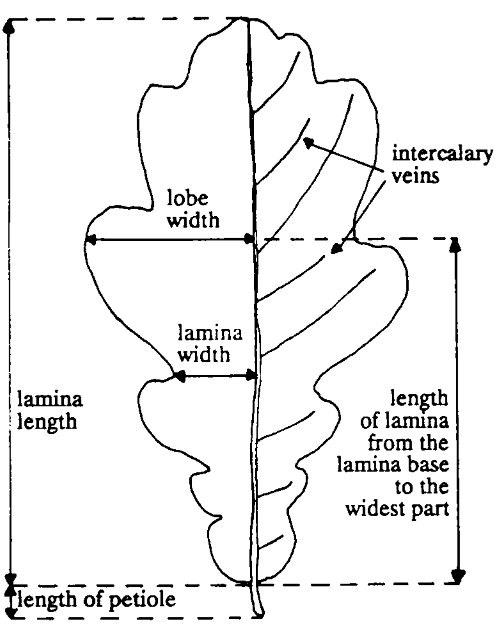

Fig 1. Measurement of leaf characters.

By means of the computer program SPSS X and the discriminant analysis, *Q robur* leaves were separated from those of *Q petraea*. In 2 stands, the leaves could be separated precisely. These 2 stands were selected as the reference stands.

Only 10 of the registered characters (8 measured and 2 others used for the calculation of sums or ratios) and 3 of the calculated sums/ratios were relevant to the distinction. The most important distinctive characters proved to be the development of the auricle the number of intercalary veins and the length of the petiole. An equation was created to calculate the discriminant score for single leaves. The scores of the leaf characters and ratios must then be multiplied by the unstandardized canonical discriminant function coefficient and a constant must be added (table I). The result is a score between −6 and +6. Typical leaves of *Q petraea* have a high positive value, while leaves from *Q robur* exhibit a high negative score. Leaves with a score between −1 and +1 are defined as intermediate forms.

Between 1986 and 1990 150 leaves each were taken as a random sample from the litter of 733 already admitted or potential seed crop stands and evaluated per stand. Existing peduncles were also collected to test the result of the discriminant analysis. Afterwards the stands were divided into the following classes:

A) stands of pure species: very few leaves may display combinations of characters of the other oak species and only if these are not highly distinctive or the stand may have a small proportion of hybrid forms;

B) according to evaluation, few single trees of the other tree species will be found, but some leaves show the typical combinations of characters of the other oak species; these trees must be eliminated before seed collection;

C) the proportion of the other oak species is so high that seed collection will not be authorized for commercial purposes;

D) the stand consists of a high proportion of hybrid oaks growing beside both species, hence seed collection for commercial purposes is forbidden.

Cluster analysis was helpful in classifying some stands with a high proportion of intermediate forms.

RESULTS

Of the investigated stands, 49% belonged to *Q robur* and 40% to *Q petraea* or consisted mainly of these species; 11% of the stands were classified as D, that is to say they include a high proportion of hybrids.

The classification A–C within the species is shown in figure 2. In both tree species, 70% are acceptable for admission according to the law concerning reproductive forest material. For *Q petraea,* 52% of the A-stands contain leaves with a combination of characters of the other species,

Table I. List of investigated leaf characters and ratios.

Measured and estimated leaf characters	*Unstandardized canonical discriminant function coefficients*
Lamina regularity	–[a]
Number of lobe pairs	–0.114
Number of intercalary veins	–0.325
Number of lamina sinuses	0.166
Length of petiole	0.121
Lamina length	0.017
Length of lamina from the lamina base to the widest part	–0.033
Lobe width (at the widest part of the lamina)	–[a]
Depth of sinus (at the sinus below the widest part)	–[a]
Auricle development	0.733
Basal shape of the lamina	0.154
Calculated sums and ratios	
Percentage venation = $\frac{\text{number of intercalary veins x 100}}{\text{number of lamina sinuses}}$	–[a]
Total leaf length = length of petiole + lamina length	–[a]
Petiole ratio = $\frac{\text{length of petiole + lamina length}}{\text{length of petiole}}$	–0.020
Lamina shape or obversity = $\frac{\text{lamina length}}{\text{length of lamina from base to widest part}}$	–[a]
Depth of sinus = lobe width – depth of sinus	–0.060
Lobe depth ratio = $\frac{\text{lobe width}}{\text{lobe width – depth of sinus}}$	–0.091
Constant	–2.065

a Not used for distinction.

