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RESEARCH NOTE No. 26

Published 1973

SILVICULTURAL CHARACTERISTICS OF WHITE CYPRESS PINE

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G 10107

Issued under the authority of
The Hon. G. F. Freudenstein, M.L.A.,
Minister for Conservation, New South Wales

ODC 181

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1973

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SILVICULTURAL CHARACTERISTICS OF WHITE CYPRESS PINE

1. INTRODUCTION

White Cypress Pine is one of Australia's most important indigenous softwoods, and is the most valuable timber producing tree in western New South Wales and southwest Queensland. It was originally abundant throughout this pastoral zone, but widespread clearing of the timber, to allow agricultural development, has caused a substantial decrease in its supply over a greater part of the area of its original distribution.

The timber has high durability, being particularly resistant to termite attack, and its versatility is such that the timber components of most buildings in western centres are largely Cypress Pine. Outside of the region, it has been used particularly for flooring timber. Apart from timber production, Cypress Pine forests are of value for sheep and cattle grazing. They also serve a useful purpose in providing areas for recreation and wildlife refuge.

2. BOTANICAL CHARACTERISTICS

2.1. Nomenclature

White Cypress Pine is a member of the genus *Callitris* in the family Cupressaceae. Other genera of this family in Australia are *Diselma* and *Actinostrobus*. All three genera have scale-like leaves and numerous seeds. The seed cones are formed from a number of valves and in the genus *Callitris* there are six valves per cone. There are from twelve to sixteen species in the genus depending upon the classification adopted. Revision of the taxonomy is required, as at the present time the botanical name of White Cypress Pine and several closely related species or subspecies cannot be confidently stated.

Formerly White Cypress Pine was known as *Callitris glauca* R. Br. ex R. T. Baker et H. G. Sm., but Garden (1956) considered the correct name was *C. hugelii* (Carr) Franco. Blake (1958) proved the name *C. hugelii* to be invalid and in addition he considered there was no satisfactory basis for separating the three species *C. glauca*, *C. intratropica* R. T. Baker et H. G. Sm., or *C. columellaris* F. Muell and, therefore, combined them under the name *C. columellaris* according to the rule of taxonomic precedence.

From a forestry aspect this has not proven satisfactory.

The three species, as defined prior to Blake's classification, occupy distinctly different habitats. *C. glauca* occurs in inland areas of all the mainland States and the Northern Territory. *C. columellaris* occurs in coastal areas of Queensland and New South Wales and *C. intratropica* occurs in the tropical zone of north Queensland, the Northern Territory, and Western Australia. There are obvious differences in gross morphology between all species and, in the case of *C. glauca* and *C. intratropica*, which have been closely compared as a result of their economic importance, there are also marked differences in the chemical, mechanical, anatomical, and growth characteristics. Gay and Evans (1968) have noted that in a provenance trial with the two species in the Northern Territory there were marked differences in colour, texture, and density of the foliage and in the branch angle and branching frequency. Growth behaviour was also markedly different as survival and initial diameter increment of *C. glauca* was considerably below that of *C. intratropica*. In addition Baker and Smith (1910) have noted anatomical differences in the wood and bark and chemical differences both in the foliage and wood. Bamber (1959) has also noted distinguishing anatomical characteristics of the bark, and finally *C. intratropica* timber is purported to be significantly denser and superior in strength to *C. glauca* (Anon. 1966).

2.2 Distinctive Characteristics

Garden (1956) has described the species as follows:

> A tree occasionally reduced to a shrub, usually glaucous, with ascending horizontally spreading, occasionally pendulous or fastigiate branches. Leaves usually 0·1–0·3 cm long, the dorsal surface not keeled. Male cones cylindrical, up to 0·5 cm long. Female cones solitary on slender fruiting branchlets, rarely remaining on the branches long after maturity, ovoid to depressed—globular up to 2·5 cm diameter. Cone scales 6, thin, often with a very small dorsal point, the alternate scales reduced in size, the larger scales angled into a broad short apex, all usually separating almost to the base of the cone and often spreading widely after maturity. Columella usually slender, occasionally up to 0·5 cm long. Seeds, numerous, chestnut coloured with 2 wings often 0·4 cm wide.

This description is accurate except that the seed is not infrequently three-winged.

Environmental influences account for some of the more obvious variations in Cypress Pine morphology. For example, the size is dependent on site quality and stand competition. Figure 1 shows an untreated stand of mature trees less than 20 feet (6 m) high on a shallow ridge top in a 14 inches (350 mm) rainfall area near Cobar. Figure 2 shows scattered trees in the same general area on a site which has its moisture supply augmented by run-off.

Figure 1. Untreated, mature Cypress Pine stand on low quality site at Cumbine State Forest, near Nymagee, N.S.W.

Figure 2. Scattered mature Cypress Pine on high site quality area near Cumbine State Forest

Environment influences crown shape in that crowns in dense stands have sparse foliage and a tendency to be flat-topped, and branching is confined to the upper part of the tree bole. This contrasts with crowns of open grown trees which have thick foliage, are often conical with a conspicuous drooping leader, and have branching over the greater part of the bole length. Differences in crown shape, apparently under genetic control, are manifest in relatively free growing stands. Here the crown shape varies from extremely long and conical to bunched and rounded.

Foliage colour commonly is glaucous and quite distinctive from other Cypress Pines. However, individual variation embraces a range of shades from green to glaucous. A very green crown colour similar to that of Black Cypress Pine (*C. endlicheri* Parl.) is uncommon, but isolated individuals can be found in most Cypress Pine forests. On very rare occasions a golden crown colour is encountered: a few such trees are known and these may have value for horticultural use.

Bark is thicker in dense stands and in low site quality stands, and bark colour is influenced by age in that old veterans, probably as a result of a bleaching effect, are a lighter grey than younger trees. In certain stands lichens may be distributed abundantly along the bole and branches, imparting a distinctive colour.

In dense stands bole taper is decreased as a result of height increment being less severely affected than diameter increment by high stocking. Conversely in open stands taper is increased as a result of greater diameter increment relative to height increment.

Anatomically, certain species of the genus *Callitris*, including White Cypress Pine, are distinctive because they demonstrate characteristic wall thickening of the bordered pit regions of the tracheids. This is referred to as "callitroid thickening" and has been investigated by Cronshaw (1961) and Davies and Ingle (1966). Baker and Smith (1910) also showed that the presence of manganese was a conspicuous feature in the anatomical investigation of wood bark and leaves of *Callitris* species.

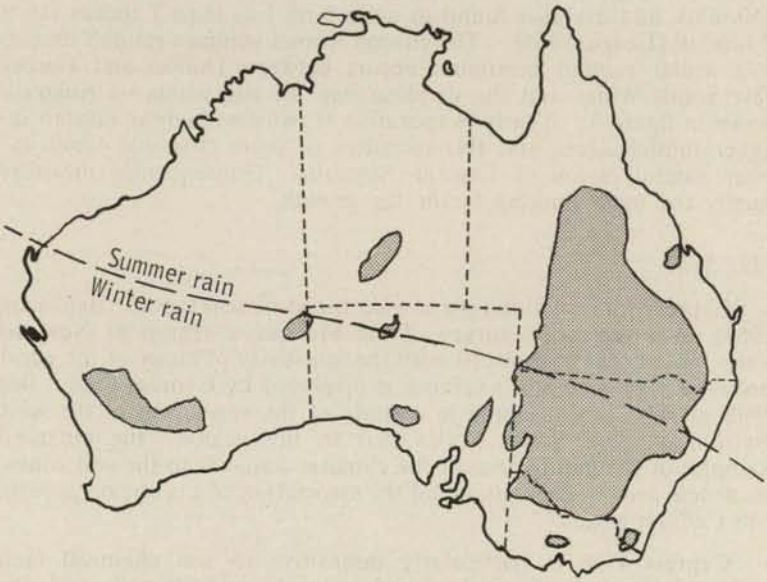
3. NATURAL DISTRIBUTION

3.1. Natural Occurrence

There is no detailed map available showing the distribution of White Cypress Pine throughout its entire range. However, the geographic area in which it can be expected to occur is depicted in figure 3. This is taken from Hall, Johnston, and Chippendale (1970) which, in turn is largely based on the distribution of botanical specimens as noted by Garden (1957). Over the major part of its natural range Cypress Pine

occurs as scattered trees or in small forested areas as a result of clearing for agricultural development. Extensive forests are now found only in the Baradine-Narrabri area of northwestern New South Wales, around Cobar in central western New South Wales, and between Dalby and Roma in southwestern Queensland. There are only minor occurrences in Victoria, South Australia, Western Australia, and the Northern Territory.

Fig 3 Distribution of White Cypress Pine shown by shaded areas.



3.2. **Factors of Distribution**

3.21. *Climate*

White Cypress Pine grows in a dry subtropical to warm temperate climate. Summers are characteristically hot but winters are mild with relatively warm days, though frosts may occur at night. From 10 to 20 air frosts can be expected, mainly occurring between May and September but occasional frosts also occur in April and October. The frost free period is usually an average of 225 days or greater. The temperature ranges from an average maximum in the mid 90's (°F) (35° C) in January to an average minimum in the mid 30's (about 2° C) in July. Rainfall is variable for any month from year to year, but most of the commercially important forest areas receive an average annual rainfall of 20 to 28 inches (500–700 mm) per year. Over the major area of its commercial distribution in New South Wales and Queensland the rainfall decreases markedly from east to west and also from north to south so that the maximum rainfall of about 30 inches (760 mm) is in the northeast part of the range and the minimum is in the southwest where it is found in forest formation under an average rainfall of 15 inches (380 mm). Scattered trees occur in much lower rainfall areas. They are relatively common in the Macdonnell and Hann ranges of Central Australia (Nelson, 1968), where the annual rainfall is approximately 10 inches (250 mm), and are also found in areas with less than 7 inches (18 mm) of rainfall (Lange, 1965). The change from a summer rainfall maximum to a winter rainfall maximum occurs between Dubbo and Forbes in New South Wales and the dividing line for the whole of Australia is shown in figure 3. Yearly evaporation is twice as high as rainfall in the higher rainfall areas and this increases to more than ten times in the lower rainfall areas of Central Australia. Consequently moisture is usually the most limiting factor for growth.

3.22. *Soil*

Cypress Pine is found on a wide range of soil types. Biddiscombe (1963), in a vegetation survey of the Macquarie region of New South Wales, noted that by contrast with the sensitivity of many of the eucalypt species, a very wide soil tolerance is displayed by Cypress Pine. Beadle (1948, p. 49) likewise noted in a study of the vegetation of the western Division of New South Wales that in this region "the outstanding examples of the indifference of the climatic climaxes to the soil zones are the *Acacia aneura* association and the association of *Eucalyptus populifolia* with *Callitris glauca*".

Cypress Pine is particularly insensitive to soil chemical factors, and good stand development occurs on very infertile soils and over a wide pH range. Beadle (p. 51) found that Cypress Pine soils ranged from pH 5 to about pH 7·5, and Downs and Sleeman (1955) recorded the presence of Cypress Pine on terra rossa soils of pH 7·9 in the Macquarie region in New South Wales. Data collected by Waring (1950) in the Pilliga region demonstrated that well developed stands of Cypress Pine occurred on soil over a wide pH range and that considerable variation could be encountered even within the one soil profile. The solodized solonetz soils investigated showed a change from a distinctly acid surface soil to distinctly alkaline conditions in the subsoil.

