1992 No 6

Forestry and Forest Products
NEWSLETTER

The Regeneration of Highland Eucalypt Forests in Tasmania

by Bob Ellis

Division of Forestry

Top height achieved by this suppressed regrowth tree after 35 years. Released four years ago, the new leader is now over five metres tall.

Managing the highland forests of Tasmania successfully requires a good knowledge of the history, species composition and ecology of the forest. After considerable research the interaction of these factors is now understood and the forests can be successfully managed under regimes which ensure satisfactory regeneration.

History

In Tasmania forests that occur between an altitude of 600 m and the limit of closed forest at about 1100 m are termed 'High Altitude Forests'. These forests cover about 375 000 ha and are dominated by *Eucalyptus delegatensis* (alpine ash). On harsher sites *E. delegatensis* is accompanied by or displaced by one or more of *E. amygdalina* (black peppermint), *E. dalrympleana* (white gum) and the snowgums *E. pauciflora* and *E. coccifera*.

Large areas of the highland forest were used as summer hunting grounds by the Aborigines who apparently patch-burned the forest regularly to provide 'green pick' for game and to facilitate travel. Thus at the time of European settlement most of the forest consisted of open stands of mixed-age eucalypts, but with a preponderance of old and mature trees and a ground

in this issue...

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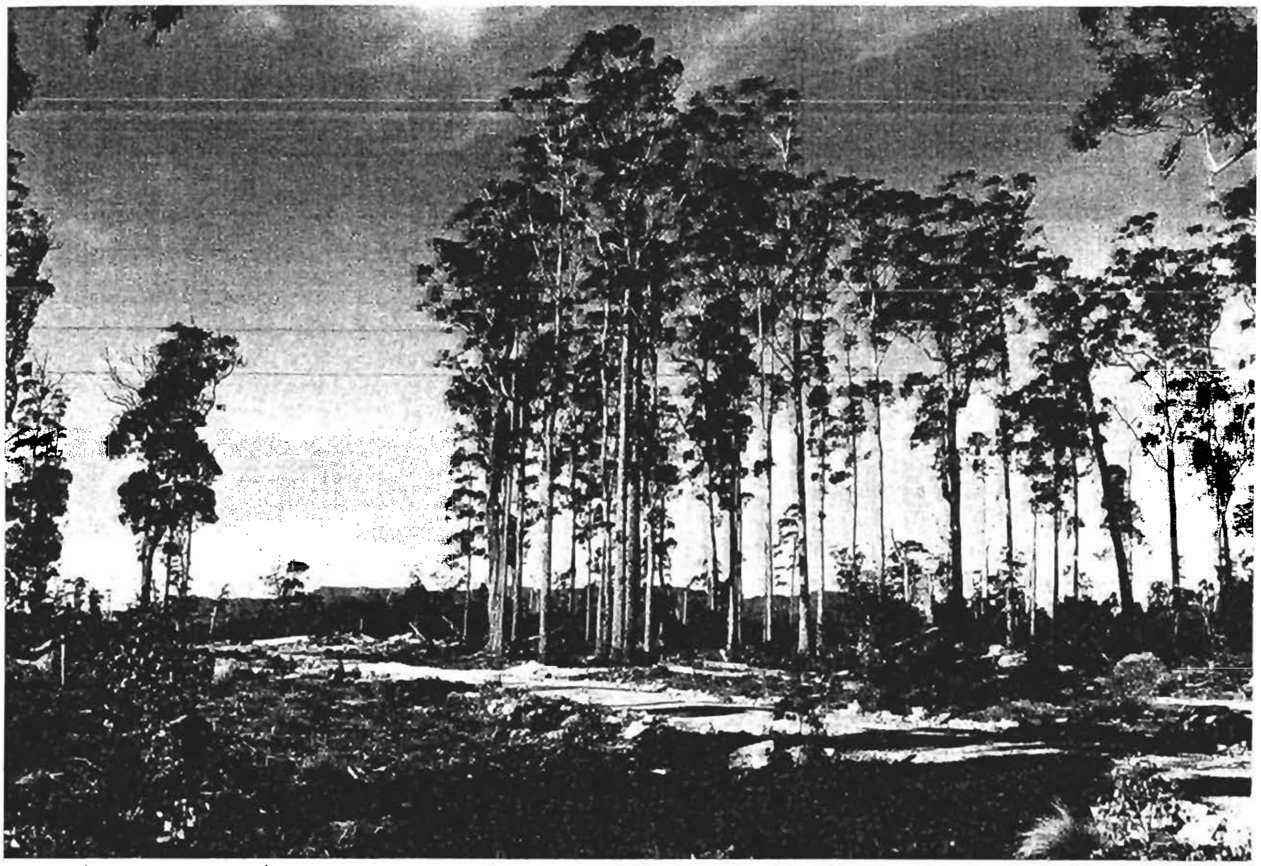


A group of small sawlogs left to grow on following a sawlog cut and subsequent pulpwood cut

cover mainly of grass on the better soils, and of scrub on ill-drained or rocky areas. Burning regimes changed with the removal of the Aborigines and it is probable that most of the area remained unburned for many years. When burning was resumed in pursuit of stock-grazing, fires were less frequent than in Aboriginal times, were hotter, and may have been conducted at different seasons of the year.

These forests were little used for wood before the mid-1950s because of low standing volumes, remoteness and, in particular, difficulty in seasoning the timber. However, for 150 years or so they have been used as summer and even year-round grazing for stock. To this end about one-third of the forests have been converted to private ownership and much of the remaining State forest and unallocated Crown forest was subject to long-term grazing leases.

After World War II selective cutting of the highland forests for sawlogs increased rapidly. These operations were commonly accompanied by wildfires, or by fires lit in pursuance of grazing which produced regeneration with varying degrees of success, depending upon factors such as the intensity and frequency of fire, the weather at the time, and the duration and intensity of subsequent grazing.

In large areas of the highlands at elevations up to 800 m or so attempts were made to clear the forest for agricultural development. Some attempts date from last century, but a major surge in alienation and subdivision commenced after World War I. In what appears from present day perspective to have been a frenzy of ringbarking and destruction of the forest, trees were killed on tens of thousands of acres with little regard for soil type, drainage, rockiness or timber quality. It soon became apparent that both climate and soils were generally unsuitable for farming and most attempts were abandoned during the depression of the 1930s or during World War II. In some cases, abandoned farms now carry fine stands of regrowth that arose from seed supplied by remnant old-growth trees. Often, however, climatic factors and absence of a seed source have combined to produce desolate landscapes of grass, scrub and burned logs.

Forest Types

Five basic types of eucalypt forest have been defined by the Tasmanian Forestry Commission on the basis of associated ground cover. They span the range from understories of rainforest, through various scrub communities to mainly grass.

In any of the five types there can be recognised a range of 'stand conditions' that reflect the history of varied burning, grazing and timber harvesting activities. For instance, a history of selective timber harvesting and infrequent fires in any of the types probably will have produced wellstocked stands of mixed ages, albeit often with considerable fire damage to the younger groups of trees. A long history of grazing accompanied by burning is likely to have produced a stand of predominantly mature or older trees with few or no young trees; and if selective harvesting for timber had been carried out as well then the stand would be composed only of fire-damaged veterans and a few defective younger trees: a derelict stand.

The advent in the 1970s of an export market for woodchips led initially to large areas being clear-felled and burned irrespective of type or condition of the stands. This resulted in the use as pulpwood of small-sized trees that had the potential to develop into first-class sawlogs, and often resulted in failure to regenerate stands adequately - particularly on sites that were prone to frost. Recognition of these problems has led to the introduction of modified harvesting practices of partial cutting to produce shelterwoods or to retain potential sawlogs and existing younger regeneration. Current prescriptions are contained in two Bulletins of the Tasmanian Forestry Commission on native forest silviculture:

Bulletin No 2, 1990. High altitude *Eucalyptus delegatensis* forests.
Bulletin No 4, 1990. High altitude *Eucalyptus dalrympleana* and *Eucalyptus pauciflora* forests.

Regeneration

Many sites in the highland forests can be regenerated readily by using standard practices. Others present special problems.

Stands with an understorey of wet-sclerophyll species present no problems. The trees usually carry ample seed and the stands can be regenerated either by natural seed-fall from retained seed trees or by aerial sowing following clear felling and burning. Moreover, seedlings will establish well on mechanically disturbed soil and this allows the option of partial harvesting by groups or other patterns without the use of fire, provided that considerations of fire-hazard-reduction are not crucial. At lower elevations, stands with a rainforest understorey can be regenerated in a similar way.

In stands with a rainforest understorey at elevations above about 800 m, and in types in which grasses are prominent in the ground cover, problems in regenerating the forest occur for one or more of a variety of reasons. The main determinants of success or failure are:

Climatic conditions

The climate of the highlands is harsh and unpredictable. Frost can occur in any month of the year, and occasional incursions of cold air have been reported to

A failed 9 year old plantation that was put in following failure of natural regeneration and aerial seeding on an area clearfelled in the mid 1970s (the bush on the left is a tree). Frost and tussock grass at 1000m has prohibited regeneration

kill even mature trees on level or concave topography. (Diurnal variation in temperature immediately above a dense sward of grass at an elevation of 900 m during one week in February has been measured at -5°C to +40°C: a formidable range for a seedling to survive).

Climatic records during the last 100 years show that hot dry summers tend to occur in sequences of 2 to 6 years, and to be separated by similar sequences of cool wet summers. Analyses of growth rings of long-lived rainforest species suggest that this variation is contained within a longer-term pattern of variation that produces peaks of hot dry years at intervals of about 70 years; those 'peaks' are separated by 'troughs' of relatively cool wet years. Under natural conditions the regeneration and establishment of eucalypts is likely to be episodic. Which segments of a cycle are favourable to a species and which are not will depend upon the environmental tolerance of that species.

The episodic nature of regeneration is enhanced at elevations above 900 m by irregular flowering of eucalypts. For instance, a Forest Ranger who was for long a resident of Bronte Park recalled that *E. delegatensis* on that part of the Central Plateau produced seed about once every 7 years. Even longer intervals between seed years can be expected as the altitudinal limit is approached.

