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SILVICULTURAL EFFECTS ON WOOD PROPERTIES

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ABSTRACT – Anything that can change the growth pattern of a tree may result in wood variation. The objective of silvicultural operations in to change growth patterns. One cannot predict the response of the tree as to wood properties from this change and the only way to tell for sure is to grow the trees under the extant conditions. Usually, added growth from nitrogen fertilization will decrease wood density in the hard pines while a similar amount of added growth from thinning levels the wood relatively unchanged. Fertilization can greatly affect the wood produced, as will drastic thinning. Differences in stocking density in plantations from initial planting has less effect. Pruning, if done correctly, generally has only a minor effect on wood other than the obvious increase in clear wood. Actually, almost any extreme silvicultural activity can alter the wood enough to have a real affect on the final products produced. This is especially true for exotic species when planted in their new and different environments.

RESUMO – Qualquer coisa que consegue altera o padrão de crescimento de uma árvore pode resultar em variação na qualidade da madeira. O objetivo das operações silviculturais é mudar os padrões de crescimento. Em termos de propriedades da madeira, a resposta das árvores a tais mudanças não é previsível. A única maneira de conhecê-la com exatidão é submeter as árvores às condições de crescimento existentes. Normalmente, o crescimento adicional produzido pela adubação nitrogenada reduz a densidade da madeira em espécies de ***Pinus*** de alta densidade básica, enquanto que uma quantidade similar de crescimento adicional resultante de desbaste praticamente não altera a madeira. A adubação pode alterar profundamente a madeira produzida, da mesma forma que desbastes drásticos. As diferenças de densidade em povoamentos resultantes de espaçamentos iniciais de plantio tem um menor efeito. Em geral, a desrama, quando corretamente executada, não tem grande efeito além de aumentar a proporção da madeira livre de nós. Na realidade, qualquer atividade silvicultural extremada pode alterar a madeira a ponto de influenciar a qualidade dos produtos finais. Isto é particularmente verdadeiro para espécies plantadas em ambientes novos e diferentes dos de sua região de origem.

INTRODUCTION

For a subject such as the effect of silviculture on wood properties, the only proper initial statement to make is that anything that causes a change in the growth pattern or form of a tree may result in differing wood properties (ZOBEL & VAN BUIJTENEN, 1989). But the curx of the problem is the “may”. Sometimes wood is affected by forest management practices, sometimes it is not. (BLAIR & OLSON, 1984). Under identically the same conditions, the wood of one tree will be stable under varied silviculture regimes, an adjacent tree might show considerable change in wood properties. It is not possible to make absolute generalizations because there are always exceptions to any rule that may be made about the effect of silvicultural treatment on wood properties. However, even while being aware of the above, I will make some general statements about silviculture and wood properties to at least show the direction of any relationships that may occur.

Although an usual criterion for assessing the affect of silvicultural treatments on wood is based upon the simple determination of the silvicultural effect on growth, this is not satisfactory since numerous factors and interactions are involved. (CHOONG et alii, 1970). Thus, the only other general rule that can be stated about the effect of silvicultural actions on wood properties that one must apply well regulated and documented silvicultural treatments and then to assess the wood produced.

Some silvicultural influences on wood, like the use of fertilizers, are relatively well known. The effect of others, such as differing methods of site preparation, are poorly understood and not well documented. Since nearly all silvicultural activities result in a changein growth rate, growth patterns or tree form they can affect the wood produced; such relations are therefore of interest to foresters. The literature on some aspects of the subject is voluminous but it also contradictory. (See ANONYMOUS, 1962 – TAPPI Monograph 2 series N^{o} 24 on the influence of environment and genetics on wood quality, published in 1962, and the similar one by WEINER & ROTH in 1966 or the more recent one on loblolly pine in 1985 by MEGRAW).

The difficulty with relating silvicultural treatment and their effects on wood properties is to determine cause and effect. Even though a change in wood properties may occur related to a given silvicultural treatment, the question still remains whether the change in wood is caused by the resulting differing growth patterns or by the treatment per se.

