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Original article

The possible status of wood quality in oak breeding programs (*Quercus petraea* Liebl and *Quercus robur* L)

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Summary — The first part of the paper presents experimental results illustrating the very high level of phenotypic variability of the anatomical and physical characteristics of the wood (*Quercus petraea* and *Quercus robur*) (density, shrinkage, color, *etc*) and technological properties, namely suitability for slicing. Then some studies are reviewed, which show that a large part of the phenotypic variability in the wood of oak is likely to be under genetic control (individual level). In the second part of the paper, 3 kinds of studies which are still needed for optimum selection of wood quality are proposed: 1) defining realistic selection criteria for wood quality; 2) confirming genetic control of wood quality criteria; and 3) defining conditions for performing optimum selection for wood quality. This last point is treated in the context of possible developments in oak silviculture and regeneration.

***Quercus* / wood / quality / breeding / selection**

Résumé — Place possible de la qualité du bois dans les programmes d'amélioration génétique des chênes (*Quercus petraea* Liebl et *Quercus robur* L). *Dans une première partie, l'auteur présente des résultats expérimentaux témoignant d'une variabilité phénotypique très forte pour les caractéristiques anatomiques, physiques (densité, retrait, couleur du bois,* etc*) et technologiques, notamment l'aptitude au tranchage, des bois de chênes rouvre et pédonculé. Il poursuit en faisant état des résultats de quelques études qui montrent qu'une partie importante de la variabilité phénotypique serait sous contrôle génétique (variabilité génétique intraprovenance). Dans une seconde partie, les études préalables à la prise en compte de la qualité en matière de sélection des chênes sont évoquées : 1) définition de critères réalistes de sélection pour la qualité; 2) confirmation de la réalité du contrôle génétique sur les critères de qualité et 3) définition des conditions de réalisation de la sélection. Ce dernier point est traité en tenant compte des évolutions possibles de la sylviculture appliquée aux chênes.*

Quercus *bois / qualité / amélioration génétique / sélection*

INTRODUCTION

The aim of this paper is to examine the importance of wood quality in an oak breeding program. Two questions arise: why take wood quality into account? How can it be taken into account?

Only *Quercus petraea* Liebl and *Quercus robur* L are considered here. In France, these are the only oaks of economic interest.

First of all, it seems to be useful to define realistic criteria for the wood quality of oak.

Furniture and joinery are uses of primary interest for oak. The decreasing availability of high-grade tropical timbers will emphasize the economic significance of oak for such uses. For these purposes, the following characteristics are necessary (Nepveu, 1990), in addition to suitably shaped logs: 1) low wood shrinkage; 2) no internal cracks, namely frost shakes; 3) straight grain; 4) suitable color and other esthetic traits (especially regularity of radial growth); and 5) small amount of sapwood.

WHY TAKE WOOD QUALITY INTO ACCOUNT IN AN OAK BREEDING PROGRAM?

High level of phenotypic variability for basic and technological properties in wood of oak

All studies devoted to oak have shown that the phenotypic variability of the wood properties of *Q petraea* and *Q robur* is very high. Table I gives some examples of such variability observed on some wood anatomical characteristics, basic and technological properties.

In oak, high levels of phenotypic variability have also been detected for spiral grain (Birot *et al,* 1980) and sensitivity to frost cracks (Miller, 1987).

If the priority of wood quality for some forest species is sometimes discussed, these data clearly show that in oak, wood

Table I. Phenotypic variability for wood traits observed in *Quercus petraea* and *Quercus robur.*

Wood trait		*Ratio between extreme tree means*	*Reference*
Individual vessel area in earlywood		2.0	Huber (1991a)
Early wood width		2.1	Huber (1991a)
% fiber in latewood		4.1	Huber (1991a)
Number of large rays in tangential direction		3.2	Nepveu and Huber (1991)
Wood density		1.3	Huber (1991b)
Volumetric shrinkage		1.7	Eyono Owoundi (1991)
Shrinkage anisotropy		1.4	Eyono Owoundi (1991)
Lightness (on sliced veneer)		1.2	Flot (1988)
% wood extractives in heartwood		2.0	Feuillat (personal commun)
Deformation after drying	sliced veneer	4.7	Marchal (1983)
Smoothness	sliced veneer	1.8 to 2.7 according to criteria	Marchal (1983)
Thickness homogeneity	sliced veneer	2.0	Marchal (1983)