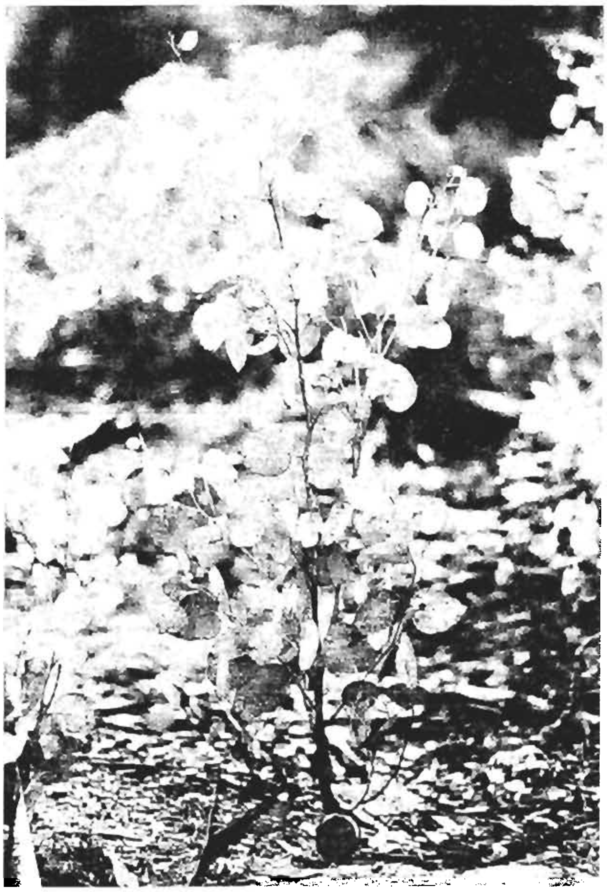
Seedlings of *E. delegatensis* are relatively resistant to frost; but even so they are damaged by temperatures of -5°C where those occur during active growth of a seedling, and by temperatures of -10°C when they are inactive and hardened during winter. Such summer and winter minima at ground level can be expected in most years throughout the highlands on open ground with level or concave topography. As a result,lethal or non-lethal damage to seedlings by frost is very common when they are less in height than the 0.5 to 2.0 m or so depth of cold air that accumulates during radiation frost events. Damage can take the form of killing the seedling back to ground level, from which it may resprout; but more commonly it is lesser damage that includes death of naked buds and young unfolding leaves and the rupture of some mesophyll cells of older leaves. Such damaged leaves are subject to attack by leaf-spot fungi and by insects and become tough and leathery. If frost damage is chronic then the seedlings become flat-topped and bushy, grow ever more slowly, and eventually may die. This is one manifestation of 'growth check'. However, even after a prolonged period of growth check the occurrence of one or more favourable years will allow some seedlings to recover sufficiently to grow beyond the layer of cold air and to assume a normal form. If the event that produces regeneration coincides with favourable years then growth check can be avoided altogether; such happy coincidence is not predictable.

At an elevation of 900 m it has been found that, beneath a wellstocked eucalypt stand, minimum temperatures at ground level are on average 2°C higher than they are in the open, and this difference can be as great as 5°C on still, clear nights. In summer, maximum temperatures beneath a canopy are up to 10°C lower than they are in the open. Seedlings that become established beneath an existing canopy, therefore, enjoy considerable protection from extremes of temperature, but may suffer severely from drought during dry spells. Such drought induces growth check in the seedlings that differs from that induced by frost and exposure. Beneath an overstorey, seedlings of *E. delegatensis*, for example, remain healthy but grow only very slowly; they do not become bushy but simply fail to make apical growth and they retain leaves of juvenile form. Mortality is low, and the seedlings can remain in a state of suspended animation for up to 45 years and be less than 1 m in height whilst retaining an ability to respond vigorously in height growth when the overstorey is removed. Such released 'advance growth' behaves in most respects like seedling growth. It is an important source of regeneration in much of the highland forest.

Competition from grass

Few tree species can live happily with grass, least of all in the early stages of their establishment. The reasons for this include competition for water, for nutrients and/or for space; enhancement of frost effects; toxicity of grass residues; harbouring by grass of damaging insects; and microbiological factors of grassland soil.

The interaction of eucalypt and grass is most variable. In dry forests at low elevations, and provided that browsing/grazing by native or domestic animals is at a



A 2-year-old seedling before invasion of grass (note lens cap for scale)

A 15-year-old seedling 'checked' in tussock grass and alpine shrubs (note lens cap for scale) low level, local eucalypts usually become established readily from seed in both native and introduced pasture grasses. Growth may be very slow initially, but the rate increases rapidly within 5 years or so. In the highland forests the tussock grasses are usually dominant. They are tolerant of frost and drought and are reinvigorated by infrequent burning. Their dead culms decay slowly and form a dense mat between the tussocks. At both the wet and the dry ends of the climatic range, with increase in elevation it is with increasing difficulty that eucalypts, and *E. delegatensis* in particular, become established in tussock grass.

Where eucalypts regenerate after fire following clear felling, good initial growth may be arrested 3-4 years later when a grass cover develops. Seedlings have the appearance of having suffered chronic frost damage. Where initial stocking is dense enough for the trees eventually to form a canopy, the grass is gradually suppressed and some trees resume normal growth. Where trees are well separated from each other grass remains vigorous and many trees die within 10-15 years. Thus the area becomes divided into patches dominated by trees and patches dominated by grass - a natural patchwork. Where eucalypt seedlings become established on disturbed ground in the absence of fire, initial growth is very slow and few survive development of a grass cover. However, where suppressed advance growth develops beneath a canopy, following fire it is able to resume rapid normal growth when the stand is felled years later, and to greatly reduce subsequent development of a grass cover.

Interaction Between Trees and Grass

Results of experiments that have addressed the interaction of *E. delegatensis* and a grassy ground cover appear to be generally applicable to other eucalypt species of the highland forest. They are summarised in the accompanying box

From these experiments it was deduced that soil-microbiological factors that include, but probably are not restricted to, the mycorrhizal associations of the seedlings are paramount in the successful regeneration of *E. delegatensis* at high altitudes.

The most complete and most rapidly grown regeneration becomes established after a fire that is severe enough to defoliate the overstorey, and usually to kill a percentage of adult trees. The twin effects of such a fire probably are to change the microbiological population of the soil to one favourable to eucalypt seedlings, and to reduce competition from established trees sufficiently for seedlings to establish. There is also a fertilising effect from nutrients released by heat and deposited in ash. Recovery of the overstorey arrests the development of grass, and the seedlings consolidate their establishment as suppressed 'advance growth' over many years.

A fire that is sufficiently hot to produce these results clearly is incompatible with the management of a forest with an uneven-aged structure, even by relatively large groups, since it would kill any young groups of trees that were present and would be difficult to control other than within well-chosen topographic boundaries. Therefore the desirability of instituting uneven-aged management for the protection of potential sawlogs, control of grass, and shelter of established seedlings must be constrained by the necessity to obtain new

Experiments

Grassland soil itself is inhibitory to the growth of tree seedlings and the degree of inhibition increases with the length of time for which grass has occupied the site.

Addition of N P K fertiliser to checked seedlings was without effect in the field, and had only a small positive effect in pot experiments: thus simple deficiency of nutrients was not the cause of inhibition.

Killing the ground cover with either a herbicide (Roundup) or a soil sterilant (Basamid) had little initial positive effect on the growth of seedlings that were planted subsequently, but the effect increased over 2 years. Pot experiments confirmed this trend of increasing beneficial effect with passage of time. Sterilising the soil was more effective than using herbicide.

A hot fire in the field promoted rapid growth of seedlings, whereas mechanical disturbance without fire did not. This was confirmed by pot experiments that used soils from these treatments.

Drought is not an important factor in this form of check. This result might be expected since check in grassland occurs throughout the range of rainfall in the highlands (750 - >2000 mm) in which trees and grass occur together.

Mycorrhizae that developed on vigorous seedlings grown in pots of recently-burned eucalypt forest soil differed greatly from those formed on poor seedlings grown in pots of grassland soil. The former were ectotrophic mycorrhizae with a loose fungal sheath covering the tree roots, whereas the latter were endotrophic vesicular arbuscular mycorrhizae that proliferate within the tree roots.

When pots of grassland soil were inoculated with as little as 10% of soil from a recently burned eucalypt stand, inhibition was removed completely: seedlings grew vigorously: and the mycorrhizae formed were ectotrophic and similar to those formed in 100% eucalypt soil.

seedling regeneration by using fire. However, once the 'bank' of advance growth has been obtained by the use of fire, then flexibility in harvesting will be available for at least 40 years, with the 'bank' being released as required to provide the new stand.

Difficult-Site Scenario

Where a well-stocked mature stand lacks seedling regeneration or advance growth, it should be burned with a hot fire either before harvesting or, if the stand is very dense, after a light felling. The fire should coincide with a good crop of seed. Subsequent harvesting can be undertaken once advance growth is well established. Epicormic shoots will form on severely defoliated trees, but the defects caused by these will be confined to the (unused) sapwood if the trees are harvested within 5-10 years of the burn. Unaffected trees can be harvested much later and in any pattern, depending upon considerations of market, overall scheduling within the forest, or aesthetics; but whilst they are retained they are a continuing source of seed and consequently an insurance against arson or wildfire.

Such a scenario should be successful with most shrub and grassy ground covers but one problem area would remain. This is where past cutting, burning, and grazing has produced an open stand of eucalypts, with no advance growth, over dense grass, with insufficient fuel to generate a hot fire, and insufficient trees to provide shelter to new seedlings. Seedlings of *E. delegatensis* can be established successfully by planting following the use of herbicide to kill the grass, with a repeat of treatment after 2 years, and the care and maintenance for 3 years or longer of plastic shelters. Growth is slow on what are essentially marginal sites, and the expense of such operations would be difficult to justify in many cases. A more promising way of reclaiming such derelict forest is by using an intermediate tree crop, of which, even at high altitudes, *Pinus radiata* is the most successful. The pine can compete with and suppress grass, and when the pine is harvested, indigenous eucalypts can be re-established - if that is an objective of management - possibly by using a reduced cover of pines as a shelterwood. Alternatively, *E. nitens* has been established successfully on problem sites at the lower elevations of the highland forest, provided that thorough ground cultivation and fertilisation are carried out. Substantial plantations of this species have been established on sites with good soils and high rainfall.

Conclusion

For the great majority of the highland eucalypt forest, rates of growth are comparatively low, and rotations, whether for pulpwood or for sawlog, are correspondingly long. Forest management practices are likely to remain extensive rather than intensive; therefore, to the greatest extent possible the cultural practices necessary to obtain regeneration should be an integral part of harvesting operations. This means that operations should be timed to coincide with and designed to reinforce natural process of establishment and early growth of seedlings.