The Cypress Pine soils are mostly alluvial, formed from coarse grained parent material such as sandstone or granite though finer grained parent materials are represented. The alluvial soils may have a uniform profile, as in the case of the deep coarse sandy soils in the Pilliga region in New South Wales, they may be gradational, becoming finer textured with depth, such as the soils around Cobar in New South Wales; or more commonly they may have distinct profile development in which there is a sharp textural change between surface and subsoil. In this latter category are the solodized solonetz soils of the Pilliga, which have a sandy A horizon overlying a kaolinitic clay B horizon at variable depth. (A cement-like hardpan may be present at the lower limit of the A horizon.) Also in this category are the hard setting loam soils overlying clayey subsoils which may be distinctly mottled. Cypress Pine forests are commonly found on these soils throughout southern New South Wales.

Cypress Pine may occur on soils formed "in situ", such as on the hills surrounding the Gwydir valley in northern N.S.W., but along the eastern limit of its range it tends to be replaced by other species such as Black Cypress Pine (*C. endlicheri*) on very shallow soils or in skeletal situations.

Soil texture influences Cypress Pine distribution through its effect on drainage. Cypress Pine often occurs on sites which receive supplementary water from run-off, but it will not tolerate areas where drainage is impeded and it is notably absent from depressions. Due to the drainage requirements of Cypress Pine, soil texture is usually within the range of sand to loam. However, it may occur on clay loams when there are compensating drainage features such as sloping topography, gravel in the profile or low annual rainfall. Cypress Pine species associations within any climatic zone are clearly related to soil types. Thus Waring (1950) found that for the Pilliga region a vegetation map could be accepted as an approximate soil map, provided the mode of occurrence of the species in certain transitional areas is understood.

Within the climatic zone in which it occurs the only extensive tracts of soils that completely exclude Cypress Pine are the cracking clays such as the Liverpool Plains in the northwest of New South Wales and the Darling Downs in southern Queensland. The cracking clays are a complex section of alluvial soils of basaltic origin and are unfavourable for the growth of many tree species.

3.23. *Physiography*

Cypress Pine is restricted by the lower temperatures associated with increasing altitude, and consequently is found at higher elevations towards the north and tropical part of its range. Its elevation in New South Wales varies from about 300 feet (90 m) on the western plains to approximately 2,500 feet (750 m) on the western slopes of the Great Dividing Range. It is generally poorly developed on steep country, but is nevertheless conspicuously present on the lower slopes of the Warrumbungle and Nandewar Ranges and on the hilly topography surrounding the Gwydir valley north of Bingara, all in New South Wales.

3.24. *Fire*

White Cypress Pine is more sensitive to fire than the hardwoods with which it occurs, and it is excluded from hardwood stands under conditions of regular burning. On the other hand, as a result of its considerable regenerative capacity in the absence of fire, pure hardwood stands and mixed hardwood-pine stands develop an increasing component of Cypress Pine and the stands may become very dense. This characteristic of forming dense stands in which grass and herb cover are almost completely excluded (figure 4), and in which litter is very quickly broken down, constitutes the chief defence of Cypress Pine against fire. The rather insignificant accumulation of fuel is similar to that of *Callitris intratropica* for which Stocker (1966) has noted that undisturbed stands will not carry severe fire and that when stands are destroyed by fire it is usually the result of "abnormal fuel accumulation in the wake of cyclonic damage or logging operations".

Figure 4. Well stocked stand of White Cypress Pine, with some Casuarina leuhmannii, **showing both light litter layer and absence of ground vegetation**

3.25. *Biotic Relationships*

Mycorrhizal relationships of Cypress Pine have not been studied in detail. However, Bevege (1968) has shown that Cypress Pine has a vesicular-arbuscular mycorrhizal infection caused by a member or members of the phycomycete genus *Endogone*.

Lichens usually occur with Cypress Pine to some extent and may be profusely developed on the bole and branch bark. The genus *Parmelia* is well represented and *P. subflava* (figure 5) is probably the most common lichen of the bole bark. *P. rudecta* and *P. cunninghamii* are other members of the genus found on the bole bark. Species which are not uncommon and have an interesting form or colour are *Usnea scabrida* (figure 6) which occurs on the finer branches, *Teloschistes spinosus* which is a small orange coloured lichen, and a species of *Collema* which has an orange ascocarp and light green thallus. Other lichens collected but not identified to species level belong to the genera *Ochrolechia*, *Lecanora*, and *Caloplaca*.

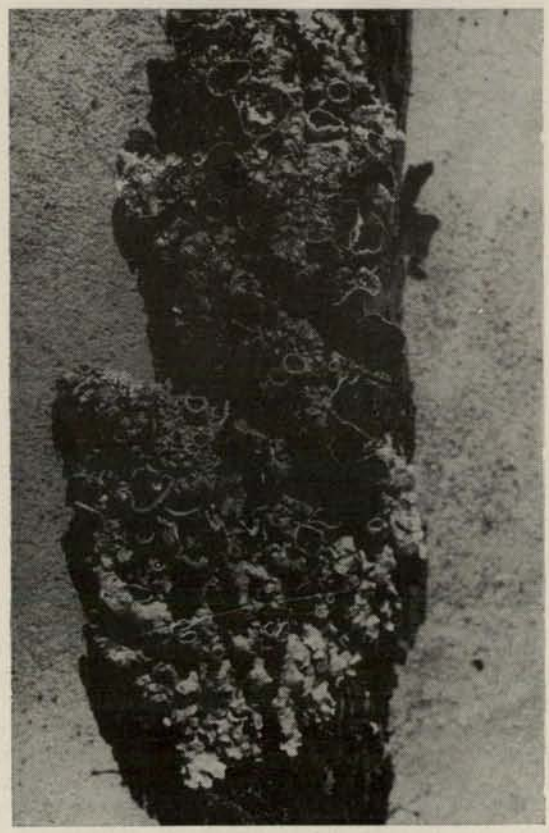


Figure 5. The lichen Parmelia subflava **on bole bark of White Cypress Pine**

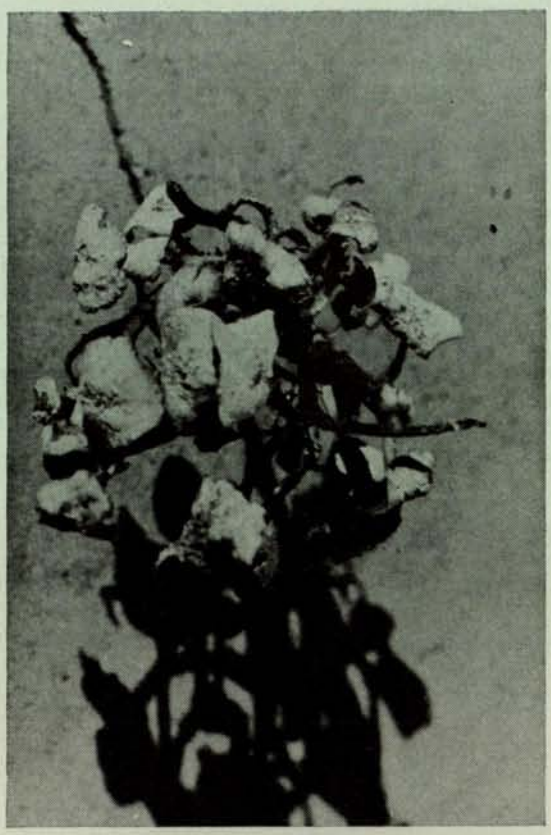


Figure 6. The lichen Usnea scabrida **on a fine dead branch of White Cypress Pine**

3.3. Natural Communities

Cypress Pine forms a large number of associations with other tree species throughout its geographic range, but none of these species has an identical range to Cypress Pine, and none is as extensively distributed. The species associations in N.S.W. have been described in detail by Lindsay (1967). In southern New South Wales the associated species belong largely to the Box group of eucalypts and include *Eucalyptus woollsiana*, *E. microcarpa*, *E. conica*, *E. melliodora*, and *E. albens*. Other species present may include the Ironbark, *E. sideroxylon*, Red Gums *E. blakelyi*, *E. dealbata*, and *E. dwyeri*, Oak, *Casuarina luehmannii* and Black Cypress Pine, *Callitris endlicheri*.

In addition to these a further assemblage of species is encountered north of Dubbo to southern Queensland, in the summer rainfall zone. All species have a more restricted latitudinal distribution than Cypress Pine. The summer rainfall group of species comprise the Box, *E. pilligaensis*, Ironbarks *E. creba*, *E. nubila* and *E. melanophloia*, Bloodwoods *E. trachyphloia*, *E. bloxomei* and *E. maculata*, and the native Apples, *Angophora costata* and *A. floribunda*. The most important commercial pine stands are formed in association with *E. bloxomei*, *E. dealbata*, *E. blakelyi*, *E. woollsiana* and *E. populnea*.

Understorey species consist of a large number of wattles, amongst which the most important are probably *Acacia deanei*, *A. homalophylla*, *A. spectabilis*, *A. cheelii* and *A. hakeoides*, and sundry other shrubs including Rosewood (*Heterodendron oleifolium*), Whitewood (*Atalaya hemiglauca*), Wilga (*Geijera parviflora*), Budda (*Eremophila mitchelli*), Quandong (*Santalum acuminatum*), Hop Bush (*Dodonea viscosa*), and Quinine Bush (*Alstonia constricta*).

In the more open stands there is often an abundant grass cover, the most important species of which are the wire and spear grasses belonging to the genera *Aristida* and *Stipa* respectively. Also common are species of *Chloris*, *Danthonia*, *Eragrostis*, *Panicum*, *Bromus*, and *Vulpia*.

4. SEEDING HABITS

4.1. Flowering

Information on the development of male and female cones of White Cypress Pine has been given by Baker and Smith (1910), Baird (1953) and the Annual Report of the Queensland Department of Forestry (1960). Baird's information is the most complete and is contained in a detailed study of the life history of the genus *Callitris* with particular attention given to *C. robusta* (syn. *C. preissii*). Some details of flower development in White Cypress Pine still require clarification, but essentially the behaviour is the same as for *C. robusta* and the following description is taken from Baird:

> . . . the young male cones and the small branches which bear the primordia of the female cones can be recognized in November or December. There is little change through late summer and autumn and the pollen does not ripen until the following spring.
>
> Trees shedding pollen can be found from early August to late October but on any one tree the cones ripen almost simultaneously and pollen is shed over a period of ten to fourteen days with a peak of two to three days when pollen is released in dense clouds. The majority of (female) flowers are pollinated in September. During the next few weeks the sporophylls thicken slightly and almost cover the ovules but there is little increase in diameter. These minute cones, 2–3 millimetres in diameter, remain unchanged for a year or more before growth is resumed some time between September and November. Once started growth is comparatively rapid . . . cones have almost, if not quite reached their full size at fertilization . . . fertilization occurs in April and developing embryos are found through May and June.

Stages in the development of female cones are shown in figures 7 to 10.