Data are based on a large number of samples in each tree; in most cases, the size of the trees considered was homogeneous, near the size of trees in a final crop, trees originated mostly from the same stand or forest.

properties cannot be neglected because they are too important for the use in joinery and furniture making.

In addition, only part of the large phenotypic variability of oak wood properties is explained by ring width. This means that trees of good quality and relatively high rates of radial growth can be found. In many cases, between-tree variabilities are given for mixed *Q robur* and *Q petraea* trees. However, it should be noted that the amount of phenotypic variability remains very high in each species.

Presumption and first experimental results about genetic control of wood quality in oak

Presumption about genetic control

Presumptions about the genetic control of wood quality are based on 3 facts: 1) in other tree species, the genetic control of most wood properties is high at the individual tree level (Nepveu, 1986); 2) in oak, between-tree variability for wood properties appears to be high even if these trees are even-aged, have the same ring widths, have grown in the same stand. So, between-tree variability cannot be explained by silviculture and environment but only by microsite and/or genetic differences; and 3) in oak, even if between-tree variability is high, many wood properties do not vary significantly within the tree (when ring width and age from the pith are fixed). As mentioned above, this fact has to be related to microsite and genetic effects. However, taking into account the rotation length in oak silviculture, it is doubtful that microsite differences could explain the observation that the cambium of a 200-year-old tree has produced earlywood vessels of the same diameter during most of its life!

First experimental results about genetic control

Because of the small number of experimental plots available, there is little information about the genetic control of wood properties in oak. In spite of this, results obtained by Nepveu (1982, 1984a, b) and Kanowski *et al* (1990) on juvenile to very juvenile clonal or progeny material clearly demonstrate that individual genetic (genotypic) control is: 1) very strong for individual vessel area in the earlywood (h^2 = 0.6–0.9); 2) strong for basic density (h^2 = 0.3–0.6); 3) interesting for wood shrinkage and earlywood width (h^2 = 0.3–0.4); and 4) low but significant for vessel percentage in the earlywood, latewood width and fiber percent in latewood (h^2 = 0.1–0.25). These results were obtained for *Q robur* and *Q petraea* separately.

For Nepveu's results (1984a) the relatively low heritabilities observed for some anatomical traits are explained by low accurary of image analysis results at that time.

HOW SHOULD WOOD QUALITY BE TAKEN INTO ACCOUNT IN A POSSIBLE OAK BREEDING PROGRAM?

As described below, taking wood quality into account in an oak breeding program has 3 requirements.

Define realistic criteria for selection of wood quality

Selection for quality against, for example, shrinkage, frost cracks, spiral grain, for esthetic appeal and a high proportion of heartwood cannot be realistically performed directly: easily measurable criteria have to be found for this purpose.

Selection against shrinkage

The first results gained by Eyono Owoundi (1991) show that wood density combined with ring width and age from the pith are good predictors of wood shrinkage: if both of the other two characteristics are maintained constant, shrinkage increases when wood density and ring width increase and age from the pith decreases.

Additional information on shrinkage obtained by measurements of wood anatomy are expensive to carry out and yield little further information.

Selection against sensitivity to frost cracks

Some basic properties and anatomical characteristics of the wood have been identified as having value in identifying frost-cracked trees (Savill, 1986; Cinotti, 1991) namely: individual vessel area in the earlywood, wood density, wood ray number, wood shrinkage, spiral grain and stem water content.

At present, more research is needed to identify realistic and certain selection criteria for sensitivity to frost cracks.