Taking the Mystery out of 'Dry Rot'

by John Thornton

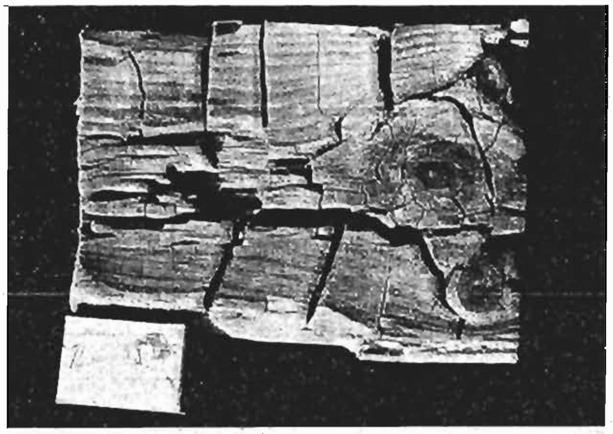
Division of Forest Products

What does the term 'dry rot' mean?

Unfortunately, the term has a different meaning for different people. To the layperson, the term is generally used to describe 'any timber member or part thereof that has rotted and is now dry'. That person may or may not know how the actual rotting phase occurred with respect to availability of moisture. To the scientist with experience in mycology, the term 'dry rot' today means one species of fungus and one species only, namely *Serpula*(formerly *Merulius*) *lacrymans*. Such a scientist uses the term 'the dry rot fungus' or 'the true dry rot fungus'.

How was the term 'dry rot' originally assigned?

Persons observing timber which 'had previously rotted and was now dry', were unable to appreciate that the cause was exactly the same organism as was present on adjacent moist timber. Hence they assumed that the entire rotting process, that had given rise to the presently dry and rotted wood, must have occurred in a continuous dry state. The scientist, however, was able to understand the problem as being caused by *Merulius lacrymans* and gave the name 'true dry rot fungus' to indicate that this fungus was the true cause of the 'dry rot'. The name 'true dry rot fungus' DOES NOT (and was never intended to) infer that this is a fungus that is capable of causing rot in dry timber.



Wood decayed by *Serpula lacrymans.* Note the cracking across the grain that is apparent now that the timber has dried out. Note also the absence of visible fungal growth from the surface of this floorboard

Should we continue to use the term 'dry rot'?

Let us first of all consider how fungal decay of timber occurs. A piece of timber that is not naturally decay resistant and that has not been commercially-impregnated with preservative chemicals would be expected to begin to decay if the moisture content was somewhat above the fibre-saturation level (i.e. in excess of 30 per cent water in the timber). Once decay is established, the ongoing process of decay will be most rapid if moisture contents stay above 30 per cent (say up to 60 per cent during early stages) BUT the decay process can continue, albeit not at an optimum rate, down to a moisture content as low as 20 per cent.

From this discussion it is clear that the term dry rot is a misnomer. As stated earlier the term was coined in ignorance. The fact is that dry wood simply will not rot. The layperson should be discouraged from continuing usage of the term. (However, the mycologist still considers the wording 'the true dry rot fungus *Serpula lacrymans*' to be acceptable today for use in scientific publications).

Why has *Serpula lacrymans*, under its former name *Merulius lacrymans*, such a fearsome reputation as the world's most destructive wood-attacking fungus?

This fungus has a long history. There is mention in the Book of Leviticus in the Bible of 'fretting leprosy of the house', which many scientists believe to be a description of the activity of this species. Many of the wooden warships of the British Navy had to be refitted even before they were commissioned, as a result of this fungus rapidly attacking the unseasoned timber that was being used for decking and interior timbers. Immediately after World War II, when many buildings were in disrepair while craftsmen and materials were scarce, this fungus reached plague proportions in many parts of Europe.

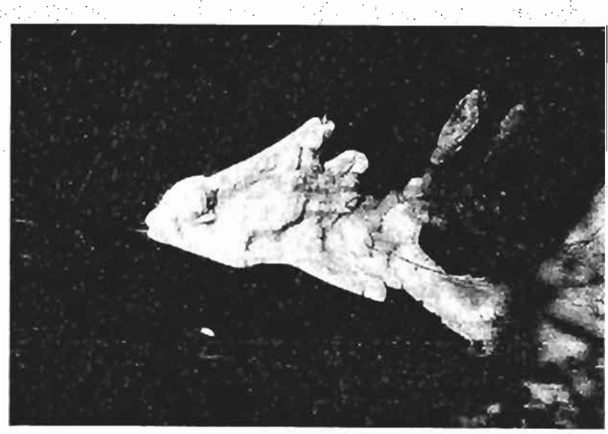
What is special about the fungus compared to the many other species of wood-attacking fungi?

This species is peculiar among the wood-attacking fungi in that it is almost exclusively associated with built structures (e.g. dwellings, but also some timber in mines and boats) and is therefore only on extremely rare occasions found in the forest or in timber in the soil outside buildings.

Also, this fungus grows fastest at 20°C (while most common wood-decayers grow fastest at higher temperatures e.g. 25 or 30°C), which just happens to be the temperature that humans often maintain inside their buildings. It can also grow on materials of quite high alkalinity.

Where is this fungus found in Australia?

Normally restricted to situations where there is a water source available and where also the ventilation (to



Early reproductive growth in the form of thickened, white and localised structure forming, in this case, at the junction of floorboards and joist

remove that moisture) is inadequate. Therefore it is not found in buildings made totally of timber, e.g. weatherboard houses, because these have adequate ventilation and don't retain moisture for lengthy periods. The fungus can grow over and obtain moisture from within soil, plaster, bricks, stone, mortar etc. Most cases have been noted in Melbourne, with very few in Sydney to date.

Is this fungus destructive in Melbourne houses?

Yes, the fastest attack that has been recorded is failure of original flooring followed just three months later by failure of replacement boards. Research has shown that the subfloor spaces of badly-ventilated houses in Melbourne (particularly the older double-brick variety) have temperature conditions that are more favourable, for more of the year, to fast growth and rapid wood decay than are subfloor areas of European or Japanese buildings.

What are the signs of attack of, for example, flooring by *Serpula lacrymans*?

The layperson often discovers only the final stages, i.e. when the decayed wood has dried, warped, cracked along and across the grain, and failed under the load of humans and/or furniture. Early indicators, such as paint peeling from wood, are not reliable signs although they are stated in popular literature.

The building professional must be able to use a moisture meter to determine whether timber is presently in a decay-prone condition or a safe condition. That person must be able to use a knife to determine if timber is decay-affected. The person should also be able to identify any of the following features as being fungal components: grey/white vegetative growth, water-conducting strands, reproductive fruit bodies, and deposits of brick-red coloured spores on horizontal surfaces.

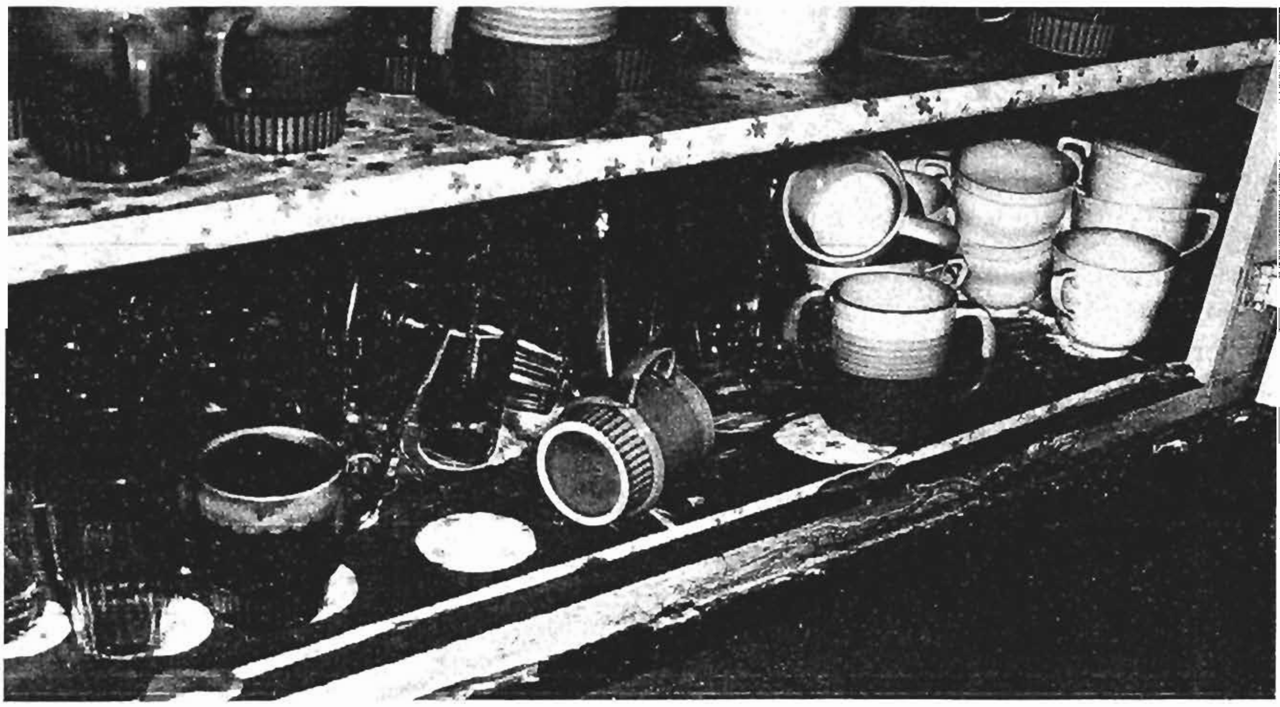
Why is an attack by *Serpula lacrymans* often seen within the first couple of years after property purchase or within a few months of extensive alterations being made?

In some cases this just has to be a result of the previous occupant being aware of a problem and making quick timber replacements prior to sale, without locating the moisture source and improving ventilation. Any alteration that results in additional moisture or makes existing ventilation inadequate is going to be a potential decay problem. One such alteration is the replacement of individual, failed, wooden floors with a concrete slab on fill, which is definitely not sound practice as far as the remaining timber is concerned. There are three reasons for this. Firstly, a large amount of water, available over an extensive period, is contained in the concrete pour. Secondly, existing ventilation to any adjoining room must be made far worse than it was before. Finally, inspection of immediately-surrounding subfloor areas is made more difficult.

What is the reliable remedy for an existing attack by this fungus?

