COREWOOD (JUVENILE WOOD) IN *PINUS RADIATA* — SHOULD WE BE CONCERNED?

D.J. COWN

New Zealand Forest Research Institute,
Private Bag 3020, Rotorua, New Zealand

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ABSTRACT

In common with other plantation softwoods, *Pinus radiata* D. Don exhibits a characteristic corewood zone which contributes significantly to the overall variation in wood properties. Industries have developed preferences for wood with a high or low proportion of corewood and may experience problems if the desired levels are not achieved. With evolving forest management practices worldwide, the trend is to a greater proportion of corewood and this has implications for industries which consider this type of wood undesirable.

Traditional definitions of corewood are based on qualitative assessments of the number of rings from the pith at which an important property (usually wood density) becomes "mature". Since this is an interpretation of a biological pattern, subject to fluctuation in the absolute level under the influence of site and genetic factors, species differences can be large and there is often little relation to wood product performance criteria. An alternative definition based on wood density goes some way towards a technical description of the absolute wood quality.

Keywords: corewood; outerwood; earlywood; latewood; wood density; spiral grain; *Pinus radiata*.

INTRODUCTION

Pinus radiata has a well-deserved reputation for rapid growth under a wide range of growing conditions and an ability to meet diverse end-use requirements. The yield and timber quality are a direct result of the interaction of a number of factors—site, silviculture, seedlot. All of these factors contribute to the final "quality", i.e., suitability for a particular end-use. The wood quality of *P. radiata* is highly variable in comparison with that of many other plantation softwoods. Good forestry practice will attempt to optimise the match between inherent quality factors and future market needs.

The existence of a prominent central stem zone with characteristic properties is a common feature of many plantation softwoods, which is gaining increasing attention worldwide (Senft 1984; MacPeak *et al.* 1987; Saucier & Cubbage 1990; Thornqvist 1990) as its effects become apparent. This zone is most often referred to as the juvenile wood. However, since the phenomenon persists beyond the "juvenile" tree growth phase and can be located at all heights in stems, the preferred New Zealand nomenclature is "corewood" as this more correctly expresses the occurrence in the central core of the stem (Thomas 1984) (Fig. 1). Corewood is regarded as "lower quality" for many uses as it typically has low wood density, shorter cells, higher microfibril angle, greater spiral grain, higher longitudinal shrinkage, thinner cell walls, low latewood percentage, and lower cellulose:lignin ratio (Bendtson 1978). The properties concerned usually change gradually from the centre of the stem but show different patterns of pith-to-bark variation. Hence, the demarcation between juvenile and mature wood is not clear. However, the wood properties may be sufficiently different to cause manufacturing difficulties and problems in service. It has even been stated of the southern pines that "it would be wise to consider these fast-grown pines (with a large volume of corewood) as a different species and to develop processing techniques, grading rules and design specifications appropriate to their properties" (Pearson *et al.* 1980).

Corewood is particularly prominent in fast-grown softwoods and may comprise the bulk of the volume of thinnings and even of final-crop logs harvested on short rotations. The association with small logs is unfortunate from the processor's point of view, as not only are yield and productivity affected during conversion but the quality of the end product may also be inferior (Comstock 1984; Haslett & McConchie 1986; Danborg 1992).

Wood technologists agree that corewood characteristics are mostly undesirable because of their impact on both solid wood and pulp and paper products (Zobel & Talbert 1984). The most typical manifestations of corewood are an abundance of knots and low density, and this has important implications. For instance, the effect of corewood on structural timber is poorer grade recovery, lower strength, more distortion and surface checks, and poorer finishing properties (Pearson & Gilmore 1980). Corewood in structures has also been blamed for excessive movement in response to changing atmospheric conditions (Gorman 1985). Although pulp yields are adversely affected, corewood (low latewood proportion) is the preferred material for some pulp and paper products such as writing papers, tissues, and newsprint (Carpenter 1984). Corewood is not suitable for papers requiring high tear strength and the proportion in the feed stock must be carefully controlled in kraft pulping (McKee 1984).

The rapid growth rates achieved with genetically improved trees of exotic species, planted on fertile sites and managed for diameter growth, permit crop rotations much shorter than are

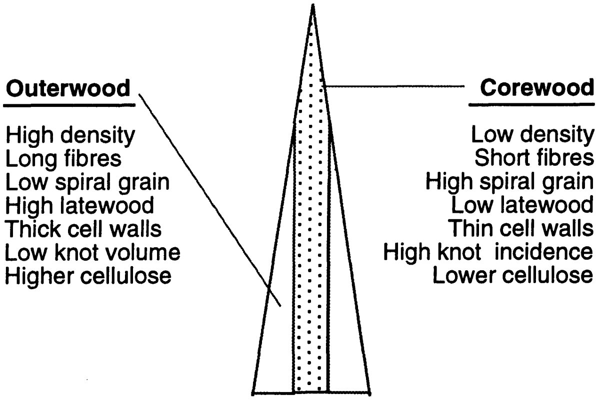

FIG. 1–Location and properties of corewood and outerwood.

possible in natural stands and so the quantity of corewood entering the market is greatly increased.