Figure 7. Young female cones of White Cypress Pine prior to pollination

Figure 8. Young female cone after pollination. The ovular scales have swollen at the base completely to cover the ovules

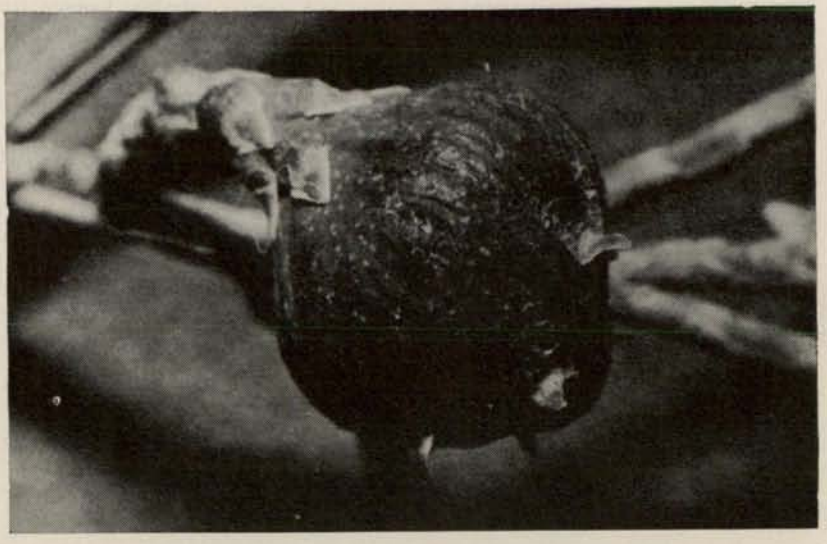


Figure 9. Growth of female cone prior to fertilization. Note that the tips of the ovular scales are still conspicuous

Figure 10. Female cone at time of fertilization. The cone has achieved almost full size

The interval between pollination and fertilization has not been determined for White Cypress Pine. Baird gives the season and duration of stages for a number of species and states that the interval is 18 to 20 months for *C. endlicheri* (syn. *C. calcarata*), and probably longer for *C. glauca.*

Flowering occurs in White Cypress Pine at an early age. In one instance this has been as early as three years for a tubed seedling which produced a single developed female cone when less than 2 feet (0·6 m) in height (figure 11). In the field individuals have been noted to produce female cones at six years. At this time the seedlings may be less than 4 feet (1·2 m) high. In such instances only a few cones are produced and these are borne on short branchlets close to the stem apex. These cones may sometimes persist for a period following seed shed and, if diameter growth is rapid, the cone branchlets are occluded to give the appearance of cones being produced directly from the mainstem (figure 12). In trees of all ages cones generally persist for 1 to 2 years following seed dissemination.

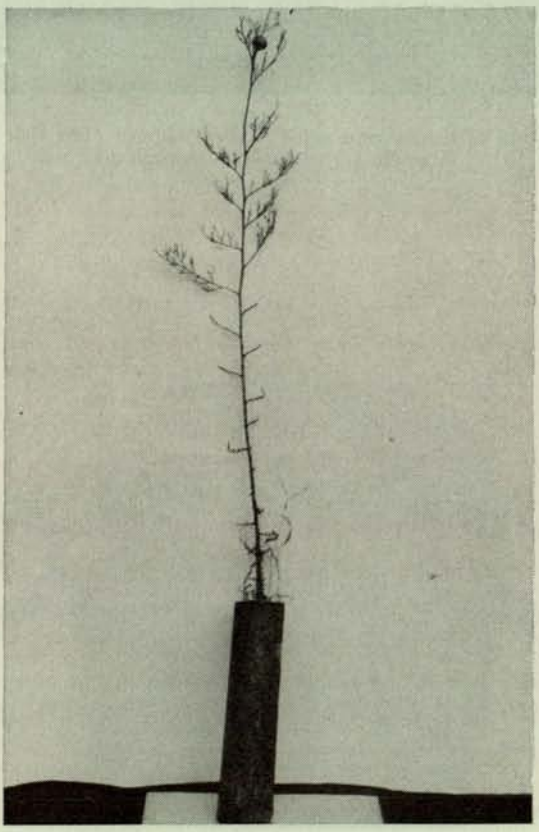


Figure 11. Cone production by a 3-year-old tubed seedling of White Cypress Pine

Figure 12. Retention of opened seed cones on the mainstem of young White Cypress Pine. Growth of the stem has occluded the cone branchlets

In contrast to the small number of cones borne by young trees at the onset of cone production, mature open grown trees may carry over 60,000 cones.

4.2. Seed Production

Cypress Pine seed is light brown, and two or three winged. There is a variable number per cone. The number of seeds increases with cone size, and average cone size can vary markedly between individual trees (figure 13). Small cones have from 18 to 24 seeds per cone and large cones from 30 to 36 seeds per cone. Seed weight also increases with cone size. Seeds from large coned trees may number 27,000 per pound (60,000/kg) whereas seeds from smaller coned trees may number up to 55,000 per pound (120,000/kg).

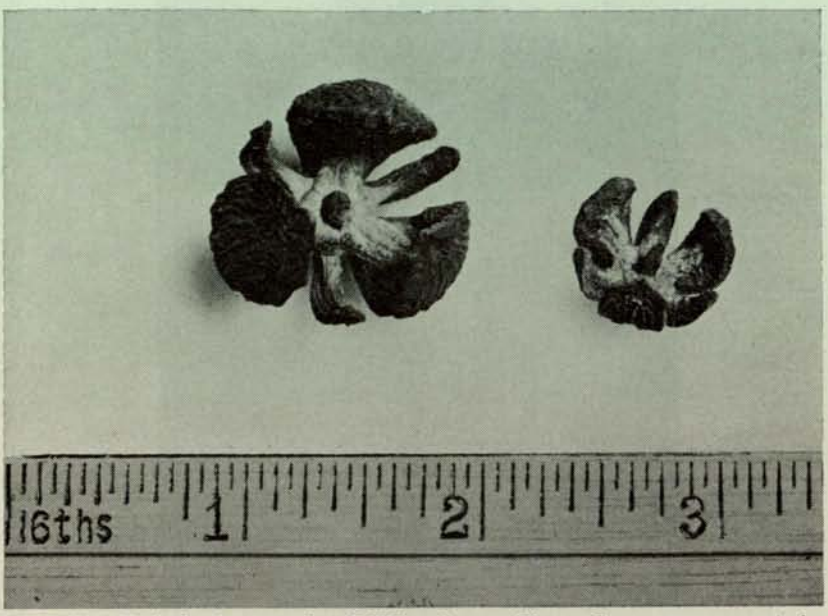


Figure 13. Variation in cone size of White Cypress Pine. Cones are representative of collections from two trees: on left, Merriwindi State Forest, Baradine District; on right, Backyamma State Forest, Forbes District

The quantity of seed produced in Cypress Pine stands naturally shows marked annual variation, but good seed supplies can be expected at frequent intervals. Hawkins (1966) found that seed production could be as high as 62·3 lb per acre (70 kg/ha), or 2,173,000 seeds per acre (5·4 million/ha) for a good seed year and as low as 0·6 lb per acre (0·7 kg/ha) or 24,000 seeds per acre (60,000/ha) in a poor seed year.

Production of Cypress Pine seed is influenced by the same factors as affect other tree species. Stand density markedly influences the quantity of seed produced in any one year, and within defined limits seed production is inversely proportional to stand basal area. At basal areas greater than 80 sq ft per acre (18·5m²/ha) negligible seed is produced and seed production is increased dramatically when basal area is lowered. In one seed trap experiment during a good seedfall year production varied from 48·7 lb per acre (54·5 kg/ha) or 1·6 million seeds per acre (4 million/ha) at 20 sq ft per acre (4·6 m²/ha) basal area to 6·0 lb per acre (6·7 kg/ha) or 0·3 million seeds per acre (750,000/ha) at 62 sq ft (14·2 m²/ha) basal area. (Lacey, 1972.) Similar results have been observed in a wide variety of other forest trees.

At very low basal areas, mature individual trees can carry considerable quantities of seed, sometimes as high as 22 lb (10 kg) per tree. For small coned trees this is greater than a million seeds.

Individual trees vary considerably in their production of seed. As a natural extension of the effects of high stand density, suppressed trees exhibit little flowering and, therefore, have poor seed production, while the dominants of the stand or trees that are free grown form far more seed. Again, as a consequence of normal genetic variation, some trees in a stand are consistently more prolific seed producers, independently of their dominance classification.

Age also has an effect and trees which have been suppressed and consequently stunted have produced more seed following their release by stand thinning than recently regenerated trees of the same size which have originated in the last 20 years.

4.3. Seed Dissemination

Dissemination of the seed is a natural consequence of the cone drying out. Usually this occurs from October to January, with the majority of the crop usually falling in a four weeks period of November/December. The Cypress Pine seed is winged and this aids considerably in obtaining a uniform dispersal around seed trees. Most seed is shed in close proximity to the tree as illustrated by figure 14, which shows two groups of seed trees surrounded by dense patches of regeneration. However, a small number of seeds may travel for a considerable distance. The absolute distance is naturally dependent upon the height of the tree, stand density and wind strength at the time of shedding, but isolated seedlings have been recorded up to 400 yards (370 m) from open grown parent trees. Figure 14 also demonstrates this effect.

Figure 14. Occurrence of Cypress Pine regeneration in patches surrounding seed trees, and showing isolated regeneration spread over a wide area. The group in foreground has five seed trees. Narrabri District

Possibly some seed is transported, either at seedfall or subsequently, by whirlwinds. These are not uncommon during summer throughout the Cypress Pine zone, and carry small particles considerable distances. Movement of seed by wash could also account for seed spread on sloping sites, though sloping sites are of restricted occurrence in White Cypress Pine areas.

4.4 **Seed Collection**

Cone ripening is indicated by a change in colour from green to brown or grey and a variable degree of wrinkling of the scales. Ripe seed can be collected generally in mid November immediately prior to the cones' opening and artificial ripening is not required. When seed is collected within a month prior to natural ripening, air drying has been sufficient to induce artificial ripening. Seed is generally easily dislodged from the cones as a result of the cone scales' opening very widely on drying. Only gentle shaking of dry cones is required to ensure that the cones are emptied.

A small percentage of seed is often retained in cones on the tree following completion of general seedfall. This seed generally has poor viability as a result of insect attack prior to maturation of the cone and seed. In these instances the cones may be only partly opened, indicating a degree of case hardening. Serotinous cones are not produced in White Cypress Pine, though they may be produced by other members of the genus, e.g., *C. preissii* and *C. endlicheri.* Seed purity is largely governed by the percentage of infertile seed and empty seed resulting from insect damage. This latter seed is often externally indistinguishable from sound seed but, since it is lighter, seed quality can be improved by methods involving specific gravity.

4.5. **Seed Viability**

Viability of Cypress Pine seed is variable, but is highest in heavy seedfall years as is commonly the case with tree species. The recorded viability has ranged from less than 20 per cent (Hawkins, 1966) to over 70 per cent (Lacey, in press), but does not commonly exceed 45 per cent. A large number of imperfect seeds is a feature of most *Callitris* species (Baird, 1953). There is no dormancy of Cypress Pine seed and hence seed germination is related directly to seed fertility with the exception of any damaged seed. Viability of Cypress Pine seed can be determined by cutting tests as non-viable seeds are readily detected either by discolouration of the contents or by the more obvious indications of insect damage or empty seed.

