PN-AAL-088

# CASUARINAS

"the best firewood in the world"

Resources for charcoal, construction poles, windbreaks and shelter-belts and soil erosion and sand dune stabilization.

TECHNICAL SERIES #10
COMPILED BY:
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Washington, D.C. 20523

INFORMATION MEMORANDUM

SUBJECT: Casuarina Species*

Casuarina are a group of 80 or so shrubs and trees, native to the Southern Hemisphere, notably to Australia. There are some 35 tree-type Casuarina species of which eighteen seem to have the most promise. Of these, Casuarina equisetifolia has been the most widely planted.

The casuarinas produce high quality fuelwood and charcoal and the wood is easily split and has a low ash content. Casuarina wood burns with great heat and has been called, "the best firewood in the world." It burns readily, even when green, and makes exceptionally fine charcoal. The wood is very dense, but it splits and warps and is not useful for lumber or furniture. However, casuarina poles and beams are used for construction they are notably strong and resistant to decay.

Casuarinas grow rapidly. In parts of the Philippines, Casuarina equisetifolia has been known to outgrow Leucaena leucocephala and Gmelina arborea. In India Casuarina equisetifolia has been measured as growing 3 m a year for saplings and 25 year old trees may reach 30 m in height. Rotations as short as 7 years are being used in firewood plantations. Some of the species resprout vigorously when cut and they can be managed under coppice rotations.

These resilient trees also have value for reclaiming land such as sand dunes, eroding hillslopes, and marshy soils periodically inundated by fresh or ever brackish water. The living trees are used for windbreaks and shelterbelts; the form of their foliage makes them excellent for this, and most species are windfirm and often retain branches to ground level. They can make useful shade trees. Most make poor forage sources, but Australian farmers use them extensively in times of extreme drought as an emergency animal feed. Newly planted seedlings are subject to damage by browsing livestock.

Individual species tolerate a wide range of extremely harsh habitats, from rainforest to the driest country, from the seashore to the tops of high mountains, and from cool temperate regions to the hot, humid tropics. They have modest site requirements and are rapid-growing, carefree trees. They tend to be salt tolerant, wind resistant, and adaptable to moderately poor soils.

Casuarinas are tolerant of a wide range of soil types, including some of the most inhospitable. They have the basic physiology for survival in diverse situations, often serving as pioneers for revegetating poor sites. They grow on soils of low fertility, some thriving on light soils, others on heavy soils. In inland India, for instance, casuarina is found on lateritic soils. In Uruguay, Brazil, Senegal, and elsewhere Casuarina equisetifolia thrives in very deep sandy soils. In Hawaii volcanic sites have been reclaimed by

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*A major portion of the information in this memo was extracted from a upcoming National Academy of Sciences publication, Casuarinas: Tree Resources for the Future.

Casuarina equisetifolia; the trees grow well in the sterile pumice. At a lime-grinding factory southwest of Cairo, Egypt casuarinas grow right in the lime, where no other tree survives. In Kenya Casuarina equisetifolia grows well around a cement works. The trees seem good candidates for such polluted areas. In Agrentina casuarina has been observed colonizing abandoned land that is bare limestone.

Some casuarinas are salt tolerant. Close to Bangkok, Thailand there are commercial plantings of Casuarina junghuhniana in salt marsh areas sometimes inundated with saline water. Casuarina fraserana is the only tree to grow in the salt-lands of the wheat belt of Western Australia. Casuarina glauca grows natively on estuarine plains of Queensland that are sometimes flooded with brackish, tidal water. And Casuarina equisetifolia thrives at the seaside--often directly in the path of salt spray from the ocean.

The tree also have great tolerance to heat. For example, Casuarina decaiseneana is almost the only tree to grow in parts of the control Australia where daily temperatures may reach 47 degrees C.

To propagate most Casuarinas, even under primitive conditions, is easy. Seeds are usually set in abundance, they store well and germinate readily. Seed sources for Casuarina species are listed in S&T/FNR's compilation, Technical Series No. 1, Selected Tree Seed Sources in Australia, India, Holland and the United States. It is necessary to have both male and female trees present to obtain fertile seed production. The propagation of trees from root suckers may result in plantings of trees of one gender which would not produce viable seed.