The correct stepwise remedy is to open up and dry out (in order to convert decaying wood into dried and decayed wood that can be more readily assessed). While the area is being dried out, determine the wettest point (usually the last place to dry out), and search for any source of water entering the building. For the latter it is necessary to survey the whole of the building, top to bottom, in order to look for any access of water via broken roofing tiles, defective stormwater collection, plumbing leaks etc. Determine whether ventilation is adequate and if necessary upgrade with modern ventilators. Remove and replace decayed timber.

The only reliable means of preventing fungal decay is to keep the moisture content of timber at less than 20 per cent. For remedial purposes, heat sterilization is difficult (poor heat conduction of building materials), labour intensive and has no lasting effect. Remedial preservative applications are difficult because access to all sides of the timber is rarely available and because the fungus causing decay may be most active deep in the wood where the chemical may not readily reach.



Deposit of billions of spores (coloured brick red) released by a mature fruit body located somewhere else in the building. The spores have settled on the horizontal shelving as shown by the area from which crockery has been moved immediately prior to photography

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Forestry and Forest Products NEWSLETTER

Commonly Asked Questions on Pulping and Papermaking

by Alex McKenzie

Division of Forest Products

Something to sing about?

How can I tell whether a paper has been made from recycled fibre ?

Generally speaking, recycled fibres don't look any different to unused ones. Eventually, they may get a bit more damaged, but it is really not possible to tell whether or not a fibre has been used previously.

If the pulp has not been de-inked or has only been partly de-inked, this provides a clue that some recycled fibre has been used. The grey colour of some packaging boards (or of some plies of multi-ply boards) is typical of a pulp which has been recycled without de-inking. On the other hand, recycled office and business papers often have a slightly greyish tinge and a few black specks to emphasise the point that they have been made from recycled fibre which has not been de-inked or re-bleached. However, it is impossible to tell how much recycled fibre and how much new fibre is in any sheet of paper.

in this issue...

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CSIRO AUSTRALIA

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How much wastepaper is recycled by the paper industry?

1989-90 figures show 841 000 tonnes of waste paper and 1 230 000 tonnes of pulp was used by the paper industry. Thus, fibre recovered from waste paper comprised 41 percent of the total wood fibre used by the industry. It uses equivalent to 29 percent of total paper consumption.

Most recycled fibre is used in producing packaging paper and there is little likelihood of much increase here. There are prospects for some recycled fibre to be made into newsprint in the relatively near future, but it is unlikely that there will be much increase in recycled fibre use in fine printings and writings until the supply of better quality waste paper improves. This may require some major changes to our waste management systems.

What effect will paper recycling have on the environment?

The Industry Commission Reports on Recycling indicate that in many places paper accounts for at least 20 per cent of the material sent to landfill for disposal. Any increase in recycling will reduce the demand on landfill for waste disposal.

It is often said that recycling will save trees, the implication being that the saving will be from native forest. What is actually saved depends on how recycling changes the pattern of manufacture and import. For example, if recycled fibre is used to increase newsprint production, the effect on native forest will be zero because the alternative wood source is plantation pine. On the other hand, recycled fibre may be useable to extend a new resource which might otherwise be inadequate for a new papermaking venture.

It is generally assumed that recycling is environmentally friendly, but de-inking effluent will contain salt, which will add to the problem of salinity in inland waterways, and may also contain residues such as heavy metals which are not easy to dispose of. It is sometimes claimed that ink residues are not a problem because ink is only oil and carbon black. This may be true for recycled newspapers, but is not necessarily the case with other inks.

Recycling is also claimed to reduce energy consumption. Certainly, this is true if the recycled fibre is used to replace mechanical pulp in products such as newsprint. However, the mere collection of waste paper requires considerable energy and greenhouse gas emissions from the collection vehicles.

Thus, while recycling is undoubtedly beneficial, it may not always achieve what is expected of it.

Why isn't straw and other plant material used more as a source of papermaking fibre ?

Some non-wood resources provide excellent papermaking fibres. Jute, ramie and hemp fibres which are frequently obtained from used rope are outstanding and are used for specialty applications. Textiles such as cotton and flax also yield high quality fibres. Although these fibres are expensive to produce, they are still preferred for products such as cigarette paper, Bible paper, banknotes, filter paper and so on, whenever the price can be justified.

In countries where wood is scarce, it is quite common to find cereal straw, bagasse (from sugar cane), bamboo and similar materials being used as a source of papermaking fibre. In many cases, the raw material cost is low, particularly where it is an agricultural by-product. Fibre quality is roughly the same as a hardwood, sometimes a bit less because the fibres have been damaged during harvesting/processing, but usually adequate as a component of printing and writing papers. And there are enormous amounts available.

So why don't we use more of these materials instead of wood? The first difficulty is that one can harvest the crop at only one time of the year. This means that a whole year's supply of raw material must be collected and stored within a few weeks. Furthermore, it cannot merely be cut and stored, but must be protected from decay immediately after harvesting. Also, the prospect of a crop failure (for whatever reason) and the subsequent closure of a multimillion dollar manufacturing operation for lack of raw material is enough to deter the average investor.

Many agricultural residues have a high silica content (rice straw and bamboo are notorious in this respect) which dissolves in alkaline pulping liquors and redeposits throughout the pulping plant. The bulkiness of straws and similar materials compared to wood chips can also be a problem, as the productivity of a digester

Laboratory made paper from Pinus radiata thermomechanical pulp depends on the amount of raw material which can fit into it. This means that the cost of a mill designed to produce straw pulp will probably be much higher than the cost of a wood chip mill capable of producing the same amount of pulp of the same type.

Overall, the cost of producing pulp from non-wood material is high. It can only be justified economically if the pulp is of superior quality, such as is the case with pulp produced from textile or cordage grade fibres. It is significant that in many countries where wood is scarce but agricultural residues are plentiful, it is common to import wood pulp rather than to produce non-wood pulp from materials such as wheat straw. In other countries, straw pulp and the like is only used because of government restrictions on the importation of wood pulp. It is estimated that China and India produce nearly half of the annual world total of 10 million tonnes of non-wood based paper.

Mechanical pulping (groundwood, thermomechanical pulping TMP) gives twice as much pulp per tree as does chemical pulping (kraft). Why do we need kraft pulp (and kraft pulp mills) ?

There is no doubt that paper manufacturers prefer to use the cheaper mechanical pulps wherever possible. Unfortunately, there are some combinations of paper properties which simply can't be obtained from mechanical pulps. The typical mechanical pulp gives a paper which is relatively weak, fairly bulky, high in opacity and with poor colour stability. It can be used quite satisfactorily to make newsprint and low quality tissues and also for paperboards where it is possible to compensate for the lower strength by using more pulp. However, if we are looking at packaging materials such as the paper used for cement bags, these need to be both strong and flexible and one can't get this combination by using a heavier grade of poor quality paper. At the other end of the scale we can consider book papers. Books which are printed on paper made from mechanical pulp will discolour rapidly (as does newsprint), they will be relatively thick (taking up excessive room on bookshelves) and they will be relatively heavy. Thus, both the cement bag paper and the book paper need characteristics which can only be obtained from chemical pulps or from blends containing some chemical pulp.

When is very highly bleached paper really necessary?

Generally speaking, extremely white papers are used to attract attention and to give an impression of purity and cleanliness. Probably the only time where high whiteness is a functional requirement is when the paper is being used as a substrate for high quality printing. Any lack of whiteness in a printing substrate will distort the colour rendition of the print.

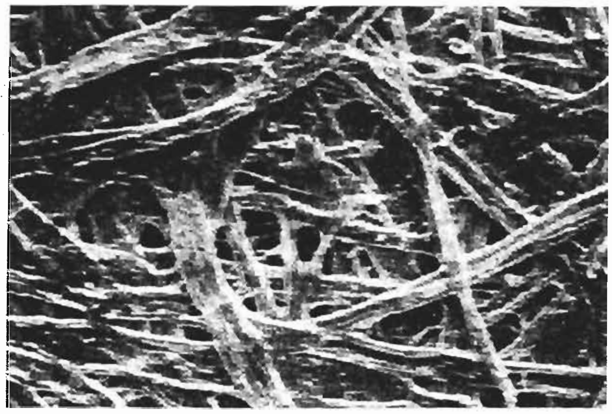
Which makes better paper, pine or eucalypt?

This commonly asked question assumes that all types of paper have the same requirements. This is not true. There are a variety of properties which are sometimes important and sometimes not, depending on the intended end-use.

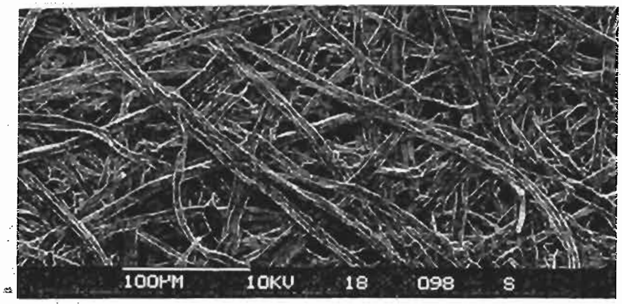
The longer fibres of pines and other softwoods are of great benefit when tough packaging papers with high tearing resistance are needed. They also help augment the strength of the wet fibre web as it leaves the wire part of the paper machine. This reduces machine down-time and improves productivity. Pines and other softwoods are also preferred for the manufacture of mechanical pulps (groundwood, TMP and the like) because they are usually light coloured and the long, low-density fibres suffer less damage during mechanical pulping.

Eucalypts and other hardwoods have shorter fibres which do not clump together as easily as their longer softwood counterparts. This means that paper made from hardwoods is more uniform in appearance and in thickness. The smaller diameter gives a smoother surface and higher opacity. All of these things mean that hardwoods are preferable for printing papers

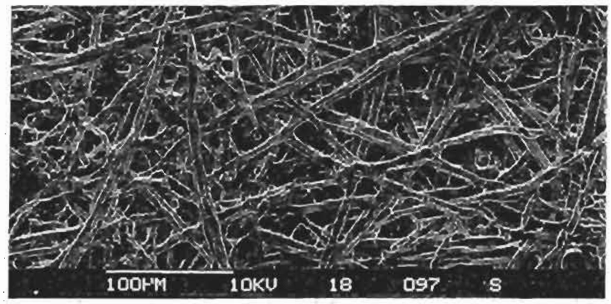
Laboratory made paper from Pinus radiata kraft (chemical) pulp



Laboratory made paper from Eucalyptus globulus kraft (chemical) pulp



Eucalyptus globulus - surface of laboratory-made paper
Pulp fibres have not been treated - uneven surface



Eucalyptus globulus - surface of laboratory-made paper
Pulp fibres have been beaten - more even surface, better for printing

Can you test this piece of paper and tell me if it's any good ?