Corewood is often defined in terms of the rate of change in wood properties from the centre of the stem outwards, and it has been convenient to describe its location in terms of the number of growth rings from the pith. Most researchers consider that anywhere from the first five to 20 rings can be classified as "juvenile", depending largely on both the species and the subjective judgement of the investigator (Zobel & Talbert 1984). An important aspect of corewood formation is that growth rate, as reflected in ring width, has been reported to have little, if any, effect on the corewood/maturewood transition (Bendtson 1978). Differences in the patterns of wood properties between trees and sites are far more likely to arise from genetic and environmental influences (Loo *et al.* 1985; Saucier & Clark 1992).

There are signs that some researchers are seeking a better definition, more related to end-use considerations (Chantre & Leban 1992).

COREWOOD IN NEW ZEALAND PINUS RADIATA

In contrast to many other parts of the world, the New Zealand forestry sector has adapted to some extent to the inherent properties of plantation softwoods. However, the characteristics of the plantations are still evolving as new techniques are developed for optimising growth performance, e.g., genetic improvement and cultural practices. It is not uncommon for *P. radiata* stands to reach a size which could be considered suitable for sawlogs in 15 years. Since a large proportion of the stem has juvenile characteristics, it is important to understand the implications. Already the effects of low density and high spiral grain, coupled with knots, abnormal longitudinal shrinkage, and compression wood, have given "young" logs a poor reputation in some sawmills.

The wood properties of *P. radiata* grown in New Zealand have been extensively studied and reported (Cown, McConchie, Young 1991; Cown 1992a; Kininmonth & Whitehouse 1992). Quality parameters vary in accordance with patterns described for other pines within trees, between trees, and between sites (Thomas 1984). The occurrence of corewood in *P. radiata* has been highlighted in a number of wood quality studies, and for convenience it has been suggested that the inner 10 growth rings be considered corewood on the basis of the known patterns of wood density variation. This inner zone typically shows the widest growth rings and contains knots, compression wood, and spiral grain. While there is no doubt that the corewood concept is an important quality parameter in *P. radiata* plantations, the "first-10-rings" rule of thumb may not always be the most appropriate indicator.

The problems with the "first-10-rings" definition of corewood are two-fold: (1) the transition from the juvenile to the mature levels for each wood property is gradual and hence can only be determined arbitrarily, and (2) it gives little indication of the absolute wood properties, which can vary significantly between species, sites, and seed sources. The results of applying this definition in a 25-year-old managed crop are shown in Fig. 2. Corewood averaged 35% in the pruned butt logs and increased up to 90% in the uppermost logs.

The "first-10-rings" definition of corewood has severe limitations in species, such as *P. radiata*, where the wood properties of the inner rings vary significantly between stands. The wood density of the inner 10 growth rings varies predictably from 360 to 400 kg/m^3

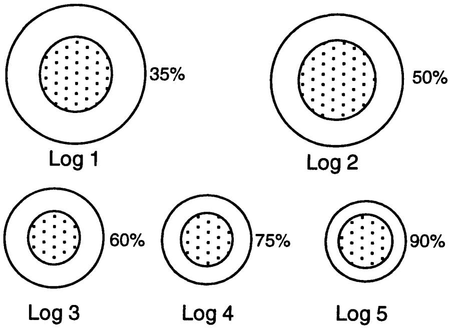

FIG. 2–Corewood incidence by log height classes in a 25-year-old crop, assuming the "first-10-rings" definition.

according to geographic location in New Zealand (Cown, McConchie, Young 1991). An alternative approach would be to select the most important juvenile characteristic(s) and define an appropriate corewood/maturewood transition, based on measurable end-use requirements.

Basic wood density is the most important property, other than knots, affecting both stiffness and strength of structural timber on the one hand, and the surface hardness of appearance grades on the other. A reasonable minimum wood density value for clearwood to ensure satisfactory in-grade performance of framing members is 400 kg/m^3 (Australian Standard AS 1720.1, 1988). Density requirements for structural plywood (Bier 1986) and furniture and cabinet making may be higher (Kininmonth & Hellawell 1979).