The plants have fair resistance to pests and suffer no major diseases, and with their hardy nature, they need little care. However, it is extremely important to ensure that seedlings are inoculated with Frankia. A commercial source of Frankia is not available, and generally plants are inoculated by chopping up the fine roots of a well established casuarina tree and mixing this with the potting soil (see enclosed papers).**

The casuarina's outstanding ability to grow vigorously on poor soils is largely due to their unusual symbiosis with a microbe that enables them to use nitrogen directly from the atmosphere. Only a few plants, other than legumes, can convert nitrogen gas from the atmosphere into a form they can use. Casuarinas are a group of non-legumes that can, and the amounts of nitrogen they "fix" is at least as much as legumes.

When infected with a special bacterium, called Frankia, fine casuarina roots change shape and size, and branch out repeatedly. They become large masses that may cover several square meters of ground beneath the trees. These woody nodules are perennial and contain the Frankia in the root tissue. The "nitrogen fixation" can be so extensive that the casuarinas are able to grow vigorously on soils would be too poor to sustain most other plants. In sand dunes in the Cape Verde Islands nitrogen in the soil around casuarinas has increased anually at rates up to 300 kg per ha.

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**Persons with expertise on Frankia and casuarinas are: Dr. John Torrey, Harvard Forest, Petersham, Mass., and Tomas F. Geary, U.S. Forest Service, presently at Southeastern Forest Experiment Station, Lehigh Acres, Fla.

Actually casuarina roots have symbioses with four types of organisms. Bacteria of the genus Frankia that fix nitrogen help the trees grow in nitrogen-deficient soil is only one. In addition, two forms of mycorrhizal fungi--one which remains on the root surface the other which invades the root cells--facilitate the uptake of minerals, notably phosphorus, and perhaps also water. Furthermore, an unidentified fungus produces dense mats of "proteoid roots" whose large surface area and inherent efficiency also helps solubilize phosphorus and other vital minerals. Experiments have shown that proteoid roots can double the growth of casuarinas in soils that are very low in phosphorus (for further information on mycorrhizae see S&T/FNR Tech. Series No. 4, The Comparative Advantages, Disadvantages of Root Trainers, Dibble Tubes, Plastic Bags and Bare-rooting).

Like many plants, casuarinas can become weedy. Some species are agressive, especially in fragile ecosystems. Root suckering of some species can become a problem around buildings, sidewalks and adjacent agricultural fields, however, this trait can be advantageous in highly erosive areas and in fuelwood plantations.

Casuarinas have other limitations as well. Some species are sensitive to fire (such as Casuarina equisetifolia). It has been reported that casuarinas suffered a high incidence of blow down due to strong winds (hurricane force), however, this may have been the result of improper nursery practices (see S&T/FNR Tech. Series no. 4, Ibid.) and many other trees suffered similar damage in the same storms. The leaves of casuarinas are often rich in selenium, silica and salt. This makes the copious leaf litter under casuarinas toxic to many plants. It is thought that on some sites the thick litter under the trees may contribute to acidification (which could prove advantageous on highly alkaline sites) or salinization of the soil and casuarinas are generally not good companion crops because of this allelopathy. In both these cases the effects are probably similar to those of pine trees. However, in New Guinea, casuarinas are planted in abandoned slash-and-burn agricultural areas as a fallow-cover crop to enrich the soil. After a few years rest, the trees are harvested and the fields are again planted to agricultural crops.

During the past century most casuarinas have been largely neglected whereas Australian Eucalyptus species have become established forest resources in many of the world's warm, dry regions. But casuarinas warrant increased recognition for their qualities.

I am including in this compilation some papers relevant to casuarinas and I will ensure that the N.A.S. publication on Casuarinas, which is presently in press, is sent to the field as soon as it is available. Seed sources and nursery techniques can be found in the two S&T/FNR Technical Series compilations mentioned in the text of this memorandum.