Seed germination is highest at 15° to 20° C (Floyd, pers. comm.; Scott, 1969) and is reduced to zero at 25° C (Floyd, pers. comm.). As mentioned, there is no dormancy of Cypress Pine seed, but Floyd (pers. comm.) found that though germinative capacity of Cypress Pine seed was unaffected following stratification, the germinative energy was initially increased indicating that there was a type of response by some seed to the treatment.

4.6. Seed Storage

Provided seed is stored in dry air-tight containers and kept in cool storage there is little reduction in viability of the seed for at least three years and possibly longer. However, under field conditions viability is drastically reduced and may be less than 1 per cent several months after seed shed (Lacey, in press).

5. ESTABLISHMENT

5.1. General

Perpetuation of Cypress Pine forests is entirely dependent upon natural regeneration, as apart from economic considerations, the artificial establishment of Cypress Pine in plantations has been unsatisfactory for timber production. Within New South Wales, Cypress Pine plantations have been established in the region of its natural occurrence as well as outside of this region in the higher rainfall areas of the east coast. The plantation grown trees have characteristically demonstrated poor form and slow growth relative to natural stands. This cannot be attributed to the seed source, but it may be partly due to the poor root system caused by confinement of the seedling roots in the metal tubes used for raising seedlings in the nursery.

Even if the problems associated with form and vigour of plantation Cypress Pine are overcome it is unlikely that artificial establishment will be very important to Australian forestry practice because of the economic advantage of natural regeneration. However there will be some demand for afforestation work where seed trees are not present or are destroyed or damaged by wildfire, so that investigation of various techniques of artificial establishment is required.

Outside of Australia Cypress Pine appears to have attained most usefulness as a plantation species in Malawi (formerly Nyasaland), where it has been recommended for timber production in the subtropical and temperate warmer zones at 2,000 to 6,000 ft (600–1,800 m) with minimum annual rainfall of 30 inches (750 mm) and mean annual temperature of 62° to 75° F (17° to 24° C) (Street, 1961).

Good growth has been recorded also in the Republic of South Africa where one plantation with 192 trees per acre (474/ha) at 38 years had the surprising height of 86 feet (26 m) and diameter of 15 inches (38 cm) (Street, 1961). The growth rates necessary to attain these dimensions are far higher than any recorded in Australia. This particular plantation was grown under a combination of conditions which are not encountered by White Cypress Pine in its natural distribution, being on a deep clay loam soil at 3,400 feet (1,100 m) elevation and with an annual rainfall of 50 inches (1,270 mm).

5.2. Natural Regeneration

The development of natural regeneration is dependent upon the favourable condition of a large number of biological and environmental factors. Together with seed supply, seed viability and soil type previously discussed, these factors include rainfall and soil moisture, degree of overstorey, grass, shrub and litter cover, grazing and fire.

Field germination is most commonly observed in the autumn to early winter months (late March to June) under good soil moisture conditions following high rainfall. Germination associated with high rainfall can be very dense whilst only scattered regeneration has been noted following average to low rainfall. Timing is also critical because high rainfalls occurring at a later date, such as August and September, have not given a germination density comparable with that of early rains, probably as a result of declining seed viability.

There have been no confirmed observations of germination occurring during the spring and summer months of October to January, and only isolated observances in February. The normal climatic conditions in summer of high temperatures and low frequency of effective rainfall make it less likely that suitable conditions for germination will occur.

Given favourable conditions germination rates over restricted areas may be very high and germinated seedlings in excess of one million per acre have been registered. Over widespread areas, 20 years after germination regeneration densities in excess of 50,000 stems per acre (125,000/ha) are commonly encountered.

As a normal development of the limiting effect of soil moisture, greatest mortality can be expected through the summer months immediately following germination. The extent of the mortality depends very closely on the frequency and amount of summer rainfall. In moist summers very high survival of germinated seedlings may be obtained while in dry summers complete mortality may result.

As mentioned, good drainage is required for the occurrence of Cypress Pine and, therefore, regeneration commonly occurs on soils with texture ranging from pure sand to loam (see section 3.22).

There is an obvious relationship between stand density and the amount of regeneration which becomes established. Overstocked stands have very little regeneration while understocked stands are seldom without it. However, the presence of established regeneration in understocked stands cannot be interpreted as solely the result of the low level of competition with the overstorey because, as mentioned previously, seed supply is also much greater in these stands. Generally speaking, stands with basal areas in excess of 60 sq ft per acre (14 m^2/ha) will produce little or no regeneration and regeneration increases down to very low levels of seed tree spacing which might be less than 7 sq ft per acre (1·6 m^2/ha). It follows that, in order to obtain adequate but not excessive quantities of regeneration, the stand basal area must be kept within certain limits. These cannot be defined for all sites, regions and stand ages, but for the typical older stands under management, a stand basal area of 30 to 40 sq ft per acre (7–9 m^2/ha) will allow regeneration to occur but will not allow excessive regeneration.

Stand density effects grass and herb cover similarly to regeneration and consequently Cypress Pine regeneration and abundant grass cover frequently occur together. Since grass cover is an indicator of the low level of competition within stand, and in addition therefore of good seed availability, it is difficult to determine what is the influence of grass cover *per se* on developing Cypress Pine regeneration. It probably has a favourable influence in providing shade and, since it is ephemeral, characteristically "haying off" quickly in summer, it is less likely to compete with the young pine for soil moisture at a critical period. Grass cover may also have definite inhibitory effect on regeneration occurrence by preventing a proportion of the seed from reaching the ground. Notwithstanding this inhibitory effect, regeneration frequency varies directly with grass cover, and both grass cover and regeneration are inversely proportional to stand density.

Apart from the factors mentioned, for effective seedling establishment strict protection from grazing and fire is essential.

5.3. Regeneration Tending

Regeneration stands usually require removal of useless hardwood competition, logging of old seed trees and thinning of the young regeneration.

In order to minimize costs where regeneration is very dense, a variety of heavy machinery has been used to remove strips of seedlings. Depending upon the density of the original stand, the machine employed and the skill of the operator, mechanical thinning may be used for near final spacing. In these instances expenditure on follow up manual thinning is largely avoided and total thinning cost is very favourably related to anticipated financial returns. Thinning can be carried out within a lengthy period from the development of the regeneration stand as there is no evidence that suppression for a 10 years' period seriously affects the ability of stands to respond to thinning.

Though the growth rate is depressed in stands which are left unthinned for a long period, these stands tend to have the utilization advantages of low taper and smaller branch development. On the other hand the tendency towards development of sharp taper and large branches in early thinned regeneration is confounded to some extent by different sites and/or genetic constitution, and hence early thinning to wide spacing does not automatically produce undesirable log quality. Further research is required into the effect of site quality and stand density on tree form.

6. STAND DEVELOPMENT AND LIFE HISTORY

6.1. Phenology

Cypress Pine forms growth rings comprised of early- and latewood and these average one per year, but growth is related to favourable environmental conditions rather than a particular seasonal period and there may be several growth rings in some years and none in others (Lange, 1965). Very little growth occurs in winter months and growth at other times is dependent upon favourable soil moisture conditions.

Environmental conditions such as soil moisture may fluctuate over short intervals between an adverse and satisfactory condition for Cypress Pine growth, so that early- or latewood bands may be only several cells wide. Growth rings are thus of little value for accurate age determination, but exceptional circumstances such as prolonged periods of good soil moisture and rapid growth following thinning of dense stands can be detected by inspection of the growth ring pattern.

6.2. Early Crop Growth

Following germination—in late summer to early winter—the cotyledons expand to approximately 0·75 cms. The first true leaves formed are in a single opposite pair. These are followed by four-ranked juvenile leaves which are completely free from the mainstem. When the seedlings are several inches high branching occurs and the juvenile foliage is replaced by the mature, three-ranked decurrent leaves.

Initial seedling growth is usually quite slow and after the first summer from germination, seedlings may be from only 1 to 4 inches (25–100 mm) high and it may take three years for them to reach a height of 2 feet (0·6 m).

Initial root growth is much more pronounced than shoot growth. Zimmer (1960) found that a seedling 160 days old and 5 inches (125 mm) high had a root penetration of 42 inches (1,070 mm). Depending upon the competition, top growth may continue to be very slow for an extended period and seedlings less than 6 inches (150 mm) high 17 years after germination have been recorded. However, in good conditions a height growth increment of between 1 to 1½ feet (0·3–0·45 m) per annum is reached in about 6 years. In one thinning trial, regeneration that was 6 years old at the time of thinning showed a height increment of 1·3 feet (0·4 m) per annum and a diameter increment of 0·37 inches (9 mm) per annum for a 7 years' period following thinning to 16 feet (4·9 m) spacing. (Plot 416 Tomanbil State Forest, Forbes.)

6.3. Growth Rates

Henry (1960) presented data for growth of White Cypress Pine stands in Queensland showing that removal of competing weed species and thinning of White Cypress Pine regeneration gave a very marked increase in diameter increment. Thinning of older stands, 30 to 40 feet (9–12 m) in height, to 20 feet (6 m) spacing gave a maximum value increment and near maximum volume increment. Finally, routine silvicultural treatment over extensive areas gave a very good financial return on the cost of thinning.

The Queensland data are comparable with unpublished New South Wales data, which have been derived from experimental plots in commercially important stands in the Baradine area. Historical records indicate that these stands are approximately even-aged and arose between 1880 and 1900. Only scant regeneration occurred between 1900 and 1950 and as a consequence there is little gradation of age classes. For this reason it has not been possible to formulate relationships of stand basal area and stand volumes with age for a range of treatments. Most natural stands are in an overstocked condition and experimental work therefore has been concerned with determining the effect of stand density on growth of these stands and their recuperative ability following differing degrees and estimated durations of suppression.

The growth data available have been derived from two series of plots. The older plot series was established between 1930 and 1940 and demonstrate the long term growth trend of stands following thinning. Changes in stand statistics with time for this series are presented for selected plots in table I. Periodic annual increments for the same plots are given in table II.