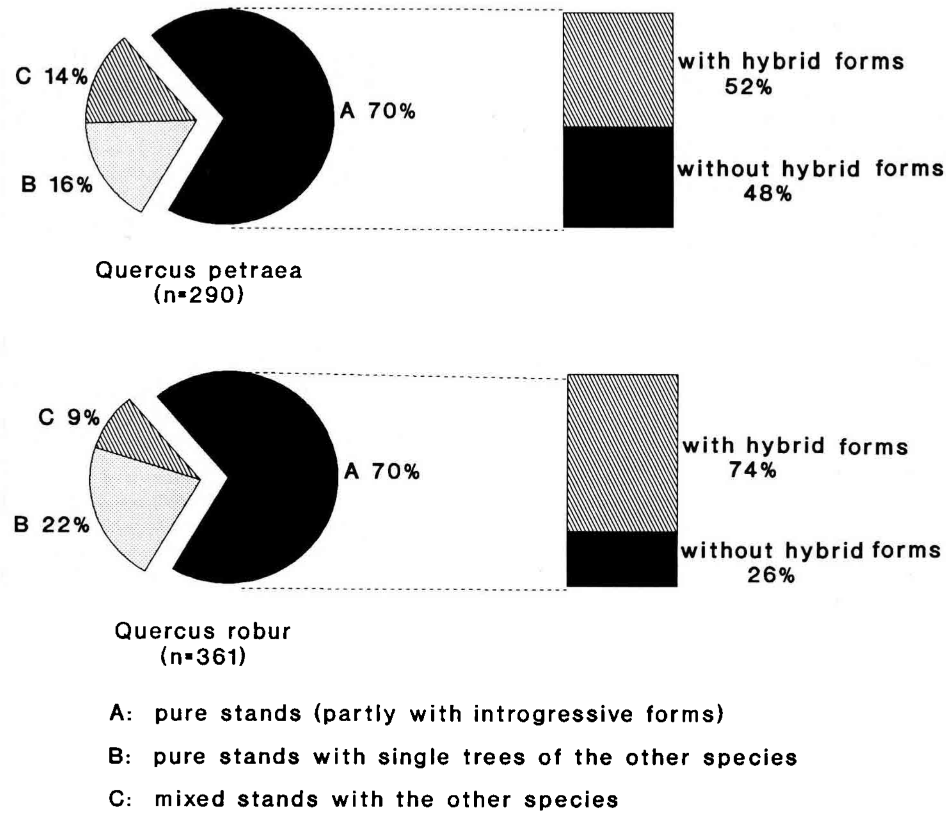

Fig 2. Classification of stands.

but these characters are not highly distinctive. In the figure, these stands are labeled as 'with hybrid forms'. For *Q robur,* 74% are considered to express hybrid elements.

DISCUSSION

The calculated discriminant scores reflect the relationship between species and phenotypic expression of species characters for each leaf. In addition to species-typical leaves, there are also many intermediate forms. Because the samples were collected from the litter, the leaves could come from epicormic or lammas shoots and all parts of this crown. Thus, it is possible to find an atypical leaf of the pure species. Our investigations of single trees exhibited high variations of the discriminant scores in some cases.

On the other hand, a leaf can represent an introgressive form. An exact classification is not possible. However, it can be expected that, in stands with high proportions of intermediate leaves, a high level of introgressive forms also exists. The high proportion of intermediate forms in D-stands cannot be explained only by a high number of species-atypical leaves. There must likewise exist a high proportion of hybrid forms.

Furthermore, our results suggest that leaves of stands with only minor characters but no typical leaves of the other species have a certain number of hybrids. In figure 2, these stands are called 'with hybrid forms'. This conclusion presumes, of course, an earlier transfer of pollen from the other species.

That just the part of intermediate forms in pure *Q robur* stands is higher may be attributed to the high crossing ability of *Q robur* as a mother tree (Dengler, 1941; Aas, 1988, 1990; NFV, 1989) or only to the higher diversity of forms within the species *Q robur.*

REFERENCES

Aas G (1988) Untersuchungen zur Trennung und Kreuzbarkeit von Stiel- und Traubeneiche (*Quercus robur* L and *Quercus petraea* (Matt) Liebl). Dissertation, Univ Munich

Aas G (1990) Kreuzbarkeit und Unterscheidung von Stiel- und Traubeneiche. *Allg Forstzeitschr* (9-10), 219-221

Anonymous (1979) Gesetz über forstliches Saat- und Pflanzgut. *Bundesgesetzblatt 1979.* Teil I, 1242-1261

Cousens JE (1965) The status of the pedunculate and sessile oaks in Britain. *Watsonia* 6, 161-176

Dengler A (1941) Bericht über Kreuzungsversuche Zwischen Trauben- und Stieleiche und zwischen europäischer und japanischer Lärche. *Mitt Akad Dtsch Forstwiss* 1, 87-109

Dupouey JL (1983) Analyse multivariable de quelques caractères morphologiques de populations de chênes (*Quercus robur* L et *Quercus petraea* (Matt) (Liebl) du Hurepoix. *Ann Sci For* 40, 265-282

Ietswaart JH, Feij AE (1989) A multivariate analysis of introgression between *Q robur* and *Q petraea* in the Netherlands. *Acta Bot Neerl* 38, 3, 313-325

NFV (1989) *Jahresbericht der Niedersächsischen Forstlichen Versuchsanstalt. Abt Forstpflanzenzüchtung.* Annual report, Escherode, 32-34

Olsson U (1975) A morphological analysis of phenotypes in populations of *Quercus* (Fagaceae) in Sweden. *Bot Not* 128, 55-68

Rushton BS (1974) The origin and possible significance of variation of leaf structure in the two native British oak species, *Quercus robur* L and *Quercus petraea* (Matt) Liebl. Ph D Thesis, University of York

Rushton BS (1978) *Quercus robur* L and *Quercus petraea* (Matt) Liebl; A multivariate approach to the hybrid problem. 1. Data acquisition, analysis and interpretation. *Watsonia* 12, 81-101

Rusthon BS (1983) An analysis of variation of leaf characters in *Quercus robur* L and *Quercus petraea* (Matt) Liebl population samples from Northern Ireland. *IR For* 40, 52-77

Schwarz O (1936) Monographie der Eichen Mitteleuropas und des Mittelmeergebietes. *Feddes Rep* (Sonderbeiheft D) 5, 72-173

Spethmann W (1986) Artbestimmung von zugelassenen Eichenbeständen durch Untersuchung von Einzelblättern und Fruchtständen. Manuscript, Escherode, 17 pp

Wigston L (1975) The distribution of *Quercus robur* L, *Quercus petraea* (Matt) Liebl and their hybrids in south-western England. 1. The assessment of the taxonomic status of populations from leaf characters. *Watsonia* 10, 345-369