Mike

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July 21, 1982

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# Section I

# NOTES ON FIFTEEN AUSTRALIAN CASUARINA SPECIES


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J.C. Doran
and N. Hall

PREPARED FOR THE
CASUARINA WORKSHOP
CANBERRA AUGUST 1981

# NOTES ON FIFTEEN

# AUSTRALIAN CASUARINA SPECIES

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## ABSTRACT

*Notes are provided for fifteen Australian* Casuarina *species and subspecies with value or potential for planting. The two-page description of each species includes a map of geographical distribution and photographs showing tree, habit, "cone" and usually bark. The accompanying text gives information on size and form, botanical features, geographical occurrence, climate, topography, soils, vegetation types and utilization. The main characteristics and uses of each species are tabulated.*

## CONTENTS

## INTRODUCTION

The genus *Casuarina* (as distinct from the recently described genus *Gymnostoma*) consists of about ~~fifty-six~~ 99 species and most of these occur in Australia. Individual species range in size from bushes less than one metre high to forest trees some 20–30 m tall. Casuarinas occupy a wide variety of habitat types ranging from the arid desert to high rainfall coastal sites, and occur in both tropical and temperate zones. In addition, many species inhabit sites of very low fertility, a feature which is thought to be enhanced by the capacity to form symbiotic root nodules which are capable of fixing atmospheric nitrogen. There is also the possibility of mycorrhizal associations.

The wood of most species of *Casuarina* is heavy, dense and very hard. It makes an excellent fuelwood, producing good heat while being relatively smokeless. Sawing may be difficult, but the appearance of the wood, caused by the usually dark coloured, wide, medullary rays renders it attractive for wood turnery and parquetry. The timber is also used for pulp in the Philippines and Okinawa. *C.equisetifolia* has been used as windbreaks, for street trees and in parks, for sand stabilization after beach mining activities, and on mining spoil dumps; individual trees lend themselves for ornamental purposes. The branchlets of some species (e.g. *C.cristata, C.stricta*) can be lopped and fed to stock during periods of drought. *C.glauca* and its allies can spread from root suckers and have become a problem in some areas overseas.

The aim of this article is to give basic information on some Australian *Casuarina* species as background for this meeting. The choice is necessarily subjective and includes species that are already in fairly wide-spread use about the world (e.g. *C.cunninghamiana, C.equisetifolia*), although their full potential may not as yet be fully realised. Little-known species that possess particular attributes suggesting that they have potential for use in certain environments are also included.

*Casuarina campestris* Miq. **A SHEOAK**

*Principal features:* Subspecies *campestris* is often a very bushy, multi-stemmed shrub 1–3 m high and when growing in the open 1–2 times as wide as high. It may also grow with a more erect habit but even in this form the crown is dense, especially on young plants. Based on limited collections subsp. *eriochlamys* has the same height range and is erectly branched; subsp. *grossa* also has the same heights and tends to be bushy, whilst subsp. *tessellata* is an erect shrub with a narrower crown and comparable heights. The bark of subsp. *campestris* is flaky-fibrous and rough on the lower parts of the main stems, but smoother on the smaller branches.

The deciduous branchlets of subsp. *campestris* are slender and tending to be sub-erect. The minute leaf-teeth are in whorls of 7–9 (8–9 in subsp. *grossa*). The "cones" are globular to sub-cylindrical, 1.3–4 x 1.2–1.6 cm, with surface of the fruiting bracteoles smooth and undivided. The "cones" of the other subspecies vary both in shape and size from subsp. *campestris*: details are given by L.A.S. Johnson *Nuytsia* 1(3), 261–5 (1972).

*Geographical occurrence:* This is a species of south-western Western Australia, where it occurs on the inland side of the Darling Range from the southern end of Shark Bay to the southern coastline. It approaches to within 100 km of Perth and extends eastward to a line from near Menzies, north of Kalgoorlie to Esperance on the coast and the Mt Ragged area. The altitudinal range is from near sea level to about 375 m.

*Climate:* The distribution is mainly in the warm semi-arid climatic zone, but nears the warm sub-humid zone about 100 km inland from Perth. Two of the new (1972) subsp. extend to the warm arid zone. Frosts are only absent from northern and southern coastal areas, elsewhere the range is mainly 1–12 per year. The 50 percentile rainfall is 225–400 mm, and the lowest on record 140–250 mm. There is a clearly defined winter maximum.