Selection for wood esthetics

Because of its high variability and, as a consequence, large variability in prices of the final products, esthetics cannot be neglected in selection. However, in spite of initial work in this field performed on oak veneers (Mazet and Janin, 1990), end-user's needs still have to be identified clearly in terms of wood structure and properties.

Such studies will probably have to include quantitative and qualitative measurements on wood extractives.

Selection against percent sapwood and spiral grain

Possibilities other than direct selection are difficult to imagine for these 2 important characteristics. Spiral grain is known to be genetically controlled but patterns of within-tree variability are confused and seem to be closely dependent upon individual trees.

For these 2 characteristics, phenotypic and within-tree variabilities will have to be studied intensively before any decisions about selection strategies can be made.

In addition, a possible consequence of decreasing the percentage of sapwood has to be evaluated in terms of tree physiology, namely the role of sapwood thickness and water content during drought.

General comments

In attempting to identify realistic criteria for selection based on wood quality, one important point can be stressed: recent preliminary results (Eyono Owoundi, 1991; Huber, 1991b) appear to show that wood density *versus* ring width curves in oak could provide synthetic information about wood properties and anatomy. In addition, parameters of such curves depend upon individual trees and seem to be under genetic control, as shown in figures 1 and 2.

It can be noted too that: figure 1 confirms the previous intuition and results of Polge and Keller (1973), who found that for the same ring width, 2 oak trees can exhibit very large differences in wood density; figure 2 indicates that clones with low density (and probably as a 'statistical' consequence, low shrinkage) can be found in spite of wide ring widths. This type of tree, if not susceptible to frost cracks and esthetically acceptable, could be valuable for farm forestry and to complete the natural regeneration in 'classical' silviculture.

The results show that we can hope that curves giving density *versus* ring width for

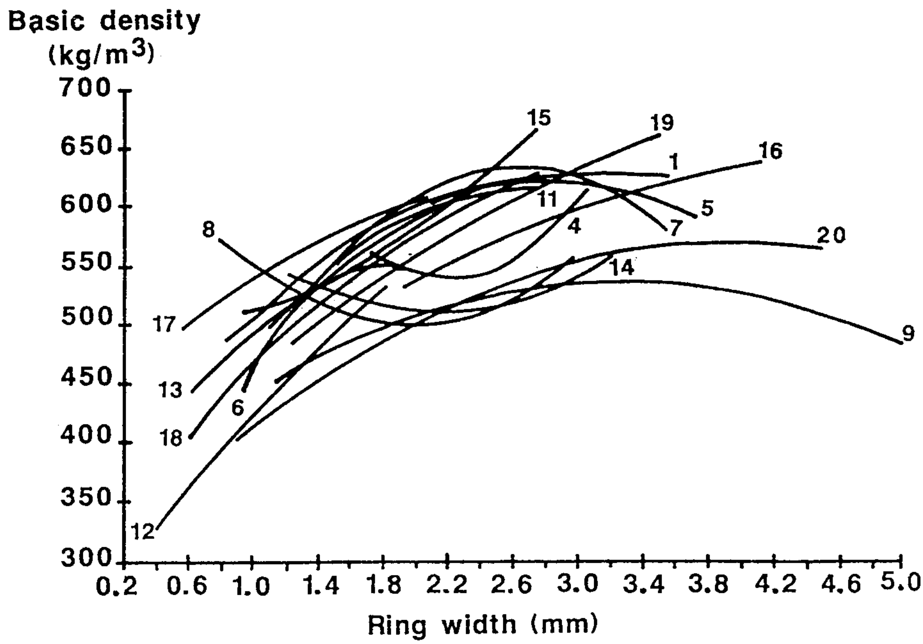

Fig 1. Wood basic density *versus* ring width in oak (*Q petraea* and *Q robur).* A curve represents a tree (after Huber, 1991b).

individual trees might provide information on other wood properties and anatomy, and on the genetic value of the tree. If verified, their use for effective and realistic selection, even on phenotypes in the forest, could be valuable.

Such selection could be non-destructive using X-ray scanning of increment cores.