A good example of this is the confusion resulting when ***Pinus taeda*** is caused to grow more rapidly from thinning or by the application of nitrogen fertilizers. When mature trees of the same age on the same site ar assessed, those made to grow more rapidly with nitrogen fertilizer produce wood with a gretly reduced specific gravity for a few years while the released trees, growing equally rapidly, have essentially no change in specific gravity from that before release. (POSEY, 1965; ZOBEL & VAN BUIJTENEN, 1989). The same differential response to cause of additional growth rate and wood was reported by HIGGS & RUDMAN (1973) in ***Eucalyptus regnans*** and in ***Pseudotsuga menziesii*** by PARKER et alii, 1976. It has been reported that release stimulates growth which in turn results in the production of lower density wood in ***Acacia mearnsii*** (SCHONAU, 1982) and in ***Pseudotsuga menziesii***.

Despite its importance, and the large amount of variation related to it, growth rate is not the subject of this paper. (For a detailed treatment, see Chapter 5 of “Wood Variation: Its Causes and Control” (1989) by ZOBEL & VAN BUIJTNEN. But it is essential to always remember that silvicultural treatments usually affect growth rate which in turn might be the reason for the wood variation.

There are a myriad of silvicultural actions that affect wood which could be discussed including nutrient status stocking, pruning, planting techniques, resin tapping, coppicing and others. As will be shown later the simple expedient of manipulating age of harvest will often have a major effect on the wood properties of the harvested trees. (MARTIN, 1984). Most frustrating is the interaction among silvicultural treatments, an emphasized by CHOONG et alii (1970) who concluded that when a rapid growth rate results from a silvicultural treatment, wood specific gravity may be independent of the effects of any single silvicultural manipulation. As one example, COWN & MCCONCHIE

(1981) reported a much larger wood response from combined thinning and fertilization than when either was used alone on radiate pine.

To add to the confusion, as was well pointed out by LARSON (1967), no matter how much the environment is changed by the silviculturist, the inherent huge among and within tree variation tends to mask any specific cause for variation. His emphasis is that forester needs to produce more uniform and higher quality timber which can be major result of silvicultural manipulation.

Time limitations for this paper necessitate that only a couple of the more important and well known silvicultural actions will be covered as they may affect wood properties.

FERTILIZATION

Fertilization in forestry is just coming into wide usage, currently being more common in the hardwoods than in the conifers. In many tropical area, fertilization of trees such as the eucalypts at time of planting is a standard operation. Results of studies on the effect of fertilization are quite numerous but often not definitive because of lack in design or because complications from interactions were not take into account (ELLIOTT, 1970). Usually, response to fertilization is assessed by the volume increase; this is not correct because, even though the added growth many more offset the effects on wood, the true assessment of fertilizer response must also include how it may change wood. (WALKER, 1960). As one example, in ***Pinus elliottii*** SMITH et alii (1971) found that fertilizing increased volume production five times while weight loss from the nitrogen was 4%. The greater importance of fertilizers was also emphasized by SCHMIDTLING (1973) for southern pines and ROSS et alii (1979) for ***Liriodendron tulipifera***. Results assessed by wood weight alone are not satisfactory since quality of the wood for the final product must be determined, both in the fibers produced and in tree form. (LARSON, 1967).

All things such as time, kind and amount of fertilizer have an affect on wood properties. For example, POSEY (1965) and NICHOLLS (1971) reported that fertilizing in several small doses usually does not affect wood characteristics as much as applying it in a few large doses.

One method of fertilizing forest trees much talked about (but rarely applied) is the use of nitrogen-fixing plants in the forest. (DAVEY & WALLUM, 1979). As examples, VON PECHMANN & WUTZ (1960) found that for older trees, wood density was about the same after as before planting lupines. More growth with more earlywood was obtained but also more latewood was formed. In young pine and spruce planting lupines with the trees reduced wood specific gravity. When ***Eucalyptus-Leucaena*** mixtures were grown, in Brazil, after seven years there were no differences in wood density or holocellulose yields of the eucalypts in the mixture; also there was no growth response (JESUS et alii, 1988).