This is another common question which assumes that all paper is pretty much the same. Before answering it, a lot more information is required e.g. what is the paper supposed to be good for, what tests relate to its performance and what test levels are required in a satisfactory product. Without answers to these questions, one has no idea of the necessary characteristics of the material.

Is mechanical pulping more environmentally friendly than chemical pulping ?

It is commonly believed that mechanical pulping has much less environmental impact than chemical pulping because less material is removed from the wood during the pulping process. However, this oversimplifies the situation, as it neglects the possible effects of chemical recovery systems and of bleaching operations, as well as major differences between various pulping and bleaching processes. It also depends on the criteria used to judge environmental 'friendliness' or lack thereof.

For example, a kraft pulp mill invariably includes a chemical recovery system fuelled by the material dissolved during pulping. Relatively little of the extracted material would go to the effluent treatment plant. On the other hand, a TMP mill will not have a chemical recovery system because there is no chemical to recover. All of the dissolved material goes directly to the effluent plant. A chemi-thermomechanical operation may have an even greater impact because of the chemicals present. These are too dilute to be recovered by a normal recovery system and are not removed by the effluent treatment plant unless specially designed for the purpose. In this context, 'chemicals' refers to soluble inorganic salts, mainly sodium-based. The impact of these materials depends both on their composition and their point of discharge. Thus, simple chemicals like sodium chloride or sodium sulphate are unlikely to have much effect if discharged directly into sea-water, but could be a real problem for inland waterways.

Neither of these examples gives an effluent containing organochlorines, because organochlorines are not produced during pulping or papermaking, but only during bleaching with some chlorine-containing chemicals.

Requirements for energy from external sources also differ greatly. A kraft mill, for example, may be almost self-sufficient for energy whereas a mechanical pulp mill will require large energy inputs.

Overall, it is unwise to generalise about the environmental impact of a proposed venture without knowing full details of the proposal. This would include the pulping process, the bleaching process, any chemical recovery system, effluent treatment system and the effluent receiving environment.

What is the difference between mechanical and chemical pulping?

It is possible to separate wood or other raw materials into individual pulp fibres in one of two ways, by the application of mechanical force to wet wood or by dissolving the material which cements the individual fibres together.

Mechanical action such as forcing the wood against a rotating grindstone or passing chips between the moving surfaces of a refiner would produce wood dust if the original wood was dry. However, if the wood is wet, it tends to break apart into fibres. Because the only material lost in this process is that which dissolves in water or breaks down to fine powder, some 85-95 percent of the original wood is recovered as pulp.

At the other end of the scale, if the material (lignin) holding the fibres together is dissolved by cooking the wood with an appropriate chemical, the fibres separate without further treatment. However, by this time, maybe half of the original wood has been dissolved.

In addition to these extreme cases, there are an almost infinite variety of combined chemical and mechanical treatments, where the chemical treatment softens the interfibre layers, giving easier mechanical fibre separation but a lower yield.

Tree Seeds for Food?

by Chris Harwood

Division of Forestry

Acacia colei ms. bearing a heavy seed crop in the Northern Territory.
(Photo: Lex Thomson)

Although Australian trees, notably eucalypts and acacias, are widely grown around the world for products such as wood and tannins, no plants or animals from this country except the macadamia have become significant sources of food. There is now a real prospect, however, that seed of Australian acacias may become a valuable food in semi-arid savannah environments, particularly in the 500-700 mm rainfall zone in Sahelian Africa where famines follow the recurrent failure of grain crops.

The attributes which lead to this conclusion are:

- The seed has low levels of toxic and anti-nutritional factors, especially in comparison with African acacias, and high nutritional value
- Seed of some acacias was a seasonally-significant component of Australian Aboriginal diets
- Some Australian species have easy establishment, rapid early growth and heavy early seed production compared with African acacia species
- Foliage is not palatable to livestock, so protection of plants is not required
- Seed is easily collected and processed using local technology
- Preliminary trials indicate palatable foods can be prepared by modifying local recipes
- The species can have other beneficial effects when incorporated into farming systems (windbreaks, fuelwood production, soil amelioration). Yields of existing crops need not be reduced, and could be increased through these effects.

Where do we go from here?

The Division of Forestry's Australian Tree Seed Centre manages an international development assistance project, the 'Seeds of Australian Trees' project, on behalf of the Australian International Development Assistance Bureau. In August 1991 the Centre organised a workshop to examine the food potential of

Acacia tumida growing in Niger, Africa. Note the heavy crop of seed pods and the fallen pods under the tree.
(Photo: Lex Thomson)

Traditional African recipes incorporating acacia seed flour prepared in Niger.
(Photo: Tony Rinaudo)

seed of *Acacia* species. The workshop brought together 20 people with diverse expertise including nutrition, silviculture, ecology and taxonomy. Participants reviewed the nutritional value of seed, the genetics and ecology of key species, the performance of Australian *Acacia* species in Sahelian Africa and traditional Aboriginal processing and use of the seed. A report from the SIM International Development Assistance Program in Niger described promising initial food trials of seed of *Acacia holosericea*, an Australian species which grows well there and produces heavy seed crops. Working groups developed plans for an integrated research program on nutrition, taxonomy/seed collections, and silviculture/genetics.

What role does science have in developing this new source of food?

In parts of Africa seed of a species closely related to the acacias, *Faidherbia albida*, has traditionally been used as a food source in famines, although it requires extensive processing to remove toxic compounds. There is increasing awareness in Sahelian countries, where Australian acacias have been introduced, that seed of some species has potential food value and was eaten by Aborigines.

People have traditionally taken up new food sources through trial and error. This has led to problems of toxicity and nutritional imbalance, particularly when foods have been moved from one country to another. Because of their easy cultivation and high yield of palatable seed that can be stored year-round, the Australian acacias have the potential to be a major component of diet, and perhaps an exclusive food source during famine. This makes issues such as nutritional balance and chronic toxicity more important than for minor items of diet. Fortunately scientists can help to minimise risk and maximise likely benefits of adopting this potential new food source.

Research can speed up the processes of identifying the species and varieties which are most productive of edible seed, the silvicultural techniques to maximise plant survival, growth and seed production, the varieties which are most nutritious and least toxic, and the best ways of processing and cooking seed for maximum nutritional benefit.

Accurate identification of research seedlots is a fundamental step. The taxonomy of key species groups such as the *Acacia holosericea* and *A. tumida* groups is still uncertain, and provides some fascinating and challenging opportunities for research. Dr Gavin Moran of CSIRO Division of Forestry and co-workers have demonstrated that three distinct geographic races of *A. holosericea* correspond to three different chromosome states (diploid, tetraploid and hexaploid). The nature of the breeding systems involved, which has major implications for strategies of genetic improvement, has yet to be determined.

Scientific study of mycorrhizal and Rhizobium root symbionts to boost plant productivity, and of levels of potentially toxic components of seed can provide information, understanding, and (usually) improved genetic material not available to farmers through trial and error.

Chemical assay of known toxins and anti-nutritional factors, particularly those known to be present in other legumes or in seed of some acacias is required. Chemical testing of nutritional composition, and evaluation of this data in relation to the nutrient composition of existing diet in target countries, is also fundamentally important.

Such testing will enable scientists to advise that seed of a particular *Acacia* species appears safe to adopt as a component of human diet, assuming the tests show that known toxic factors are not present at potentially-dangerous levels.

An integrated, international research program

The workshop concluded that prospects for seed of certain Australian dry-zone *Acacia* species to make a contribution to human nutrition appear good, and that continuing effort to develop this potential is warranted. The total cost of the recommended five-year research program would be around A$ 4-5 million, depending on the number of countries involved. Collaborative research programs might use the Australian Centre for International Agricultural Research approach, with

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researchers in target countries and Australia working in partnership. Aboriginal involvement in the program will be actively sought.

The multi-disciplinary nature of the research makes overall project management particularly important for cost-effective use of financial and human resources. Most aspects of the work will or may influence the other aspects. A negative result in one research area (e.g. if a species was found not to produce enough seed in a certain environment, or the seed could not be processed into food acceptable to the target community) will mean that other research and development activity should be modified accordingly. An effective development and extension process will be required to ensure that results of scientific studies benefit target groups.

Further action

The extent of further action will depend on available funding. While funding is sought for a larger-scale, integrated program the Australian Tree Seed Centre is proceeding with certain low-cost tasks:

- proceedings of the workshop, 'Australian Dry-Zone Acacias for Human Food' edited by A.P.N. House and C.E. Harwood, is now available from CSIRO Bookshop, 314 Albert St, East Melbourne, Vic, 3002. Phone 03 418 7217
- further analysis of the nutritional value of key species
- chemical testing for toxic and anti-nutritional compounds in key species
- contact with prospective research and development collaborators in Africa and Asia
- limited isozyme studies to further explore the genetics of the *Acacia holosericea* group.

The potential benefits of large-scale adoption of acacia seed as a food are substantial. Many millions of people in sub-Saharan Africa and other semi-arid tropical and subtropical regions, vulnerable to famine and malnutrition, could have access to an additional food source.

More Seed form 'Miniature Eucalypts'

by Carson Creagh

CSIRO Publications

This article is reprinted from Ecos 71, Autumn 1992

Australia's magnificent eucalypts represent more than an essential element of our distinctive flora: they are also important sources of quality wood for building, pulpwood for paper-making and so on. But improving eucalypts for commercial uses involves considerable time and effort for foresters and scientists.

Many commercially important species grow to heights of at least 20 m, making collection of seed possible only with machinery such as cherry-pickers. Some are also notoriously poor producers of seed, so it is difficult to obtain viable quantities of seed from individual trees with desirable characteristics.