TABLE I

PLOT STATISTICS FOR SELECTED THINNING EXPERIMENTS

(a) *Plot* 1502. Jacks Creek State Forest near Narrabri. Thinned to 190 trees per acre

	1930	1940	1950	1960	1967
Diameter (inches)	2·24	4·45	6·18	6·97	7·40
Basal Area (sq ft per acre).. ..	5·6	21·1	40·1	51·2	57·9
Merchantable Volume (cu ft per acre)	..	66	348	605	748
Total Height (feet)	22·4	26·4	31·4	36·7	38·6

(b) *Plot* 1501. Jacks Creek State Forest. Thinned to 232 trees per acre

	1930	1940	1950	1960	1967
Diameter (inches)	2·61	4·63	5·97	6·56	6·89
Basal Area (sq ft per acre) ..	9·5	28·3	46·2	55·8	61·5
Merchantable Volume (cu ft per acre)	2·1	113	391	627	759
Total Height (feet)	22·8	27·4	32·0	36·5	38·3

(c) *Plot* 1601. Yerrinan State Forest near Baradine. Thinned to 88 trees per acre

	1940	1950	1961	1967
Diameter (inches)	4·54	7·30	9·17	9·62
Basal Area (sq ft per acre)	11·7	27·3	41·8	45·2
Merchantable Volume (cu ft per acre) ..	112	368	679	757
Total Height (feet)	33·1	35·5	43·5	44·8

(d) *Plot* 1602. Yerrinan State Forest. Thinned to 254 trees per acre

	1940	1950	1961	1969
Diameter (inches)	4·31	5·85	6·83	7·23
Basal Area (sq ft per acre)	31·3	43·7	71·0	79·0
Merchantable Volume (cu ft per acre) ..	261	573	902	1,123
Total Height (feet)	29·4	32·9	36·2	39·5

TABLE II

INCREMENT DATA FOR SELECTED THINNING EXPERIMENTS OF TABLE I

(a) *Plot* 1502

	1930–40	1940–50	1950–60	1960–67
Diameter (inches)	0·22	0·17	0·08	0·06
Basal Area (sq ft per acre)	1·5	1·9	1·0	0·9
Merchantable Volume (cu ft per acre) ..	6·6	28·1	25·7	20·3
Total Height (feet)	0·40	0·50	0·53	0·27

(b) *Plot* 1501

	1930–40	1940–50	1950–60	1960–67
Diameter (inches)	0·20	0·13	0·06	0·05
Basal Area (sq ft per acre)	1·8	1·7	0·9	0·8
Merchantable Volume (cu ft per acre) ..	11·1	27·7	23·8	18·8
Total Height (feet)	0·46	0·46	0·45	0·36

(c) *Plot* 1601

	1940–50	1950–61	1961–67
Diameter (inches)	0·27	0·17	0·07
Basal Area (sq ft per acre)	1·5	1·3	0·57
Merchantable Volume (cu ft per acre) ..	25·6	28·2	13·9
Total Height (feet)	0·24	0·80	0·20

(d) *Plot* 1602

	1940–50	1950–61	1961–69
Diameter (inches)	0·16	0·09	0·05
Basal Area (sq ft per acre)	2·2	1·5	1·0
Merchantable Volume (cu ft per acre) ..	31·2	29·8	27·6
Total Height (feet)	0·34	0·34	0·33

These growth data are substantiated by preliminary results from a more extensive series of plots which were established between 1964 and 1966. This series also demonstrates that the ability of the commercially important stands to respond to thinning has not been markedly affected by a longer period of suppression.

All available growth data relating to experimental plots in this class of Cypress Pine stand demonstrate that stand density is a most important factor influencing stand growth rate even though other factors such as age and/or tree size must have some influence.

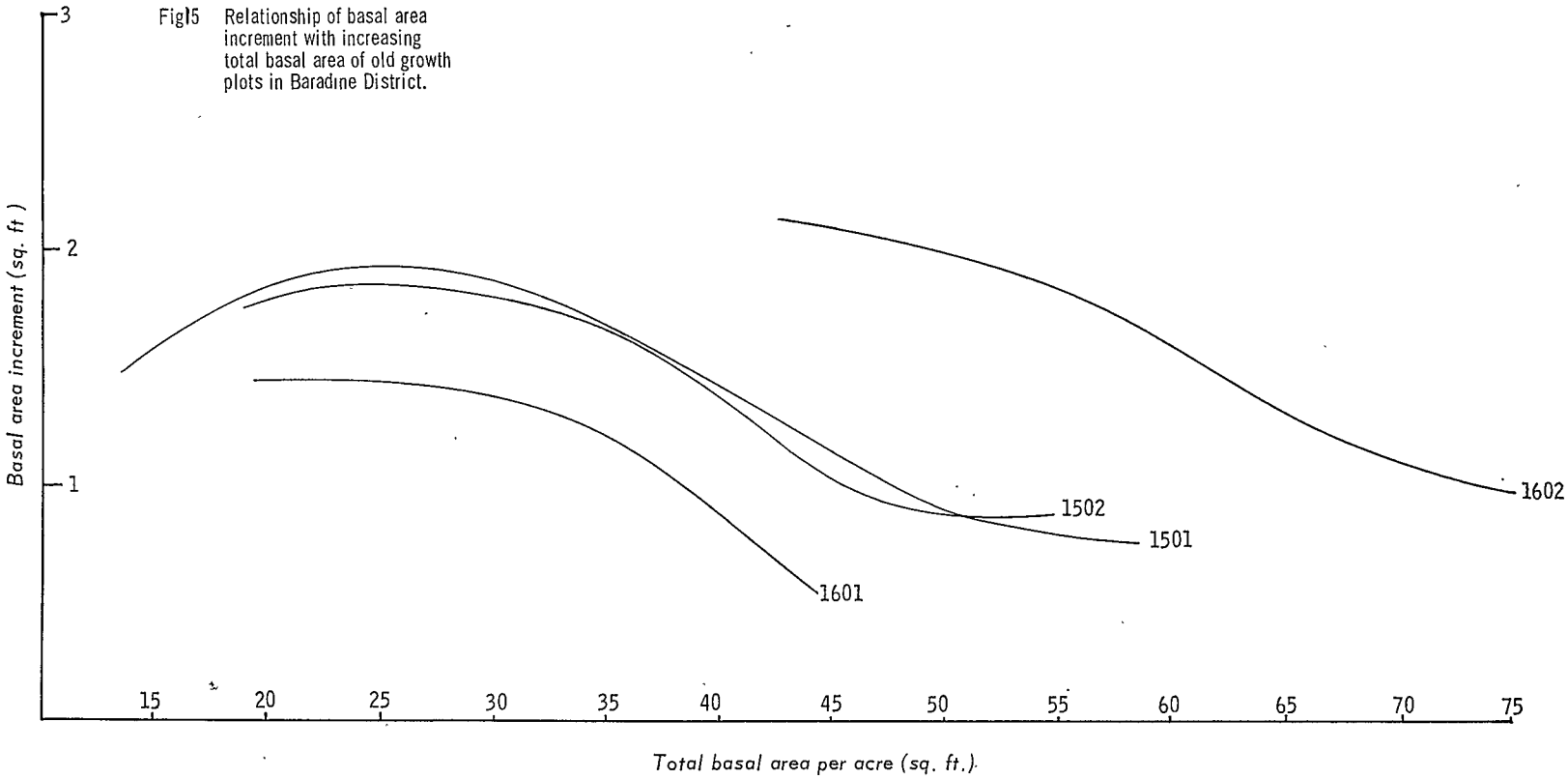
The data of tables I and II show that the magnitude of the diameter increment is dependent on the actual level to which stand density is reduced. In the first 10 years following thinning the periodic annual increment varied from 0·27 inch (7 mm) in the most heavily thinned plot (1601) to 0·16 inch (4 mm) in the most lightly thinned plot (1602). These increments declined to as low as 0·05 inch (1 mm) as stand density increased with time. A severely suppressed plot elsewhere (plot 1701, Merriwindi State Forest near Baradine) has shown a mean annual diameter increment of 0·01 inch (0·3 mm) for a 20-year period.

Merchantable volume increment declines with high stand density, but it is also naturally dependent on the percentage of trees which are of merchantable dimensions. Consequently, in well thinned low average diameter stands merchantable volume increment is initially small although diameter and basal area increment may be at a maximum. In well thinned stands with a wide range of diameter classes, merchantable volume increment may be sustained for a considerable period by recruitment of sub-merchantable stems. However, once all or most stems become merchantable, decline of volume increment accompanies increase in stand density.

Despite the trend towards decline, the data show that annual volume increments of between 20 and 30 cu ft per acre (1·4–2·1 m^3/ha) are possible for the length of a 20-year cutting cycle or longer. Such increments can only be expected from restricted areas of well stocked stands. For extensive areas that have been well treated the data of Henry (1960) are more applicable. Henry showed that an increment of 13·1 cu ft per acre per annum (0·9 m^3/ha/an) was maintained for a 20-year period from a treated area of 1,200 acres (485 ha). In comparison a comparable adjacent untreated area showed only 6·6 cu ft per acre per annum (0·46 m^3/ha/an). In determination of yield from areas designated as Cypress Pine forests for the purpose of forest management, Turner (1968) has estimated that 5·5 cu ft per acre per annum (0·38 m^3/ha/an) could be sustained from 38,500 acres (15,500 ha) and Vidler (1970) has calculated a sustained yield of 3 cu ft per acre per annum (0·21 m^3/ha/an) for 595,000 acres (240,000 ha). Calculation of average yield per acre can vary considerably depending upon what is considered productive Cypress Pine forest and the extent of investment in hardwood removal and thinning programmes.

The initial response of basal growth following thinning and its subsequent decline with increasing stand density, given in tables I and II, is expressed graphically in figure 15 where basal area increment is plotted against total basal area. In the 20 years immediately following thinning, basal area increment was maintained mainly between 1·5 and 2 sq ft per annum (0·35–0·46 m^2/ha) but in the final years of measurement this fell to 1 sq ft (0·23 m^2) or less for all plots. The data also illustrates the effect of variation in spacing and site quality. Plots 1601 and 1602 are continuous plots of the same site quality, but have had different spacing treatments, viz. 88 trees per acre (218/ha) and 254 trees per acre (630/ha)

Fig15 Relationship of basal area increment with increasing total basal area of old growth plots in Baradine District.



respectively. Following thinning, plot 1601 was understocked, the site was not fully occupied, total growth of the residual stand was lower than in 1602 and Cypress Pine regeneration and shrubs became established. Plot 1501 and 1502 are also contiguous plots of the same site quality but the disparity in stocking of these two plots after thinning was not so great, viz. 232 and 190 trees per acre (575 and 470/ha) respectively. Their total growth was very similar and they were similarly affected by minor shrub regeneration. They are of inferior site quality to plots 1601 and 1602, but their stocking levels have enabled them both to fully occupy the site and attain superior total growth to plot 1601.

Height growth of older Cypress Pine stands is less responsive to thinning than other growth characters, and in young well thinned stands which have rapid diameter increment this may lead to sharp taper of the bole and an undesirable log shape for utilization. In the older stands, represented by the plots above, height growth has averaged approximately 0·5 ft (0·15 m) a year since thinning. In thinned regeneration stands less than 20 years old height growth is commonly over 1 foot (0·3 m) a year.

There is very little mortality in overstocked Cypress Pine stands. Consequently, the decline in increment with increasing stand density is due to a decline in total increment and is not simply due to lower nett increment (total increment minus mortality), as with species which are more disposed towards self thinning. Mortality is most marked when increment is reduced to a minimum, or in other words when the maximum stand density is attained. In terms of basal area, current annual increment can be considered minimal for average site quality and average seasonal conditions when it is less than 0·7 sq ft per acre (0·16 m^2/ha) per annum. Maximum stand density for average site quality is about 85 sq ft per acre (20 m^2/ha).

6.4. Site Quality Determination

Site quality can only be described in broad qualitative terms and requires further research. Site height is of limited value for assessing site quality since there are only restricted areas where mature free grown trees or immature free grown trees of known age can be found. Total basal area has greater application, but is confined to situations where overstocked stands are present and significant mortality indicates that maximum basal area has been attained.

Maximum growth rate of Cypress Pine in New South Wales is found on soils which have good moisture availability but are nevertheless well drained. These are mostly deep sandy sites which, due to particular drainage features, have moisture always present at depth. Conversely, the poorest development is found on drier sites, such as ridge tops or shallow soils, as well as on the other extreme of sites which are poorly drained because of heavy soil texture or topographical impediments. Soil fertility appears to be of much lesser importance in determination of site quality. Very low levels of the macronutrients are often encountered on areas of high site quality, especially the deep sands. There is an approximate relationship between species associations with site quality, but species associations will only achieve real usefulness as indicators of site quality when modified by the soil characteristics mentioned. As yet, this has not been seriously attempted.