Cown, McConchie, & Young (1991) presented average wood density trends for three broad density zones for *P. radiata*, indicating that the 400 kg/m^3 level will be reached on average after 8, 14, and 18 rings respectively on high-, medium-, and low-density sites (Fig. 3). The 10-ring corewood definition most accurately reflects the situation of *P. radiata* growing on a high-density site.

Recent research using the NZ FRI wood densitometer has highlighted further extremes of wood density development in *P. radiata*. Wood from agroforestry stands maintained at low stocking (100 stems/ha) on fertile sites in the central North Island (medium-density zone) did not average 400 kg/m^3 until about 20 rings from the pith. This effectively extends

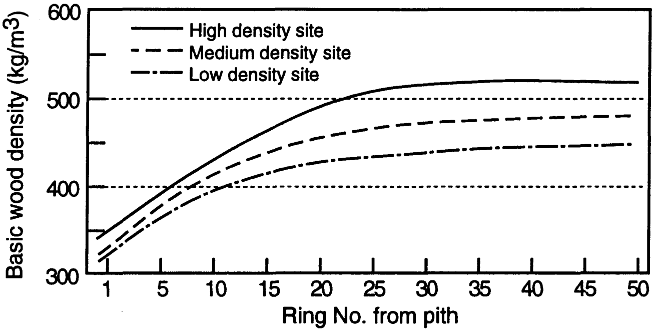

FIG. 3–Average density of *Pinus radiata* in relation to site and age.

the juvenile phase by 5 years while allowing a shortened rotation due to the increased log diameter growth. The difference was attributed to a combination of site, regime, and seedlot. Sawing trials using logs from a similar crop at less than 20 years of age have confirmed the very poor strength properties of framing timber and the poor machining characteristics of some of the timber from such stands in comparison with predictions based on "forest" crops (unpubl. data).

The indications are that a more practical definition of corewood should take account of the major sources of variation in wood density of *P. radiata*. This approach would also highlight benefits from site selection and the use of genetically improved seed stock which offer reduced corewood. In Fig. 4 density trends are plotted for six families growing in the same trial area in the central North Island, with juvenile cores ranging from seven to 14 rings (based on the 400 kg/m^3 level). It would appear that while the genetic extremes represented in the data are broadly comparable to the range in site averages given above and attributed to environmental factors across the whole of New Zealand, site factors are dominant in the overall picture.

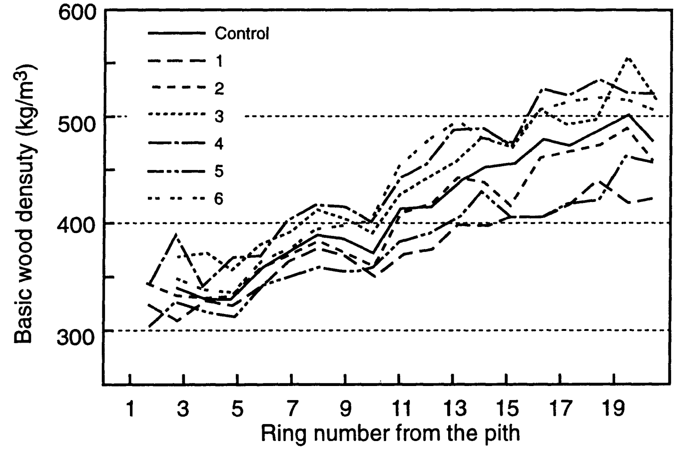

FIG. 4–Wood density of selected *Pinus radiata* families.

Spiral grain is much less well understood. It is accepted that grain angles are greater in the inner growth rings, but it was not until very recently that good data on within-tree patterns were derived (Cown, Young, Kimberley 1991) (Fig. 5). Wood drying studies have shown that grain angles in excess of 5° are likely to cause problems with twist, even under favourable drying conditions. In terms of spiral grain, the danger zone is clearly the first 10 rings, but to date there are insufficient data to identify the extent of possible site, cultural, or genetic influences. However, the extremes in individual-tree spiral grain patterns apparent in the recent study (Cown, Young, Kimberley 1991), suggest that (a) spiral grain is likely to be a significant problem in young logs, and (b) there may be scope for selective breeding to reduce the impact of spiral grain on sawn wood products.

There is strong evidence that spiral grain can contribute very significantly to the economics of processing. In a recent sawing and drying study (Haslett *et al.* 1991) involving logs from a 25-year-old tended stand, excessive twist was estimated to account for an average reduction in return of about \$40/m^3 of sawn product.