When there is a change in wood following fertilization with nitrogen, the effect on the wood usually disappears after a few years and the specific gravity returns to normal (POSEY, 1965; PARKER et alii, 1976). For loblolly pine 12 to 16 years old, a drop of specific gravity from 0.48 to 0.39 was obtained immediately after heavy fertilizing with nitrogen. The reduction in specific gravity was proportional to the amount of nitrogen used. After the sixth year the specific gravity of the fertilized trees returned to normal or slightly above normal. There was also a reduction for 12% in tracheid length, but the tracheids were still shorter than normal after six years. Fertilizer did not affect all trees the same, and those with the higher initial specific gravity or tracheid were most affected (POSEY, 1965).

It is of interest than on the same species MEGRAW (1985) states that fertilization did not alter specific gravity depending on the initial values.

In their partial summary of the effects of specific gravity on wood properties, covering 44 studies and 16 species of conifers, ZOBEL & VAN BUIJTENE (1989) assessed the studies as:

1. Nitrogen causes the greatest change in wood properties. Occasionally phosphorus aline or phosphorus plus nitrogen also were effective but most other nutrients rarely had an effect. As usual, reported results were not unanimous; for example, for ***Pinus radiata*** NICHOLLS (1971); MCKINNEL & RUDMAN (1973); COWN (1971), and NELSON et alii (1980) reported reductions of 3 to over 20% in specific gravity with phosphorus fertilization on radiate pine. Oppositely, GENTLE et alii (1968) found no reduction with phosphate fertilization of radiate pine but wood density was reduced with nitrogen.

2. Nitrogen fertilization cause a mild to severe decrease in specific gravity as well as shorter tracheids. In many studies fertilization did not cause any change in wood any major wood properties.

3. Fertilization frequently increases the percentage of earlywood and often does not affect the latewood. In some instances it makes earlywood cell walls thicker and latewood cells thinner. Frequently nitrogen fertilization increases the period of juvenile wood production.

4. Fertilization plus thinning increase growth rate and may reduce specific gravity; the reduction is reported to be primarily associated with fertilization, not with thinning.

5. For the best solid wood products, nitrogen fertilization should be light and frequent.

6. In all studies, the added value of greater volume from fertilizers more than offsets an adverse change in wood properties (MCKINNEL & RUDMAN, 1973; HUNT, 1977).

7. Since fertilizing with nitrogen sometimes produces earlywood tracheids with thicker walls and latewood tracheids with thinner walls, within ring uniformity is increased.

Fertilizing hardwoods is more general, and the reported affects on wood are inconclusive and contradictory. In the more than sixteen studies reported on hardwoods (fourteen species, five of the eucalypts) ZOBLE & VAN BUIJTENEN (1989) summarized generally as follows:

1. Fertilization can cause degrade in the quality of solid wood products by stimulating poor tree form, and epicormic branching, but this usually does not happen.

2. Mineral deficiencies such as calcium, boron and phosphorus cause a high wood specific gravity. In ***Populus deltoids***, deficiencies of nitrogen and sulfur result in short fibers and small diameter fibers and vessels.

3. Nitrogen may reduce cell size, wall thickness and specific gravity as for the conifers, but there are many exceptions especially in the diffuse porous hardwoods.

4. As for conifers, the better volume growth following fertilization more than offsets wood quality loss expcept for a few specialty products.