6.5. Life Span

Mature trees of Cypress Pine on reasonable sites will attain 60 feet (18 m) in height and 1·5 feet (45 cm) in diameter. In the Baradine area the largest tree known is now dead and measured 93 feet (23 m) in height and 2 feet 2 inches (69 cm) in diameter. Individuals elsewhere have been recorded over 100 feet (30 m) high and 3 feet (90 cm) in diameter (Baker and Smith, 1910). Using ring counts as a rough guide and feasible diameter increments, such veterans could be about 200 years old.

7. SPECIAL SILVICULTURAL FEATURES

The production of epicormic shoots (figure 16) is the principal means of defence of White Cypress Pine against defoliation by fire, grazing, hail, wind and insects. The epicormic buds are contained within the smooth living bark of Cypress Pine and do not arise from parts of the tree that have a covering of rough dead bark. Hence the survival of injured trees is dependent upon the health and extent of smooth bark. In mature trees the smooth bark is confined to the finer branches and the top few feet of the mainstem but, in young regeneration of up to 1 inch (2·5 cm) in diameter at breast height, all branches and the mainstem are covered. Thinning of young smooth barked regeneration results in production of epicormic shoots (figure 17) from a proportion of the stem stumps, enabling their survival. However, some stumps, even though they have ample smooth bark, do not produce epicormic shoots and are consequently killed when the mainstem is severed. The proportion of survivors is undoubtedly strongly influenced by environmental conditions.

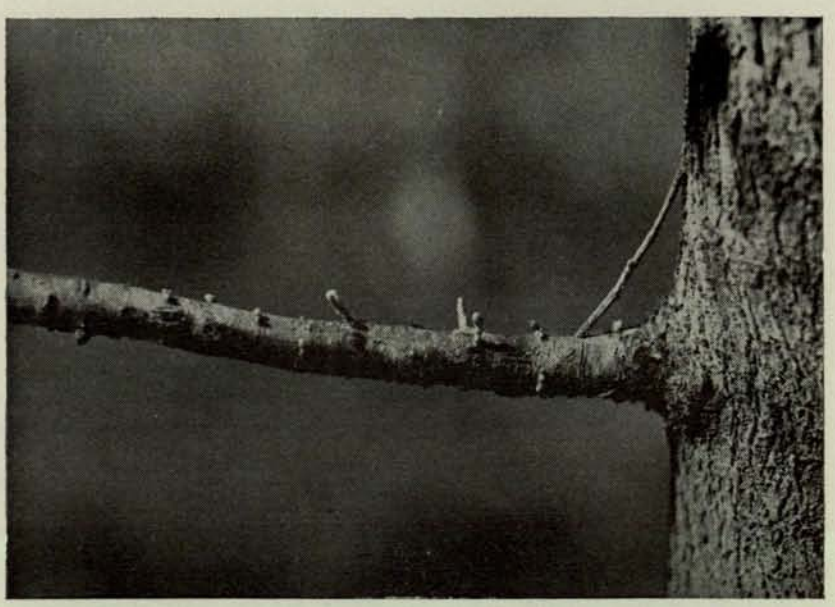


Figure 16. Foliage development of White Cypress Pine from epicormic buds in the smooth bark of the branch

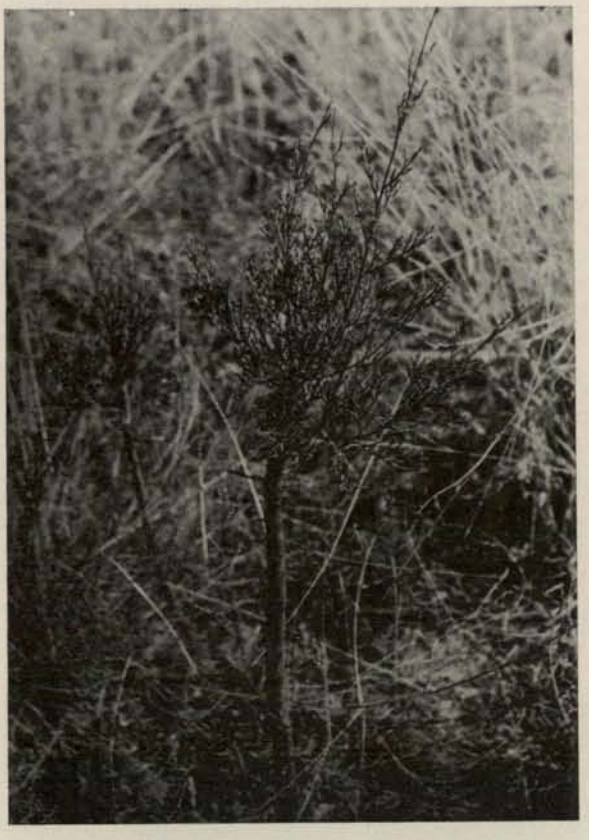


Figure 17. Foliage development from epicormic buds in the smooth bark of a small diameter stump

The production of sandarac resin which exudes from cracks in the bark during prolonged periods of moisture stress and from the inner bark following mechanical damage is another defence mechanism of the species.

8. DAMAGE AGENCIES

8.1. Diseases

The most serious defect of White Cypress Pine is caused by the fungus, *Fomes robustus* Karst, which causes a yellow heart rot. *Fomes robustus* is common on a wide range of hosts in most countries of the world and most States of Australia. Its hosts are commonly hardwood species and rarely softwoods (Walters, pers. comm.). Of the species occurring with or in the same region as Cypress Pine, sporophores of *F. robustus* have been collected from Ironbarks (*E. melanophloia* and *E. crebra*), Red Gums (*E. blakelyi* and *E. camaldulensis*), Bimble Box (*E. populnea*) and, most commonly of all, the Bull Oak (*Casuarina leuhmannii*).

In comparison to their frequent occurrence on Bull Oak, sporophores are rarely found on Cypress Pine. Sporophores are generally found on living trees near ground level in the manner illustrated by figure 18. However, they may be found at higher levels, especially on dead trees. In most instances the wood behind the sporophore is decayed, but it has been observed where only the bark is decayed and this is associated with decayed wood below ground level. *Fomes robustus* is a root rot and spreads most commonly by root contact. In the absence of sporophores there is no practical way of determining whether decay is present and, as a further result of the method of spread, the yellow rot is more often associated with the butt end of the log. However, the whole length of a log may be attacked. Instances have been recorded where the top only has been attacked and on these occasions it appears that fungal infection has occurred through broken branches. *Fomes robustus* causes a stringy rot which appears lamellate as a result of decayed wood occurring in tangential strips (figure 19). The rotted wood has a spongy texture and though it is referred to as "yellow rot" it may occasionally be chocolate coloured.

Figure 18. Sporophore of Fomes robustus **Karst on White Cypress Pine**

Figure 19. Lamellate heartwood decay ("yellow rot") of White Cypress Pine caused by Fomes robustus

The incidence of decay tends to increase with increasing tree size, but young trees are not necessarily immune. Decay of trees less than 20 years old and with diameters of less than 4 inches (10 cm) at breast height has been recorded. (Turner, pers. comm.).

Another unidentified fungus which attacks White Cypress Pine causes a brown butt rot. No sporophores have been recorded for this species. The rot can be distinguished from yellow rot by the cubical or blocky appearance formed by radial as well as tangential cracking of the decayed wood (figure 20). The decayed wood is also dry and powdery when crushed, rather than spongy. The defective part of the log is usually not extensive and can be satisfactorily butted prior to transport to the mill. Occasionally both yellow and brown rot are encountered in the same log.

Figure 20. Brown cubical rot ("brown rot") of the heartwood of White Cypress Pine

No extensive survey has been carried out on the heart rots of Cypress Pine so that it is possible that a number of other organisms may be involved, though less commonly, with standing defect. Notwithstanding this possibility, White Cypress Pine trees are generally highly resistant to heart rots.

Fungi which are commonly found attacking the sapwood of dead standing timber are Gloeophyllum abietinum (figure 21), causing a brown cubical rot (figure 22), and *Pycnosporus sanguineus* which has a bright red sporophore and produces a white stringy rot.

Figure 21. Sporophores of Gloeophyllum abietinum **on fire-killed White Cypress Pine. The vertical columns of sporophores follow radial cracks in the sapwood**

Figure 22. Brown cubical rot of the sapwood of White Cypress Pine, caused by Gloeophyllum abietinum

8.2. **Insects**

Froggatt (1923) provides general information on a number of insects attacking White Cypress Pine. Several of the insects mentioned by Froggatt are seldom encountered. These are the mealy bug (*Llaveia callitris* Frogg.) and the lac insect (*Tachardia decorella* Maskell).

The most important insects are the Cypress Pine sawfly (*Zenarge turneri rabus* Moore), the Cypress Pine jewel beetle (*Diadoxus erythrurus* White) and the Cypress Pine aphid (*Cinara tujafilina* del Guer).

8.21. *The Cypress Pine Sawfly*

The taxonomy of the Cypress Pine sawfly has been investigated by Moore (1962a and 1963). Moore found that the sawfly consisted of two subspecies. One subspecies, *Zenarge turneri turneri* Rohwer, causes damage to various *Cupressus* and *Callitris* species but not to White Cypress Pine and hence is not considered further here. *Z. t. rabus* is specific to White Cypress Pine and Moore (1962b) has examined its biology and the damage caused by large populations.

The insect, in the larval stage, attacks the foliage of Cypress Pine and in severe instances may cause complete defoliation. Moore found that heavy sawfly attack occurring periodically during spring, summer and autumn was correlated with below average temperature and above average rainfall. Regeneration was preferred to older trees, and attack was more prevalent on poorly drained areas and other areas of low site quality. Sawfly does not appear to cause tree deaths, but it may lead to death by predisposing the tree to attack by the jewel beetle. It is of little economic importance as damage has been confined to southern forests and it has been notably absent from the extensive tracts of Cypress Pine forest around Baradine. Even in the southern part of the State its presence in plague proportions has not been noted for the last 15 years.

8.22. *The Cypress Pine Jewel Beetle*

This insect causes timber damage which is commonly referred to as "grub holes". The larvae feed in the conductive tissues of trunks and branches of *Callitris* and *Cupressus* species, and occasionally may cause the deaths of trees when feeding tunnels girdle the trees. Hadlington and Gardner (1959) found that *Diadoxus* does not require predisposing conditions in order to attack introduced *Cupressus* species, but does require such conditions for infestation of native *Callitris* spp. Native trees attacked have commonly suffered fire or mechanical damage, injury from defoliating insects such as sawfly or aphids, or the debilitating effects of drought.

8.23. *The Cypress Pine Aphid*

Aphids (*Cinara tujafilina* del Guer) occur briefly for about a month at periodic intervals in the spring. They puncture the thin smooth bark of the outer branchlets and the resulting resin flow may be so profuse that the crowns glisten and resin drops are scattered beneath the trees. A sooty mould is associated with the bark punctures but appears to have little parasitic ability (Hartigan and Taylor, 1949). There is little evidence that aphids can seriously damage Cypress Pine though death of foliage tips has been recorded following aphid attack. Hawkins (1966) also recorded that the seed crop was affected.