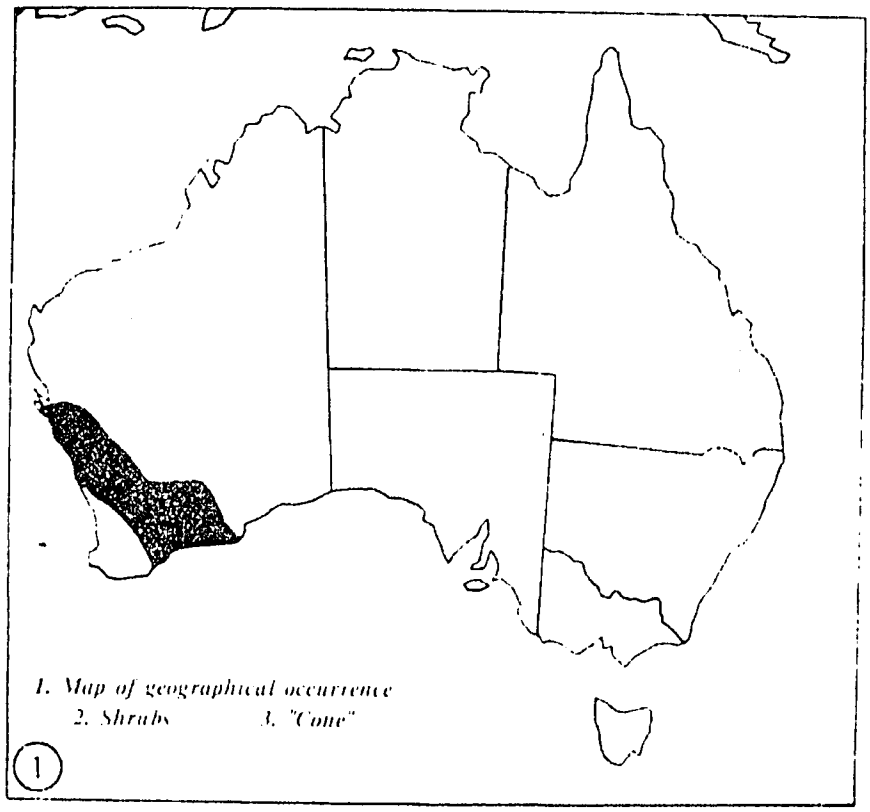
*Topography and soils:* The region of the Western Shield where this casuarina is found has been planed down to form an extensive plateau with occasional, conspicuous, low lateritic breakaways or granitic outcrops. Apart from the dominant granite throughout the area *C.campestris* has been recorded on soils derived from cemented laterite, greenstone, ferric-conglomerate, broken quartzite and limestone. Although it grows on coloured sandy soils it is not a common species of sand plains. It has been recorded on loams, shallow clays over laterite and coarse gravelly soils at the bases of breakaways.

*Vegetation type:* The broad types are open-woodland or tall shrubland and, at times, shrub steppe in places reduced to grassy open-scrub. It also may be abundant in scrub-heath when growing over laterite. The region is noted for its many shrub genera, as well as a rich eucalypt flora.

*Fodder:* Probably unattractive to stock.

*Wood:* Technical properties not known. Only available in small diameters.