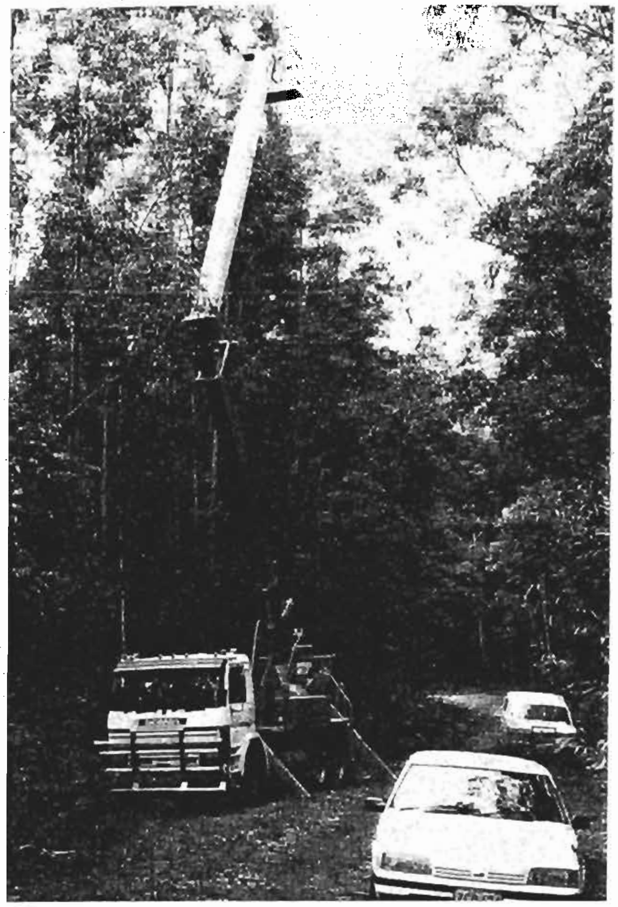
Time is the third disadvantage: commonly, eucalypts are 5 years old before they flower for the first time, and 7 years old before they produce enough seed for collection. Even then, many flower only every second or third year, so collecting seed from the best tree in a forest means long years of waiting - by which time the tree has grown so high that machinery is needed.

It's no wonder that eucalypt seed is so valuable: the seed of shining gum (*Eucalyptus nitens*), for example,

Growing eucalypts on espaliers to 2 m instead of 20 m makes seed collection easy

sells for about $2 000 a kilogram, and seed from some other species costs even more.

Since 1987, CSIRO's Division of Forestry has been addressing these problems in a deceptively simple way: by growing 'miniature' eucalypts that produce seeds rather than vegetative growth. Within the Hardwood Plantation Program led by Mr Robin Cromer, and with support from Australian Pulp and Paper Mills Ltd,



Collecting seed from 'wild' eucalypts is difficult; often cherry-pickers must be used to reach seed-bearing branches.

Mr Michael Moncur and Mr Peter Burgess have spent the past 4 years developing a management system that involves growing major plantation species of *Eucalyptus* - including *E. globulus* , *E. grandis* and *E. nitens* - on espaliers (in much the same way as grapes are grown). The program aims at increasing the amount of seed each tree produces, enhancing the speed of genetic improvements through controlled cross-pollination and enabling plantation managers to harvest seed more easily and in less time.

First the researchers looked at shortening the juvenile - intermediate - adult growth period by grafting shoots of selected eucalypts to older rootstocks and applying hormones to reduce vegetative growth. When the grafted trees had reached about 2 m - a convenient height for seed collection by hand - the researchers applied paclobutrazol, a synthetic hormone that 'shuts off' growth and stimulates bud (and hence seed) production. Tying the trees to espaliers made pruning easier, exposed more young shoots (which produce buds) to sunlight and enabled changes in the number of buds to be measured more efficiently.

Adding paclobutrazol to shining gum and southern blue gum (*E. globulus*), for example, meant these trees produced buds within 3 years rather than 5-7 years.

Regardless of treatment, however, it takes a year from the first appearance of a bud to the flowering stage, and foresters must wait a further year to obtain mature seed.

In an attempt to reduce the juvenile phase from seed germination to first bud, Mr Moncur grew shining gums in large pots and placed them in a warm glasshouse. When they were 18 months old, he exposed them to a normal Canberra winter to induce the production of flower buds.

The results were impressive. Whereas buds under field conditions can take a year to develop flowers and a further year to ripen and form mature seed, grafts grown in the glasshouse produced flowers after 6 months and mature seed 6 months later. Adding these reductions to the savings effected by applying paclobutrazol means plantation managers can begin collecting seed in an average of 3.5 years rather than 7. Further down the line, a more rapid rate of genetic improvement will also reduce costs.

The researchers are confident that they will be able to produce further reductions, and it may be possible to grow plantation trees from seed to seed-producers in less than 2 years. Even more important, however, are the spectacular increases they have effected in the amount of seed produced by each tree. A plot of untreated shining gums in the espalier orchard produced an average of only four seed capsules each, while trees treated with paclobutrazol produced an average of 560 capsules each-an improvement that could mean welcome savings in the cost of seed, and an equally welcome boost to Australia's tree-seed export industry.

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Forestry and Forest Products NEWSLETTER

More Wood From Plantation Trees

Robert Lehane

CSIRO Publications

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The amount of water stress that trees are suffering is measured using a pressure 'bomb' - a device in which pine needles can be pressurised until water is pushed out

Ways of working out how climate change may affect tree growth and what impact forests may have on the build-up of atmospheric carbon dioxide are among spin-offs from a major study of the biology of forest growth.

Australia's imports of timber and wood products exceed our exports by about $2 billion a year. If existing plantations can be coaxed to produce more wood, this will have the important economic potential benefits of reducing that trade imbalance and increasing the return on investment in the plantations. It will also reduce demand pressures from Australia on overseas timber supplies.

So research that is showing what levels of productivity are possible in plantations and what approaches should produce the best results has some important implications.

Two major reasons why plantation trees don't grow as fast as they could are fairly obvious—shortages of nutrients and water. Solutions are not so easy, largely

in this issue....

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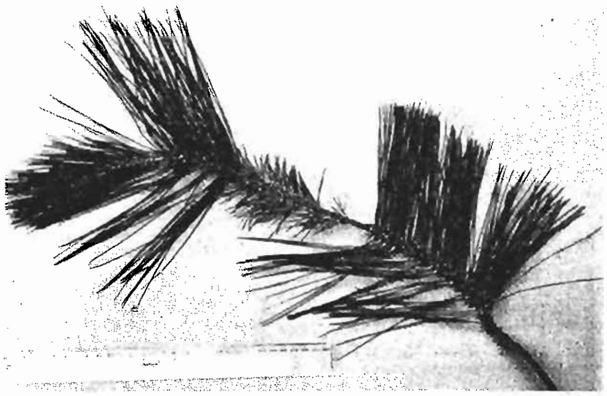


This branch, from the control stand, shows the contrasting needle lengths produced in years of differing rainfall

because we don't know enough about the intricacies of how trees respond to their environment. Without that knowledge, forest managers can't predict with any certainty how stands will respond to the main options available for boosting growth — thinning (to make more water available to the remaining trees) and application of fertiliser. The result is less-than-optimum plantation production.

Over the past 10 years a research team from the CSIRO Division of Forestry, collaborating with scientists at the Division of Soils and the Australian National University, has come a long way in filling the knowledge gaps. Working in a radiata pine (*Pinus radiata*) plantation near Canberra, the team has observed in detail what happens to stands subjected to a range of treatments. They have used their findings to develop a complex tree-growth model and are now working on the development of simpler models that plantation managers will be able to use to help plan operations.

The project, called the biology of forest growth study, began in 1983, when the researchers marked out a series of very similar quarter-hectare plots in a pine forest planted in 1973 following the harvest of radiata pine established on the site in 1935. Summer drought and soil low in organic matter and nutrient reserves make the area far from optimal for tree growth.

To enable them to find out how trees respond to different growing conditions, the team applied a varied range of treatments. Plots received one of the following:

- two applications of solid fertiliser, 6 weeks apart, totalling about double the quantity of nitrogen and phosphorus applied in routine plantation management—aimed at removing inadequate nutrition as a factor limiting growth for several years and then enabling study of the effects of redeveloping nutrient stress
- irrigation, applied by sprinklers when needed, to remove lack of soil moisture as a factor limiting growth
- irrigation plus the solid fertiliser treatment
- irrigation plus liquid fertiliser supplied through the irrigation system, aimed at removing both soil-water and nutrient deficiencies as constraints to tree growth

In addition, the team left a control plot unirrigated and unfertilised.

Showing just how much difference added water and nutrients can make, the researchers recorded an

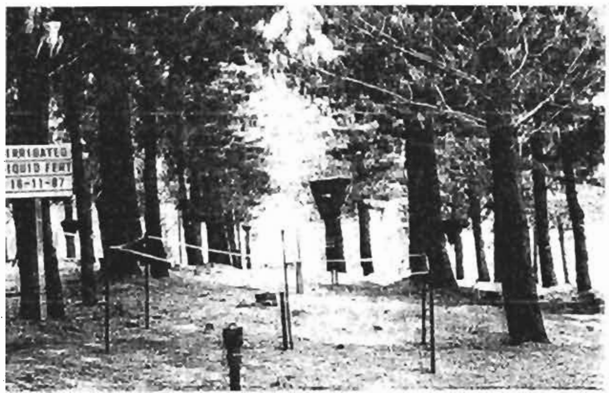
Irrigating with sewage effluent

Information from the biology of forest growth study on how plantations respond to added water and fertiliser has uses beyond helping boost wood production. An increasingly important application will be in planning plantations whose primary purpose is sewage treatment. Disposal of municipal and industrial effluents in rivers is a major source of environmental pollution in Australia, and the use of effluents to irrigate tree plantations is becoming an increasingly popular alternative.

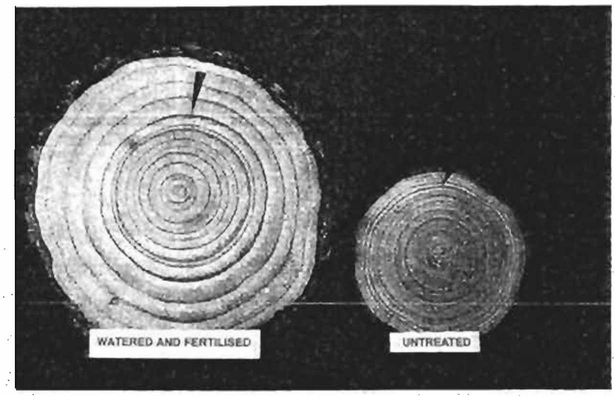
What the planners need to know is how much effluent a plantation of a particular size at a given location can treat. This information will put them in a position to plan an effluent irrigation system that eliminates the need for nutrient discharges into rivers or the ocean. How much wood the plantation will produce is a secondary consideration; to achieve maximum nutrient take-up, managers will harvest trees early—at the end of their period of maximum foliage growth—when the wood is unlikely to be good for anything except pulp, fibre products such as chip boards or firewood.