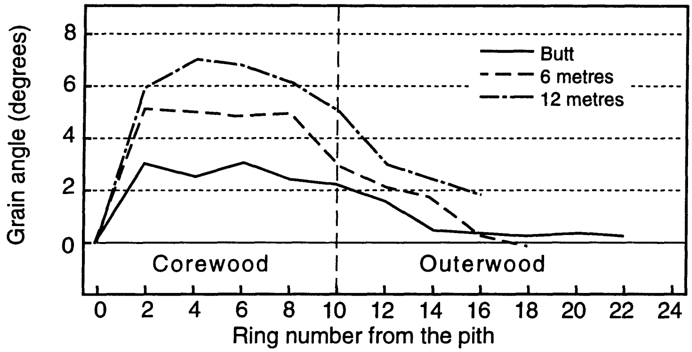

FIG. 5–Typical spiral grain patterns in *Pinus radiata* in relation to radial and vertical position in the stem

Wood processors are accustomed to variable quality in the raw material and can adapt, providing the quality does not drop below acceptable limits. On the basis of research results it can be concluded that wood density in *P. radiata* is at the lower acceptable limit and spiral grain above the upper limit for some end-uses.

CONCLUSIONS

The process of growing and utilising plantation products is driven by economics, but unfortunately the economic impacts of resource quality changes do not become apparent for decades, during which time market requirements and processing technology can change. However, the uncertainty about quality needs should not necessarily drive management to maximising volume or value without consideration of wood properties.

There is a widespread commitment to thinning and pruning for quality in butt logs which can result in some crop volume losses and reduced quality in unpruned logs. The assumption is that the benefits of a larger clearwood zone outweigh any disadvantages elsewhere in the tree. However, clearwood markets require quality in the form of appearance, stability, and machinability which cannot be guaranteed within the corewood zone. Rapid early growth rates cannot be increased indefinitely by genetic selection, siting, and silviculture without a significant reduction in wood quality. Even if wood properties themselves are not greatly altered on a year-by-year basis, the increased volume of corewood at younger harvest age can be highly undesirable. The trend to shorter harvest ages also raises the question of the applicability of species data collected from older material and assumed to apply to the entire outturn.

Forest management practices which could be used to reduce the impact of corewood are siting, initial spacing and thinning, increased rotation length, and genetic selection. Extending the rotation is the simplest effective way to minimise the proportion of corewood, but changes to silvicultural practices are unlikely to be accepted without a strong economic argument. Within this framework, the prospective gains from genetic manipulation are modest—it is not conceivable that large trees harvested at, say 20 years, will have desirable properties for most solid-wood uses, not least because rapid diameter growth also gives rapid branch growth. Large branches and low density give the most undesirable scenario of all.

It is not until wood quality is reflected in log prices that practices will change. A measure of corewood which is related to the value of the wood for utilisation would help to focus attention on the importance of wood quality.

Investment decisions are often made using financial models which include aggregated price data insensitive to wood quality. If it is assumed that a large portion of the harvest will require strength and stability for structural purposes, then corewood will have a large negative impact on profitability. Some of the financial implications can be explored by use of prediction and modelling tools such as STANDPAK, but the level of refinement is not yet sufficient to enable all the factors to be taken into account from stump to user (Cown 1992b). Where products must meet appearance grade requirements, a high-quality finish and stability will be necessary. Already it is apparent that the low wood density and high spiral grain found in some stands are detrimental to drying and machining, and any further increase in the incidence would adversely affect both structural and clearwood markets for *P. radiata*.

It is unlikely that foresters will respond to corewood in the short term by reducing growth rate in the early years, as this incurs a financial penalty from higher initial stocking rates. The pulp and paper industry will benefit from the rapid production of fibre which can be blended with other sources if necessary, but solid wood processors and users will have to rely increasingly on appropriate (mechanical?) timber grading and product design to minimise the effects of low-quality wood. In the longer term the high heritabilities of wood properties offer opportunities to select tree breeds with more appropriate characteristics or growth patterns (late starters) and a chance to respond to developing value gradients for logs, which may well include a "maturity" factor of some sort. The 400 kg/m^3 definition of corewood will help to assess the technical suitability of wood for some of the more demanding uses.

It is suggested that this density-based definition (corewood = wood < 400 kg/m^3) be used in preference to the ring-based one (corewood = first 10 rings from the pith) in situations where strength, stiffness, or surface hardness are considerations.

It is impractical to eliminate corewood entirely from plantation softwoods, so processors will increasingly have to learn to deal with it. In the meantime, more research is required on the impact and heritability of corewood characteristics, and in particular the occurrence and amelioration of spiral grain, for which no regional data are yet available comparable to the density information. The corewood definition may be altered at some later stage to take account of wood which qualifies under one criterion but fails to meet another, e.g., spiral grain.

Should we be concerned? Yes, if we are seeking to acquire and maintain a reputation for quality in *P. radiata*. Strength, stability, and machinability are prerequisites for solid wood products on domestic and export markets, and strongly influenced by the presence of corewood.

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