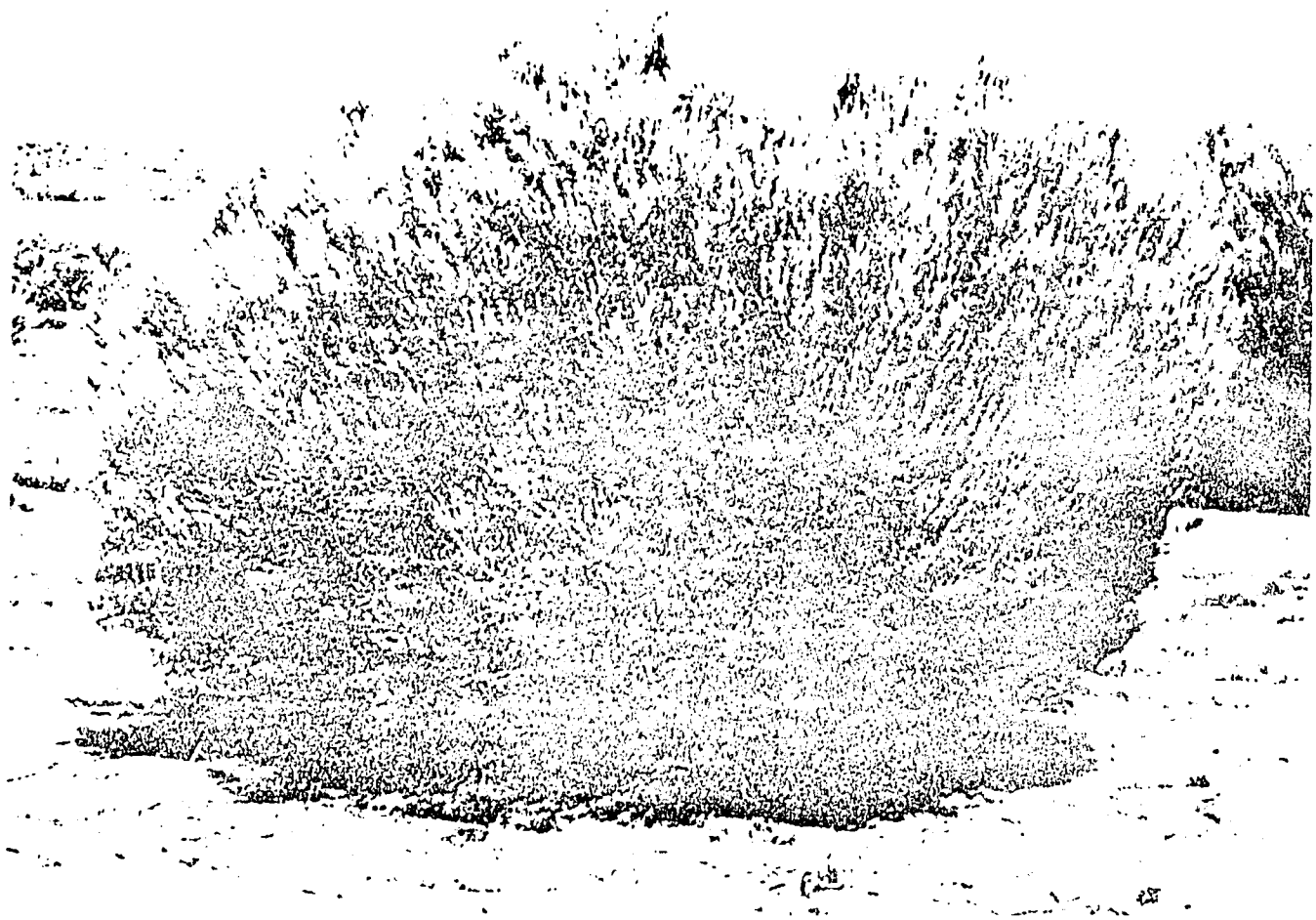
*Other uses:* The very bushy, multi stemmed habit of this species provides almost the ultimate in wind protection from ground level up. Single rows with plants 2–3 m apart will provide first class shelter for sheep and cattle and human habitation, but care needs to be given to avoid danger from fire. *C.campestris* offers a high level of soil protection when planted for conservation purposes.



*1. Map of geographical occurrence*
*2. Shrubs* *3. "Cone"*

1


3



2

*Casuarina cristata* Miq. subsp. *cristata* **BELAH**

*Principal features:* Belah is usually a moderately small tree 10–20 m in height. It has an erect habit and in moderately dense stands the main stem is straight and more than half the total tree height before it divides. Open-growing trees develop a wide dense crown. The bark on the trunk is very dark grey to almost black, thick (up to 4–5 cm), corrugated to somewhat scaly. On the branches it is thinner and smoother.

The slender ascending deciduous branchlets (0.5–8 mm in diameter) carry whorls of 9–16 leaf-teeth. Peeling leaf-teeth are a feature of the tips of the permanent branches. The "cones" are woody, somewhat rounded or sub-cylindrical and mainly 1.5–2.5 x 1.5–2.0 cm and have characteristically long thin bracteoles and pale seed.