Mr Brian Myers of the Division of Forestry has drawn on the study findings to develop a model, called WATLOAD, that enables planners to calculate the amount of effluent that can be applied to a plantation in a particular climate without causing nutrient contamination of nearby waterways. They can calculate the area of plantation needed to treat a given volume of effluent and how much effluent will have to be stored during winter, when the trees are not growing, for application in spring.

The recently-launched Wagga effluent plantation project, run by CSIRO and supported by the Land and Water Resources Research and Development Corporation, Murray-Darling Basin Commission, New South Wales Public Works Department and Wagga Wagga City Council, will throw more light on the prospects for large-scale use of plantations for sewage disposal. It will also provide the opportunity to validate and further develop WATLOAD.



An irrigated and liquid fertilised plot showing, in the foreground, a reference plot for the study of soil chemical properties and, in the background, litter fall traps



Stem sections from an untreated and from an irrigated and fertilised tree. The arrows show that tree size was similar before treatment began 4 years earlier.

increase from 13 to 44.3 sq m in the basal area of trees in the plots given irrigation plus liquid fertiliser in the 5 years to winter 1988—compared with a much smaller increase from 12.5 to 25.6 sq m in the control trees. This translates to more than double the rate of wood production in the treated plots.

The trees given solid fertiliser and irrigation did nearly as well — in fact, both fertiliser-plus-irrigation treatments produced levels of productivity higher than those previously recorded in radiata pine in Australia and near the upper limit for forests world-wide. Irrigation and fertilisation on their own each gave some boost to growth, but the effect of the combined treatments was much larger than the sum of the effects of both on their own.

While these results show that great potential exists for increasing plantation productivity, in the real world it is seldom possible to provide irrigation or to supply all of the nutrients a stand needs. So for practical purposes the detailed measurements made of how trees respond to added water and nutrients at different times of the year and under different growing conditions are more important. Such information can help foresters plan fertilisation, thinning and other activities to achieve the maximum growth benefits.

Illustrating what's possible, Dr David Flinn of the Victorian Department of Conservation and Environment and Dr John Turner of the New South Wales Forestry Commission concluded in a 1990 study that more intensive management involving thinning, fertilisation and genetic improvement could yield an additional 1.7 million cubic metres of wood each year from Australia's 650 000 ha of radiata pine plantations. That is equivalent to the production from 94 000 ha of new plantations at current yields.

More plantations?

A major reason for looking to increased output from existing plantations as a way of boosting Australia's wood production is the shortage of land suitable for new plantations. A report prepared last year for the National Plantations Advisory Committee, a federal government advisory body, gives an indication of how much land may be available.

Prepared by Dr Trevor Booth and Mr Tom Jovanovic, of the CSIRO Division of Forestry, the report looks at the potential for establishing plantations on cleared agricultural land. Excluding existing forested areas and land in national parks and reserves from consideration, the scientists assessed plantation potential in terms of rainfall, soil fertility and topography. They focused on eucalypt plantations, but their findings also broadly apply to other species, including radiata pine.

Not surprisingly, it turned out that the best land for plantations was also generally the most productive for agriculture. As new plantations take many years to begin to provide any return to an investor, the chances of any such land being turned over to trees are minimal. Marginally productive agricultural land that is also suitable for tree plantations offers the best prospects.

The researchers mapped land in terms of plantation capability and intensity of agricultural use. Of a total of about 18.5 million ha, they rated 5.6%—just over 1 million ha —as having high plantation capability and low agricultural intensity. This is the combination of categories most likely to lend itself to plantation development. A further 2.1%—nearly 400 000 ha—had medium capability and low agricultural intensity.

These areas are quite large compared with the 650 000 ha now under radiata pine and less than 100 000 ha in eucalypt plantations. Economic and social factors will determine their availability. Whether a 1987 forest industry proposal to increase the area under plantations by nearly 600 000 ha is achievable remains to be determined. Meanwhile, increasing the productivity of land already under plantations is a logical way to increase Australia's wood supply.

How good is the wood?

A potential problem with the use of nitrogen fertiliser (or sewage effluent) to boost plantation growth is that the fast-growing trees may develop growth deformities that will down-grade their value for timber production. Excess nitrogen can lead to the development of large persistent branches and other examples of 'poor tree form'; this problem has made itself felt in some plantations established in nutrient-rich former pasture land.

Researchers from the biology of forest growth study are confident that the problem can be avoided through careful selection of planting stock and management of fertilisation. They also believe that another plantation problem, a loss of wood density due to rapid growth, should not be a major concern.

They have found that wood produced when the trees are growing fastest in spring and early summer is indeed less dense than the equivalent wood in unfertilised trees, as the cells that make it up grow to a larger size. Balancing this, though, an increased quantity of denser 'late wood' forms in late summer and autumn.

Forestry Division researchers Mr Martin Benson and Mr Brian Myers are collaborating with Dr Robert Evans of the CSIRO Division of Forest Products in Melbourne in a study of plantation wood quality. At this stage it appears that fast growth does not mean a loss of pulping quality.

The detailed information gathered in the biology of forest growth project came from intensive monitoring of the experimental stands. For example, to keep track of water stress, researchers measured pine-needle water tension before dawn at 2-week intervals for 4 years. This required a fortnightly 4 a.m. tree climb, because measurements need to be made when water in the tree is in balance with that in the soil—a state reached during the night as trees do not transpire then.

Other fortnightly measurements tracked soil water content, patterns of stem growth and the development of new foliage. The scientists also measured many other variables, including rainfall interception by the trees, stem flow, plant uptake and leaching of nutrients, growth of pine cones and flowers, needle growth, litter fall and the concentration of nitrogen in different parts of the tree.

They found that on the study site nitrogen availability was the key nutritional factor limiting tree growth. As a result, they put a great deal of effort into following what happens to nitrogen as it moves between soil and tree and within the tree, and into working out the most effective ways to satisfy demand for the nutrient.

One interesting finding, by the late Dr Wilf Crane of CSIRO and Dr John Banks of the Australian National University, was the extent to which nitrogen 'translocating' from older foliage can contribute to the needs of new growth. The researchers found that during the first year after heavy fertilisation trees took up nitrogen from the soil very rapidly and 'retranslocation' from older foliage was negligible. However, in following years, even when further substantial

Newly-established plantation at Wagga being irrigated with effluent quantities were added to the soil, nitrogen flowed from older foliage in large amounts—often providing more than half the total taken up in new growth.

The team's demonstration of the importance of nitrogen in boosting tree growth has clear implications for plantation managers; for instance, it reinforces the value, shown in other CSIRO research, of 'slash retention' (leaving harvest residues to decay in the forest) and of growing nitrogen-fixing legumes between tree crops. Their detailed findings on what happens to added nitrogen can be used to modify fertilisation practices to increase efficiency.

As soil moisture is a major factor affecting trees' response to nitrogen fertiliser, the goal should be to fertilise in seasons when moist soil allows rapid uptake of nitrogen. Once stored in the tree, the nutrient can be utilised over a period of several years. Late winter is the best time to fertilise in areas likely to experience dry summers; this increases the chances for significant nitrogen uptake before the onset of water stress.

How do you tell whether a plantation is short of nitrogen and would benefit from fertilisation? This has been quite a problem, largely because of the extent to which the element moves around within a tree, making sampling of foliage for testing extremely difficult. The practical solution proposed by CSIRO's Dr John Raison is to measure the concentration of nitrogen in pine needles when they are shed, or that in fresh needle litter on the forest floor. Tests have shown this gives a reliable measure of the nitrogen status of a pine plantation.

Another practical outcome of the research is the development, by Mr Brian Myers of CSIRO, of an index of water stress—a means of smoothing out water-stress measurements taken over a period to obtain a reliable picture of the state of the plantation. The index is negatively correlated with tree growth.

Plantation managers may be able to use the information derived to assess the susceptibility of stands to insect attack, because trees under stress are the ones at most risk.

Another member of the Division of Forestry team, Dr Ross McMurtrie, now at the University of New South Wales, developed the model that brings all the findings together. Called BIOMASS, its uses include predicting the impacts that forest management practices such as thinning and fertilising, and disturbances such as disease and insect attack, will have on growth or on water use. Researchers can also use it to evaluate the likely effects on tree growth of climate changes—such as possible temperature rises and rainfall changes due to the enhanced greenhouse effect.

The model simulates tree growth in general—not just the performance of radiata pine—and is now undergoing an international evaluation under the auspices of the Scientific Committee on Problems of the Environment. The assessment team is comparing its performance with that of five other forest-growth models using data from two sites—the experimental one near Canberra and a cold forest site in Sweden.

One use for BIOMASS, as a research tool, will be to evaluate simpler forest-growth models that plantation managers can use. Research at CSIRO and the University of New South Wales on such models has received funding from the National Greenhouse Research Advisory Committee. Accurate models will have many potential applications; one of the most important may be determining the contribution that plantation and native forests could make to mopping up excess carbon dioxide in the atmosphere.

High Temperature Kiln Drying

Answers to some questions

Richard L Northway

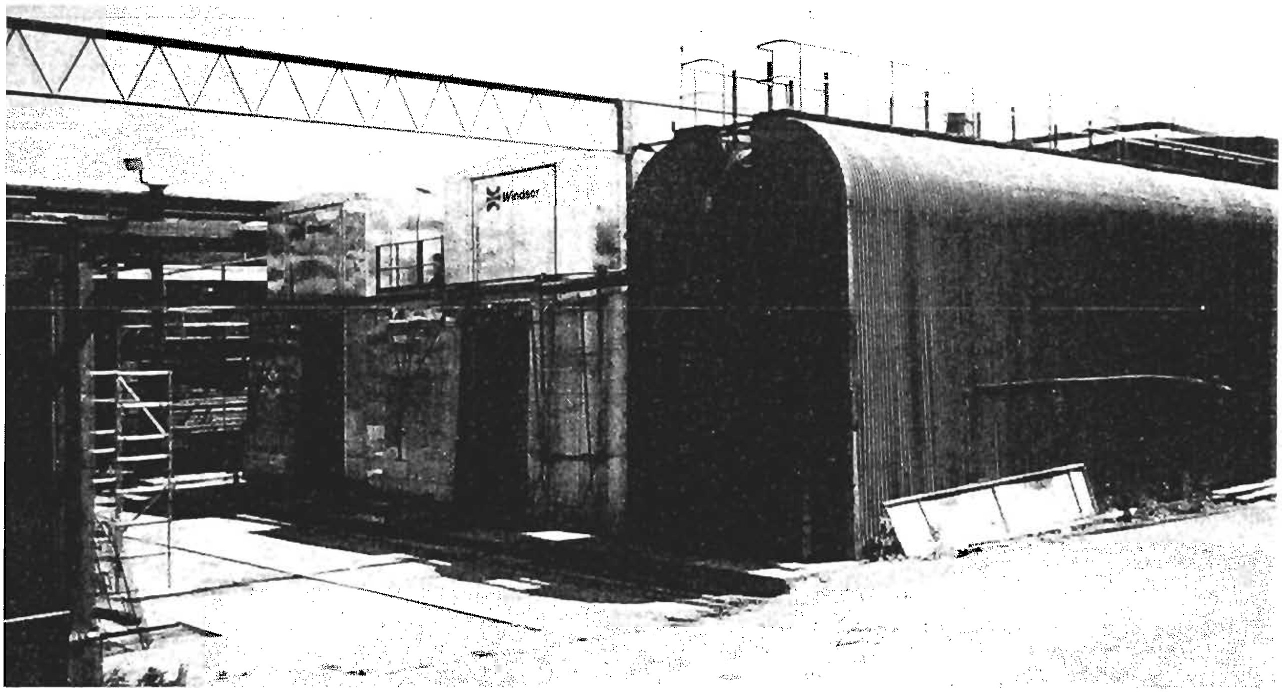
Division of Forest Products

What is high temperature?