Estimate or confirm the level of genetic control on wood criteria identified as realistic predictors of wood quality

The following points are considered important: 1) *Q robur* and *Q petraea* must be considered separately; 2) genetic gain for wood quality has to be sought at the individual tree level (*ie* genetic or genotypic level within the provenance); 3) estimation of genetic parameters must be adapted to the chosen breeding program (see below); and 4) special attention has to be given to juvenile–mature genetic correlations.

Define conditions of performance in selection for wood quality in accordance with developments in oak silviculture and regeneration

Two conditions should be considered: 1) continuation of 'classical' silviculture based on natural regeneration, in which case, genetic improvement would consist of cutting down trees which are not desirable as parents; and 2) development of artificial regeneration in existing stands or plantations of new ones (farm forestry, *etc)* in which case, genetic improvement could be more 'classical', *ie,* namely use progenies and clone testing and multiplication.

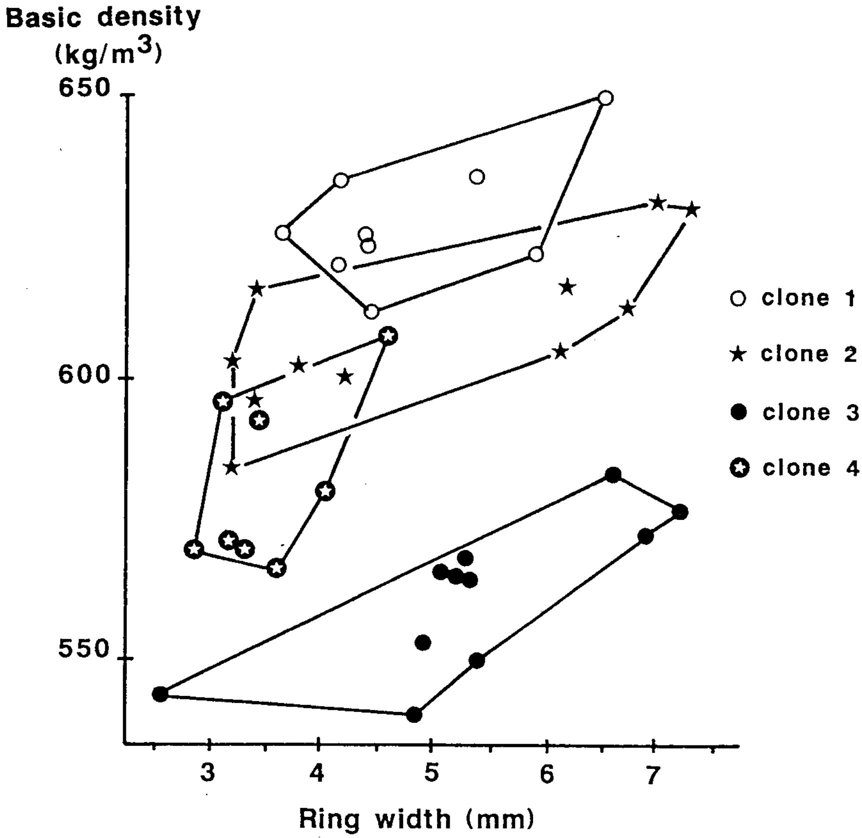

Fig 2. Wood basic density *versus* ring width in *Q petraea* according clone. A point represents a ramet; 4 clones and 8–11 ramets/clone are represented (after basic data from Nepveu, 1984b).

In either case, the time between generations will be high. Therefore, research will have to be focused on methods of selection which provide rapid genetic gain for wood quality. In this event, estimation of the genetic value of mature parent trees (for sexual or vegetative reproduction) through minute evaluation of their phenotype will be a crucial operation.

CONCLUSION

Much improvement in wood quality can be expected if wood properties are taken into consideration in possible oak breeding programs. Early results have been encouraging.

However, significant work remains, mainly in: 1) defining realistic criteria for wood selection: this point certainly represents the major part of the work; 2) confirming the level of genetic control on above-mentioned criteria; and 3) devising strategy(ies) for wood selection which are effective and adapted to oak silviculture.

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