*Geographical occurrence:* This is a species of eastern Australia where it grows in a belt about 1300 x 400 km on the inland side of the Great Dividing Range in New South Wales and southern Queensland, but extending to near the coast in the relatively drier area near Rockhampton. Altitude is mainly in the range of 175–325 m.

*Climate:* In New South Wales most of the distribution is on the higher rainfall side of the warm semi-arid climatic zone but with an important occurrence in the drier part of the warm sub-humid zone. Heavy frosts occur and range in frequency from 2–50 per year. The 50 percentile rainfall is 550–650 mm and the lowest on record 200–300 mm. The seasonal incidence varies from nearly uniform in the south to a strongly developed summer maximum in the far north.

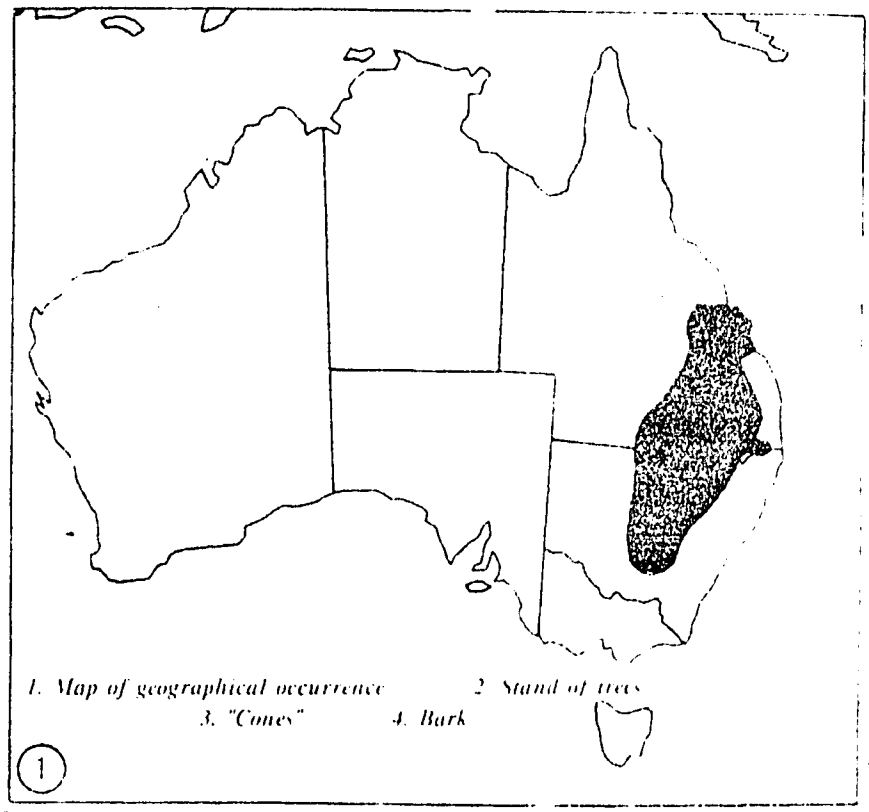
*Topography and soils:* Typically and at its best belah grows on heavy soils, often black soil plains, with an alkaline reaction and located on relatively lower topography. At the other extreme it has been recorded on Devonian quartzite hills and dissected sandstone plateaux. Other records give skeletal soils, red and grey loams, light grey sand, gravelly to deep heavy clays, as well as impressive pure stands on the red clay of river flats.

*Vegetation type:* The main broad type is woodland but varies from low open-forest to low open-woodland/tall shrubland. The species often grows in pure dense stands but may be associated with *Acacia, Eucalyptus, Atalaya, Heterodendron* and *Callitris* species.

*Fodder:* This species is generally regarded as a useful fodder tree in times of drought, for both sheep and cattle. It must be used in mixture since the deciduous branchlets have an astringent effect on stock and are reputed to cause impaction.