On result from fertilization, emphasized by several workers for conifers, is that it often leads to more uniform wood within an annual ring. No information was found for hardwoods. Some species for which uniformity was reported are:

Species	Author(s)
Larix leptolepis	ISEBRANDS & HUNT, 1975
Picea abies	VON PECHMAN, 1958
Pidea abies	VON PECHMAN & WUTZ, 1960
Pinus banksiana	KLEIN, 1968
Pinus ponderosa	ECHOLS, 1971
Pinus pinaster	POLGES, 1969
Pseudotsuga menziesii	MEGRAW & NEARN, 1972
Pseudotsuga menziesii	SIDDIQUI et alii, 1972
Pinus resinosa	SIDDIQUI, 1971
Pinus taeda	GLADSTONE & GRAY, 1972

STOCKING

Perhaps the most commonly used tool of the silviculturist is stocking control, either through tinning or by means of initial stand establishment. It is primarily a method to control growth patterns and yield but as LARSON (1969) strongly stated, it has a great influence on the properties of the wood. It affects wood by influencing growth rate and crown development as well as tree form, especially branching characteristics (BAMBER & BURLEY, 1983). The environment within the plantation is changed also; for example, SAVINA (1956) states that more moisture remains in the soil in thinned plantations. He also reported that the cambium of the trees in thinned stands becomes active 5 to 10 days earlier than in the unthinned ones. Similarly, ZAHNER & OLIVER in 1962 found thinning delayed the enception of latewood of ***Pinus banksiana*** by 2.5 weeks at breast height. Just as for other silvicultural actions, the effects of stocking control on wood properties are not predictable and results are controversial.

However, there are some patterns of wood development that are general for differences in stocking, especially when thinning is done. Although there are exceptions (see ECHOLS, 1971, for ***Pinus ponderosa***), thinning usually has a minor effect on the wood properties of the residual trees (SUTTON & HARRIS, 1973; COWN 1973). This is a little surprising because thinning results in the tree suddenly being in an environment quite different from the one in which it had been growing. Exceptions have been noted for ***Pinus ponderosa*** and SIMEON (1973) found that the wood density of ***Pinus radiate*** was reduced 8 to 10% by thinning. Of course, proper thinning increases tree size and the number of high quality logs. It will affect the age of wood in the final harvest and will alter the proportion of juvenile wood, which is mostly what is obtained from thinnings. There will be more moisture in the wood and a lower basic density because of the earlier harvest age and larger percentage juvenile wood.

The effect of thinning on the wood of hardwoods is less well known. With some species, opening the stand results in epicormic branch formation which adversely affect log quality (ERDMAN & PETERSON, 1972). If thinning is done at the wrong time, or incorrectly, it will results in large branches with bigger knots, or tree forking (CONOVER, 1958).

In summary of the effect of thinning on wood properties it can be said:

1. Wood quality is improved because the logs in the final harvest are larger and of better quality.

2. Wood removed as thinnings will have a high proportion of juvenile wood.

3. In thinned stands the cambium becomes active earlier than in unthinned stands but latewood productions delayed.

4. Thinning has more effect on the wood of the ring porous hardwoods and than on the conifers or diffuse porous species.

5. Normally, specific gravity and tracheid length are not much affected by thinning although authors such as HILDEBRANDT (1960) report a decrease in cell length.

6. In hardwoods, epicormic branches following thinning can cause a major degrade in wood qualities.

Although less work has been done relative to wood from plantations with different spcacing than spacing by thinning, the effect can be considerable. Control of stocking by initial planting density, results in no abrupt change in light, moisture or competition as occurs with thinning. As one example, GEYER & GILMORE (1965) reported that in areas where moisture is limiting, an increased specific gravity of loblolly pine can be obtained from wider spacing. AS commonly recognized, considered, initial plantation spacing has a major role in altering tree limb characteristics and related defects and reactionwood are associated with wide spacing. This was reported by POLGE (1969a) who found knots, more taper and more juvenile wood in widely spaced plantings. For ***Pseudotsuga menziesii*** GRAH (1961) found a direct relationship between knot size and initial plant spacing.