8.24. *Seed Destroying Insects*

Destruction of Cypress Pine seed appears to be brought about by several species of wasps. The insect principally associated with seed destruction is an *Epimegastigmus* sp. and is highly specialized, occurring as a single larva within the seed. The contents are destroyed by the larva and following pupation the adult insect makes a small exit hole in the apical end of the seed at the time of seed shed or shortly afterwards, so that only an empty shell remains (figure 23). The seeds attacked by these insects are not visually distinguishable from sound seed until the exit hole is produced.

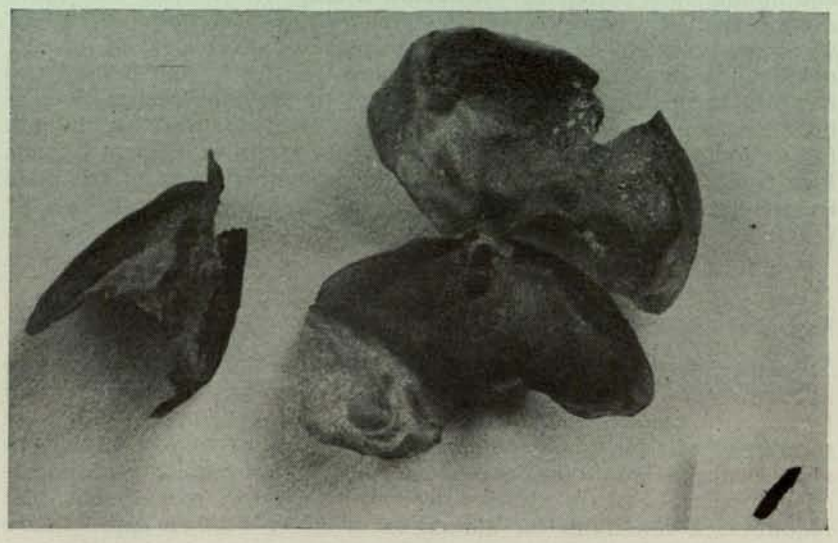


Figure 23. Damaged seeds of White Cypress Pine, associated with Epimegastigmus **sp. and showing the apical exit holes**

Another wasp occurs less frequently within cones and destroys their contents so that little residue of the seed remains. These cones are further recognizable by a light-brown resinous appearance and spiky serrations of the inner walls of the cone scales.

8.25. *Gall Forming Insects*

A variety of small galls are induced by insects on the branchlets of Cypress Pine (figures 24–26). They are commonly formed terminally and cause little if any disruption to growth. There is usually only a single larva in each gall, but these may be parasitised by other insects. The most common gall is formed by the insect *Diplosis frenelae* Skuse (figure 24).

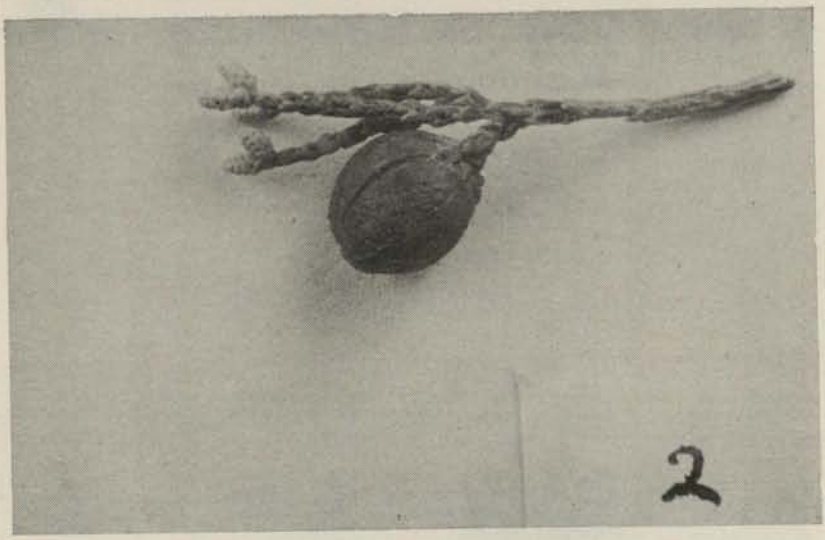


Figure 24. Round terminal gall formed by the cicidomyid fly, Diplosis frenelae **Skuse**

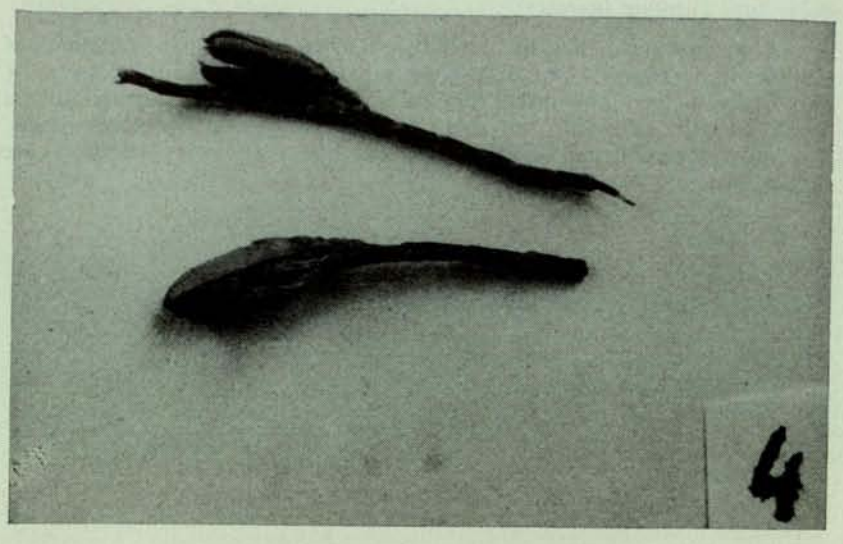


Figure 25. Galls formed on White Cypress Pine

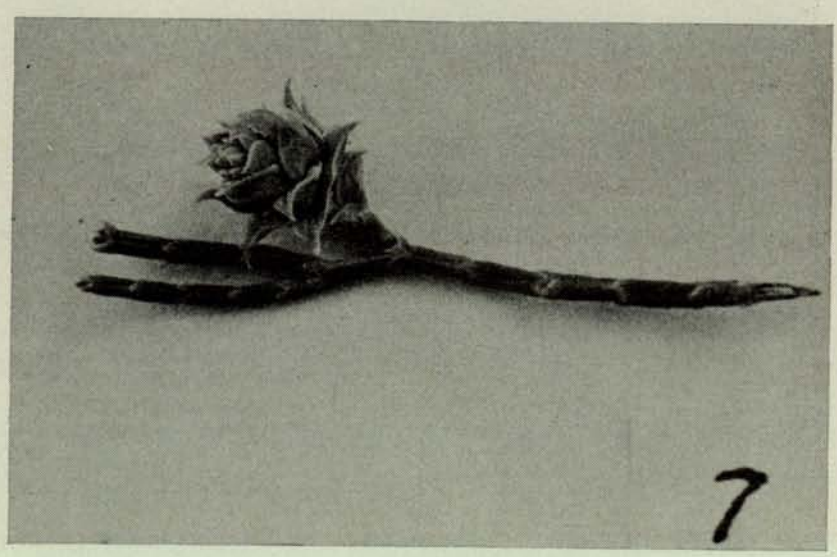


Figure 26. Galls formed on White Cypress Pine

8.3. **Other Pests**

The seed crop of White Cypress Pine may be attacked by white cockatoos (*Kakatoe galerita*) and galahs (*K. roseicappila*). The damage is usually not widespread and is of little significance to management of the species. Of more importance is the browsing damage to regeneration by rabbits, sheep and cattle. Rabbits were principally responsible for the absence of regeneration in the first half of the century. By the early 1900's their invasion of western areas was complete and no widespread regeneration occurred until their control by the myxomatosis virus in the 1950's. Rabbit damage can take the form of repeated browsing of the foliage before seedlings have developed immunity by virtue of their height, and they may also kill young trees out of browse height by removing the bark from the stems and so ringbarking them. Ringbarking damage is most common during drought periods. Sheep will also effectively preclude regeneration from becoming established. Cattle are not so severe on the pastures and do less browsing damage, but likewise have to be excluded to enable satisfactory establishment of regeneration.

Little is known on the effect of various native animals on regeneration, other than that their browsing has apparently never been sufficiently intense to prevent regeneration.

8.4. **Parasitic Plants**

The mistletoe *Muellarina bidwillii* (figure 27) is a common parasite of White Cypress Pine. Trees with extensive growths of this parasite are commonly in a poor state of health.

Figure 27. The mistletoe, Muellarina bidwillii, **on a smooth branch of White Cypress Pine**

8.5. Fire

As mentioned previously, Cypress Pine in the absence of regular burning tends to form dense stands. These are characterized by low quantities of ground fuel which will not carry a severe fire and hence such stands tend not to be subject to extensive fire damage.

Cypress Pine is most prone to fire damage when it occurs as scattered regeneration and is surrounded by grass cover. At this stage even quite mild fires may result in its death (figure 28). To some extent stands of regeneration remain sensitive to fire even after the site is fully occupied and the characteristic clean floor is produced. The degree of damage depends upon the height of the crown and the intensity of approaching bushfires outside the stand. Crown flaring of dense regeneration occurs on the edge of the stands in contact with the fire, but mostly the pattern is that a proportion of these stems recover and the stems within the stand are unaffected. In open stands with abundant ground cover even quite mature Cypress Pine will be vulnerable to fire and such stands may be completely devastated. Under mild burns foliage of Cypress Pine crowns may be completely destroyed but, provided the heat has not been intense enough to kill the smooth barked branches, the crowns will be reformed from epicormic buds and the trees will survive. This is a common development of trees in wheat paddocks which may experience stubble burns at regular intervals. Stubble burns may produce intense heat but this is usually of short duration. Apart from the most dramatic effects of fire in causing death in Cypress Pine stands, general vigour may be substantially reduced.

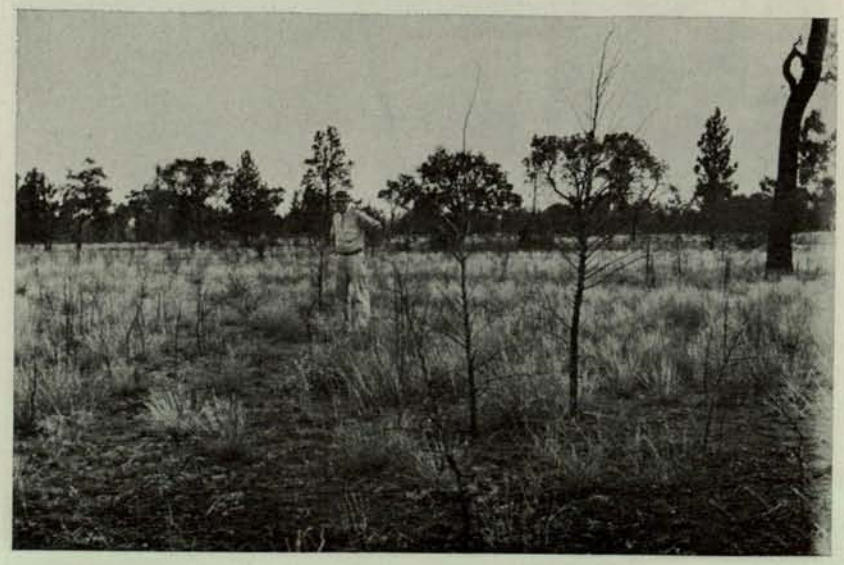


Figure 28. Destruction by mild fire of scattered Cypress Pine regeneration, occurring with Wire Grass (Stipa sp.). Older trees in background are unaffected

No data is available for determining loss of timber productivity under burns of various intensities, but Hawkins (1966) has shown that the seed supply is disrupted for 5 years and possibly longer in moderately burnt stands.