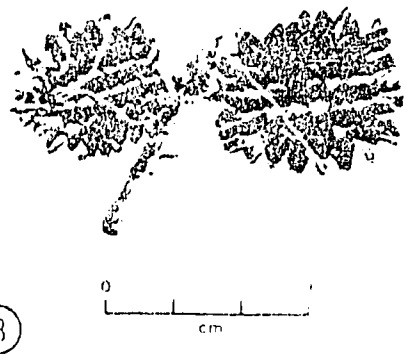
*Wood:* The heartwood is brownish-red and the sapwood narrow. It is heavy, density 1155 kg m$^{-3}$, hard, tough and fissile as a result of well-developed medullary rays. It does not saw readily but is excellent for turnery and, in the past, has been used for shingles, staves, mauls, tool handles and ornamental items. The heartwood is sufficiently but not exceptionally durable for use as fencing material and in the construction of stockyards. Fuelwood characteristics are excellent.

*Other uses:* On better sites in its native area and with a rainfall preferably greater than 400 mm, belah is an excellent tree for single or two-rowed windbreaks and makes an attractive ornamental species. Specimens growing in the open develop a dense crown nearly to ground level. Root suckers have been reported.



*1. Map of geographical occurrence* *2. Stand of trees*
*3. "Cones"* *4. Bark*

1

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2

*Casuarina cristata* Miq. subsp. *pauper* (F.Muell.ex Miq.)L.Johnson **BLACK SHEOAK**

*Principal features:* This casuarina varies from a bushy shrub only 6 m in height to a moderately well-formed tree of 10–16 m. Trees of the species usually have a straight main stem which divides into several ascending main branches at $\frac{1}{4}$-$\frac{1}{2}$ tree height. The crowns are only of moderate density, but exceptionally good for the very arid and severe conditions under which it grows. The bark is grey and finely corrugated to the smoother branches.

Whilst displaying the same general botanical characteristics as subsp.*cristata*, L.A.S. Johnson (1972) notes that subsp.*pauper* differs by having usually thicker and more waxy-surfaced branchlets and in the shorter fruiting bracteoles of the "cones", which are often persistently tawny-pubescent.

*Geographical occurrence:* Black sheoak occurs in southern Australia and extends in a wide and rather irregular belt from the Die Hardy Ranges in Western Australia, across the mainly central latitudes of South Australia to western New South Wales nearly as far as Bourke and Cobar (here there is a transition zone about 50–100 km wide with subsp. *cristata*). It also occurs in north-western Victoria, especially Mildura to Swan Hill. Altitudinal range is 25–400 m.

*Climate:* Most of the distribution is in the warm arid climatic zone with "very hot" summers and "cool" winter nights. The more southern occurrences extend into the warm semi-arid zone. The area generally experiences 1–10 frosts per annum with a few places having 11–17. The 50 percentile rainfall is 175–275 mm and the lowest on record 50–150 mm. Seasonal and yearly incidence varies considerably and potential evaporation is a very high 2500–3300 mm a year.