Opposite to the occasional effect on wood caused by wider spacing from thinning, changes in intial plantation spacing has little effect on specific gravity and tracheid length (***Pinus banksiana***, GRIGAL & SUCOFF, 1966; ***Pinus taeda*** 1965). However, as usually occurs, contrary results are reported. For example, WHITMORE & LIEGEL (1980) found that close spaced ***Pinus caribaea*** had lower wood density than wider spaced trees (specific gravity of 0.44 v.s. 0.52). It is frequently assumed that close spacing will increase wood density (BAKER & SHOTTAFER, 1967) for ***Pinus resinosa***, BARSE & LAIDLEY (1980). ECHOLS (1960) found that stocking had little effect on wood density and emphasize that close spacing is not a good way to increase specific gravity.

For species with a low summerwood percent, like the spruces, it is more common to find low density wood at wider spacing (KLEM, 1942; PERSSON, 1975). As is usually found, tracheid length is not related to plantation spacing.

For hardwood relatively few spacing – wood studies have been reported, although some have done in the eucalypts. Nearly all show no relationship between wood specific gravity and growth rate (SCHONAU, 1973). In the Congo, however, DELWAULLE (1985) found a specific gravity of 0.52 at close spacing and 0.60 at wide spacing, a surprisingly large change in the positive direction.

1. Usually, plantation spacing has little effect on specific gravity and cell length but there is a marked effect on wood properties as influenced by limb size and number which are closely related to initial plantation spacing.

2. Wider spaced trees have larger juvenile cores and often their stems have more tapes (SAUCIER, 1987).

3. Initial plantation spacing often does have an effect on species with the wider spacinga producing lower wood densities.

4. In areas of low rainfall, sometimes more widely spaced trees produce higher wood density.

PRUNING

The direct benefit of producing more clear (knot-free) wood from pruning is understood and accepted by all. The pruning can also affect the properties of the wood itself, especially when the pruning is not done correctly or is too severe. (BROWN &PAWSEY, 1969; POLGE, 1969; WYLIE, 1976). Poor pruning methodology is common, resulting in swirled grain and resin pockets; according to PARK & PARKER (1982) resin pockets are the major cause of degrade in the wood from pruned trees. The objective is usually to prune the most valuable basal log. Usually pruning higher is non-economic (BROWN, 1965).

The tree should be pruned when bole diameter is about 12 cm to allow the formation of enough clean wood outside the knot zone to make the pruning economic. Usually no more than ½ the live crown should be removed (FIELDING, 1965); recent studies show that 40% is probably better (ANDERSSON, 1967; STAEBLER, 1963).

Sometimes pruning will cause an early cessation of juvenile wood formation (MEGRAW, 1985). In ***Pinus radiate*** the specific gravity may be increased from 0.48 to 0.59 by pruning, according to POLGE (1969). An increase in wood density was also found by FIELDING (1965) and COWN (1973). Opositely, BAMBER & BURLEY (1983) found no increase in specific gravity following pruning in the same species. Just as for thinning, pruning often stimulates the formation of epicormic branches, essencially in the hardwoods (GRISEZ, 1978).

OTHER SILVICULTURAL PRACTICES

Numerous silvicultural operations other than the three major ones mentioned above can affect wood properties. Planting is one; if trees are planted crooked or with U or J roots they frequently will not grow straight throughout their lifetime. As a results of the initial angel of the stem, they correct for straightness by the production of reaction wood resulting in inferior wood in the tree bole. Other things such as resin tapping affect wood and resin content of the wood (HURLEY et alii, 1976; SQUILLACE, 1978). The question is frequently raised as to the wood properties of stems grown as coppice. In general the wood from coppice has the same properties as the original tree at the same age. However some persons, like SESBOU (1981) reported eucalypt wood properties form coppice may differ somewhat form the original tree. Unless managed very carefully , dougle and triple coppice stems have more reaction wood than a normal, single tree. A knowledge of the wood properties of coppice trees is most important because this type of wood will become more common in several widely planted trees.

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