Temperatures above 100°C are called high; temperatures above 130°C, which is now used throughout the softwood industry, have recently come to be described as very high.

Is high temperature drying necessary?

Pine can be dried satisfactorily at lower temperatures but high temperature drying (HTD) is faster, generally cheaper, and best enables drying distortion to be avoided.



Typical modern high temperature kiln (centre and left) next to older conventional kiln

Doesn't high temperature drying darken wood?

Not necessarily. Over-drying to a very low moisture content can cause darkening. The mechanism of darkening is complex and not well understood. High temperatures with inadequate air flow may be one cause.

Doesn't high temperature drying weaken wood?

Tests have proved that this is not the case. The possible mechanisms for degradation depend on time, temperature and moisture content. During high temperature drying most of the wood stays at a temperature close to 100°C while free water is present i.e. for most of the drying time. Since HTD takes only a short time no reduction in strength is likely.

What air velocity should be used?

HTD at 120°C to 130°C requires 4 to 5 m/s air velocity through the stack. Lower air speed results in uneven drying.

Is pre-steaming beneficial?

For timber that has been allowed to partially air dry, presteaming moistens the outer layer improving drying speed. In kilns with limited heating capacity, presteaming allows the wood to heat before significant drying occurs.

Why is timber steamed after drying?

Drying necessarily produces gradients in moisture content i.e. the surface layers rapidly approach a moisture content close to equilibrium with the dry kiln air while moisture further in which has to travel to the surface to escape, takes longer to fall to the same equilibrium. While the interior of the boards are wetter than the surface, an unstable situation exists. The dry surfaces will tend to pick up moisture from ambient air and will tend to distort. It is faster and more effective to equalise the moisture content of the cross section while the timber is held flat in the weighted stack.

Can timber be steamed in the kiln?

It is difficult to generate sufficiently humid conditions in most kilns, and the kiln materials and fittings are likely to be corroded. A cheaper separate steaming chamber is more effective and allows better utilisation of the expensive kiln.

Are stack weights really needed?

Without weights the upper layers of pine in stacks generally distort so much as to be unusable.

Can the weights be taken off immediately after drying?

The benefit of weights is maximised by continuous restraint throughout the whole cycle of drying, steam conditioning and cooling.

Are aluminium panel kilns worth the expense?

Well-insulated kilns of durable materials are more energy efficient and will last longer. The kiln operation imposes considerable cyclic thermal stresses on the structure.

How much heat energy is required?

HTD requires installed heating capacity of at least 50 kW/m^3 of timber in the kiln. For operation at very high temperatures more is needed.

What is the best heating system?

This cannot be answered simply. The best system will depend on the alternatives available locally and the scale of the operation.

Who can design a kiln for me?

Several consultants and kiln manufacturers operate in Australia. Contact us at the address below and we can put you in contact with them. In addition, CSIRO DFP can provide a consulting service to advise on kilns and drying practices, to evaluate tenders and to assess kiln performance.

More information from:
CSIRO
Wood Science and Technology Program
Division of Forest Products
Private Bag 10
Clayton Vic. 3168

New Research Team to Study Collapse

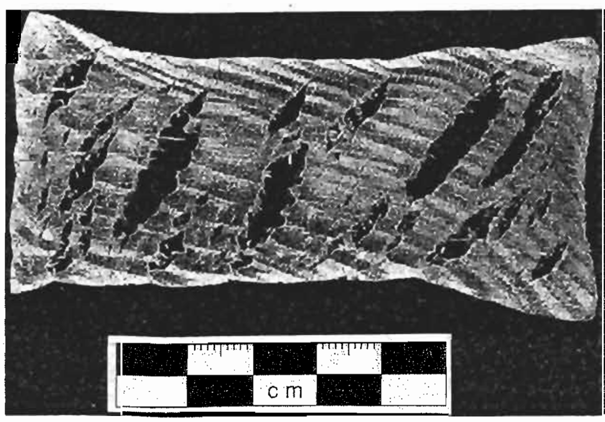
by Sam Chafe

Division of Forest Products

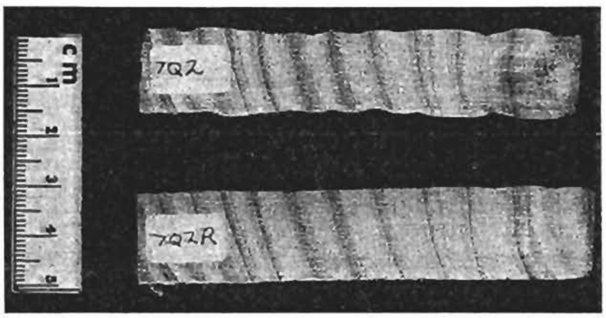
The Division of Forest Products has formed a research team to investigate collapse in wood. Collapse is a major problem in the drying and utilisation of many commercially-important Australian hardwoods and is more severe in young regrowth and plantation-grown material than in wood from older trees.

Collapse can be defined as excessive shrinkage during drying which takes place above the fibre saturation point and, as such, is in addition to normal shrinkage.

With increasing use of young regrowth and plantation-grown trees, the incidence of collapse-associated degrade is expected to rise. The Division therefore, sees the formation of this research team as a major initiative of great potential value to the industry. The functions of



Cross section of collapsed, approximately back-sawn board of *Eucalyptus regnans* showing very severe, radially-oriented internal checking



Cross section of quarter-sawn board of *Eucalyptus* sp. showing collapse before reconditioning (upper) and its removal after reconditioning (lower). Note that collapse is concentrated in the lighter-coloured, lower-density earlywood zones

the team will range from investigating the fundamental nature of wood-water relations to providing advice and recommendations to industry on appropriate action to minimise collapse.

An introductory technical publication already prepared by the Division's team will be available in the near future. This paper presents, simply, the state of current knowledge of the collapse problem and includes discussion of the cause of collapse, the role of heartwood and wood extractives, reconditioning, the problem of internal checking, within- and between-tree variability, relationships with wood anatomy, measurement and prediction of collapse, and measures to ameliorate and prevent collapse.

The paper is suitable for those who wish to gain a general familiarity with collapse without wishing to read the more technical literature on the subject. The paper will also serve as a bridge between industry and research workers at the Division. Copies may be obtained from:

The Information Officer,
CSIRO, Division of Forest Products,
Private Bag 10,
Clayton, Vic., 3168

Significant New Research Facilities for Forestry Industry

Alan Brown

Division of Forestry

Major new research facilities are being developed for the industry in Hobart and Melbourne as part of the Commonwealth Government's Co-operative Research Centres Program.

The Co-operative Research Centre for Temperate Hardwood Forestry in Hobart will share facilities of a new laboratory recently built for the CSIRO Division of Forestry in the grounds of the University of Tasmania, and which has permitted CSIRO to vacate very old premises in the city. The research of the Centre will concentrate on the three eucalypts most favoured for hardwood plantations in temperate Australia, namely *Eucalyptus nitens* (shining gum), *E. globulus* (Tasmanian blue gum) and *E. regnans* (mountain ash). Partners are CSIRO, the University, the Forestry Commission of Tasmania, APPM, ANM and Forest Resources.

The Co-operative Research Centre for Hardwood Fibre and Paper Science will operate from the CSIRO Division of Forest Products - Monash University site at Clayton. The Centre will advise and assist foresters in efforts to improve wood quality through genetic and silvicultural research on plantation and regrowth forests, and provide pulp and paper technologists with directions for improving processes and product quality. The program will include attention to the recycling of paper. Partners are the Australian Pulp and Paper Institute, Monash University, the University of Melbourne, CSIRO and the Pulp and Paper Manufacturers Federation of Australia.

These two Centres will cooperate to provide an integrated research effort not before seen in forestry in Australia. This effort is undoubtedly necessary, however, if the industries in this country are to compete effectively - not with each other, but with major enterprises overseas. The investment in research and development by our competitors is impressive - Aracruz in Brazil has been reported to have spent 10% of its operating budget on these activities over a decade, while Weyerhauser in 1988 spent about US$60M. The total Australian expenditure on R & D for forestry and forest products is about A$60M. The spirit of collaboration which has led to the establishment of these Centres will hopefully extend to at least some operational areas, such as breeding. There is now a national co-operative effort on breeding radiata pine, and similar effective arrangements are desirable for eucalypts.

More information about the new Centres is available from:

- Professor J.B. Reid, Dept. of Plant Science, University of Tasmania, Sandy Bay, Tas. 7005
- Dr G. Gartside, CSIRO Division of Forest Products, Bayview Ave, Clayton, Vic. 3168

Thirty-five Centres have been approved so far in this Program, and applications are now being considered for the final fifteen. The Centres bring together Universities, industry, and State and Commonwealth agencies such as CSIRO. The objectives of the Program are to -

- support long-term high quality scientific and technological research
- capture the benefit of research through the active involvement of research users
- build centres of research concentration, through co-operation
- stimulate education and training, particularly through programs for higher degrees

The contributions of the partners - typically staff and facilities - are augmented by supplementary new funds, planned to average about A$2M per Centre annually by 1994-95. These funds permit key additional staff, including post-graduate students, to be employed.

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