8.6. **Climatic Effects**

The climatic effects which are most damaging to Cypress Pine are, in order of severity, drought, wind and hail.

The critical influence of soil moisture on Cypress Pine seedlings in the germination and establishment phase has been referred to previously, but periodically soil moisture declines to levels which also effect the vigour of well established and mature trees. This drought effect is not uncommon and increases in frequency towards the western and lower rainfall limits of the natural range of Cypress Pine. On occasions, perhaps two or three times a century, drought may be sufficiently severe to result in widespread deaths.

The drought of 1901–02 and of 1965 illustrated this development. In the recent 1965 drought many native species were affected and deaths commonly occurred of those species growing on rocky sites or soils of low moisture holding capacity, such as shallow soils or certain very deep sandy sites. Cypress Pine was most severely affected in such situations and also where there was intense competition such as in dense older stands or dense stands of regeneration with scattered seed trees.

In regeneration areas deaths occurred in small patches of up to one-tenth of an acre (400 m^2) and some of the old mature seed trees also succumbed. In thinned stands of good site quality the effects of drought were not apparent.

Individual trees that were visibly affected first showed signs of moisture stress by development of a sparse crown, drying out and cracking of the bark of the smaller twigs and finally dessication of parts of the bole bark and wood, resulting in conspicuous splitting and checking. These extreme symptoms were usually, but not invariably, accompanied by the destruction of the cambium and death of the tree. Following the return of favourable moisture conditions, even severely affected pine rapidly recovered.

Windstorms may result in varying degrees of damage. In severe storms extensive damage from windthrow and stem breakage can result in almost complete destruction of stands in localized areas. A less spectacular effect of wind is to cause windchecks in the wood. This is a serious form of degrade and is often not apparent until the tree is converted to sawn timber.

Hailstorms can strip the foliage from Cypress Pine crowns. However, crown recovery from epicormic buds is usually rapid.

9. UTILIZATION

9.1. Timber Properties

The timber of White Cypress Pine is light-brown in colour with dark-brown longitudinal streaks; it has a characteristic resinous odour and is somewhat greasy. The grain is usually straight except around knots, which are prevalent. Wood density ranges from 35 to 50 lb per cu ft (560–800 kg/m^3), with an average of 43 lb per cu ft (690 kg/m^3) at 12 per cent moisture content.

The heartwood has considerable resistance to decay and insect attack due to the presence of quantities of resin, and also of guaiol and callitrol, and is rated as durability Class 1. The definition of this class is that it contains "timbers of the highest natural durability" which may be expected to resist both decay and termite attack for at least 25 years and sometimes 50 years when in ground contact (Anon., 1965). In addition to its durability in the ground it is very resistant to attack by the marine borers *Teredo* and *Limnoria*. Saunders and Hall (1967) tested ninety-five species of timber from different countries for their durability in a marine environment and found that White Cypress Pine was one of the six most durable of all species and one of the four most durable of the commercially available species. After 6 years' immersion White Cypress Pine showed no sign of borer attack whereas, in comparison, all other Australian species showed some damage. Turpentine (*Syncarpia glomulifera*), Brush Box (*Tristania conferta*) and Jarrah (*Eucalyptus marginata*), which have been considered suitable for marine piling, all showed some susceptibility to *Limnoria*.

Rudman (1963, 1964) has investigated the variation in resistance within and between trees to decay and termite damage, as well as the factors influencing this resistance. These factors include growth rate and the nature of the heartwood extractives. Rudman (1966) also compared the resistance of the heartwood and sapwood of several species of *Callitris* to attack by the brown rot fungus *Coniophora olivacea* and found that the heartwoods of White Cypress Pine, *C. columellaris* and *C. intratropica* were highly resistant, whereas those of other species such as *C. endlicheri* and *C. rhomboidea* were only moderately resistant.

Cypress Pine is comparable in strength properties to imported softwoods and is placed in strength group S6. In seasoning from the green condition to 12 per cent moisture content, its average shrinkage is approximately 2·8 per cent tangentially and 2·1 per cent radially. As a result of this low shrinkage it has often been used in a near green condition. Harrison (1969) has noted the undesirable features of this practice in construction of floors and has given guidelines for air drying the timber from the green in flooring sizes.

9.2. Timber Defects

Only a limited amount of clear wood is formed in Cypress Pine trees and the presence of knots is a characteristic feature of the sawn timber. When defect occurs it is most commonly associated with knots. Numerous large knots, such as occur in open grown trees, may seriously reduce timber strength properties. Loosely held knots, which fall out of board and flooring timber, are both aesthetically and structurally undesirable. Checking of the timber during drying and shearing of the grain during machining are also commonly associated with the presence of knots.

The timber is fissile, and radial cracks quickly develop as the moisture content decreases in trees that are killed. The splitting of timber as a result of windshake in the tree is a serious defect and may lead to substantial timber loss in localized areas. The timber also has a tendency to split during nailing, but this defect can be minimized by using pointless nails. Other common defects of Cypress Pine are resin pockets, bark pockets and overgrowths, bow and spring, twist and spiral grain. Allowable tolerances for such defects in various sawn products are defined in S.A.A. 091 to 095 (1964).

9.3. Availability and Uses

The timber is freely available in New South Wales and Queensland. In recent years (1963 to 1969) in New South Wales, Cypress Pine comprised approximately 9 per cent of the total timber volume extracted from State Forest and other Crown land. In 1970–71 the total production of Cypress Pine sawlogs in N.S.W. was 50 million super feet (150,000 m^3), of which 33 million super feet (100,000 m^3) came from State Forests and other Crown lands. (Annual Reports, N.S.W. Forestry Commission.) The timber is used in house construction for framework, flooring and panelling and, as a result of its particularly high durability, has been extensively utilized for transmission poles, fence posts and general farm construction such as stockyards and sheds. The major use in metropolitan markets has been for flooring.

9.4. Other Products

White Cypress Pine is used extensively for inland plantings of woodlots, avenues and windbreaks because of its timber value, its general adaptability to lighter textured soils, its drought resistance and its beautiful appearance.

Cypress Pine has also provided a useful supply of resin that has been collected from the inner bark of cut stumps following logging. General information on this subject is provided by Howes (1950). The resin from White Cypress Pine, as well as that from *C. endlicheri* and *C. intratropica*, is similar to the sandarac resin of commerce which is produced from the related species, *Tetraclinis articulata* Mast., found mainly in northwest Africa (Morocco) and to a minor extent in Spain and Malta. The resin of *C. columellaris*, which has a limited distribution along the coast of New South Wales and Queensland, is reputed to be even closer in chemical composition (Baker and Smith, 1910). Sandarac resin is used for the preparation of varnishes for special uses, such as pill coatings in the pharmaceutical industry and for the manufacture of artists' varnishes, and is also used for the manufacture of incense. There is only a limited market for the resin and about four tons are collected annually. All of this is from White Cypress Pine in New South Wales. The resin is completely soluble in ethyl alcohol or ether and aspects of its chemistry have been investigated by Baker and Smith (1910), Carman and Deeth (1967), Chuah and Ward (1968) and Hegnauer (1962).

White Cypress Pine bark gives a high yield of tannin, though barks of other *Callitris* species give even higher yields. Baker and Smith (1910) found between 10 and 14 per cent tannin in the air dried bark of White Cypress Pine, but approximately 30 per cent in the bark of *C. columellaris* and *C. endlicheri*. However, to date none of the tannins of Cypress Pine have been commercially utilized.

10. REVIEW OF SILVICULTURAL TECHNIQUES

Cypress Pine forests can be managed on either an even-aged or uneven-aged basis. Most forests have an approximately even-aged structure as a result of the past pattern of regeneration occurrence. That is, regeneration has become widely established at periodic intervals with isolated occurrences in the intervening periods. This stand structure should be perpetuated because of the many management advantages of even-aged forests.

The main aims of silvicultural treatment are to stimulate individual tree vigour, to produce maximum merchantable volume of good quality timber, and to provide regeneration in suitable quantities. Silviculturally these aims can be achieved by maintaining stand density within certain limits. This involves removal of hardwood competition, thinning of regeneration stands and dense unmerchantable pine stands, and reasonably frequent logging of merchantable stands.

Removal of hardwood competition can be accomplished by stem injection or spray application to frills of the various herbicide formulations of 2,4,5T and picloram compounds. Thinning of older, submerchantable Cypress Pine stands and Cypress Pine regeneration is carried out on a spacing basis, rather than on basal area. This results in thinning to variable and often quite low basal areas, but avoids the necessity for a second submerchantable thinning. For practical purposes 20 feet (6 m) spacing has been adopted, as this ensures that on most sites all trees will become merchantable at an average diameter of 9 inches (23 cm) breast height, before diameter growth declines to very low levels due to high stand density.

However, following thinning the site may not be fully occupied for some years and weed species and unwanted regeneration may become established. In certain forests containing good forage, and notably those in southern New South Wales, grazing can be used to prevent regeneration establishment until it is required. In areas where grazing is not possible, regeneration can only be precluded by maintaining the stands at reasonable basal area levels. In well treated merchantable stands the spacings adopted result in the basal area being maintained within the limits of 30 to 60 sq ft per acre (7–14 m^2/ha). On most sites this serves to restrict regeneration while allowing satisfactory growth of the crop trees, but regeneration may develop under higher basal areas on high site quality areas. Specification of ideal spacings and basal area levels at which particular Cypress Pine stands should be maintained for maximum growth can be only approximate. The ideal level of basal area for a particular stand is dependent upon the stand age, mean diameter, history of suppression and site quality. Except for regeneration stands, stand age and history are unknown and although differences in site quality are often recognizable on subjective criteria, being related to soil type, further detailed work is required to formulate a site index for Cypress Pine.

The use of fire as a silvicultural or management tool has limited application in Cypress Pine forests. The two possible uses of fire are for hazard reduction (controlled burning) and for removal of unwanted regeneration. Whether these uses are feasible is determined largely by the influence of Cypress Pine stand density on fire behaviour. In dense stands of all descriptions, including regeneration, controlled burning for hazard reduction will neither be necessary nor possible because the small quantities of litter and ground cover fuel in such stands precludes fire development. In low density stands, scattered regeneration may comprise an important component, especially if the crop trees are approaching rotation age. In these stands, even comparatively mild fires may result in regeneration destruction so that complete protection is required.

The possibility remains of using controlled burning in open stands for removal of unwanted regeneration or for hazard reduction where there are no regeneration requirements. However, considerably greater knowledge of fire behaviour is essential before a decision can be made as to whether fire can be employed for these purposes. Furthermore, most Cypress Pine forest areas have regeneration requirements changing within short distances. Therefore, broad scale control burning will not be possible.

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