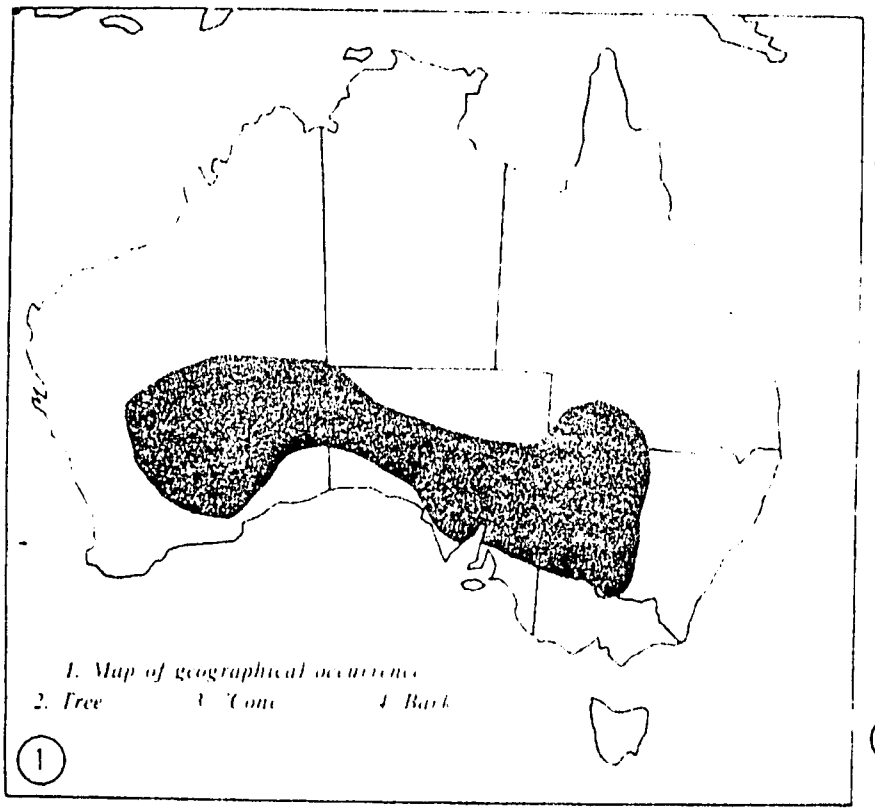
*Topography and soils:* The greater part of the occurrence of black sheoak is on the Western Shield, a very old and stable land mass. The resultant topography is gentle or plain-like with some small mesas often only 50–100 m in elevation. The species frequently occurs on sandy soils over limestone or calcrete. Other soil types include arid loams, red sands and alkaline soils.

*Vegetation type:* This includes low open-woodland, tall shrubland and tree and shrub steppe. Where the subspecies is growing best it may either be the only small tree in the landscape, or secondary to tree-sized eucalypts. Throughout the area there are many genera and species of both small and large shrubs. *Acacia* has many representatives with *A.aneura* being the most common species.

*Fodder:* Of some value in times of drought, but the somewhat woody branchlets have an astringent effect on stock and are reputed to cause impaction.

*Wood:* The dark coloured heartwood is sufficiently durable for use as fencing material and for rough farm construction, although nowadays the timber is little used. It is heavy, hard, tough and very fissile as a result of well-developed medullary rays. The wood is a very good fuel.

*Other uses:* It is more suited to drier (down to 250 mm of rain a year) and harsher conditions than subsp. *cristata*, as well as to areas where there is limestone in the soils. It also appears to be suitable for soils with some salt content. Protection from grazing stock as well as rabbits and hares is essential if young plants are to become established.



1. Map of geographical occurrence
2. Tree 3. Cone 4. Bark

1

*Casuarina cunninghamiana* Miq. **RIVER SHEOAK**

*Principal features:* *C.cunninghamiana* is usually a medium-sized to tall tree attaining 20–35 m in height and 0.5–1.5 m in diameter. It is the largest species of the genus in Australia, although in open country in the north of the area of occurrence, such as southeast of the Gulf of Carpentaria in Queensland, and in the Northern Territory it may be only 12 m in height and straggly in appearance. The bark is relatively hard and dark grey in colour.

The thin deciduous branchlets are soft and short and carry the leaf-teeth in whorls of 6–8. The permanent branches have peeling leaf-teeth. The subglobose "cone" is small, 0.8–1 x 0.8–1 cm, on a stalk about 0.3–0.8 cm long; bracteoles are relatively thin and dehisce rapidly when mature.

*Geographical occurrence:* River sheoak typically occurs in narrow belts along fresh water streams throughout eastern Australia from southern New South Wales to north Queensland and the Northern Territory. It occurs on both sides of the Dividing Range with its eastern boundary being determined by the presence of fresh water as it is replaced by swamp oak (*C.glauca*) on coastal rivers as the water becomes more saline. The westernmost occurrences in New South Wales overlap the easternmost limits of river red gum (*Eucalyptus camaldulensis*). A distinct race is found along the larger rivers in the higher rainfall areas of the Northern Territory. The species has a wide altitudinal range from sea level to about 1000 m.

*Climate:* The climate varies from warm sub-humid to warm semi-arid. The species is able to tolerate up to 50 frosts per year; such incidences mainly occur in the southern parts of its distribution. Rainfall varies from 500 to about 1500 mm per annum, but as the tree is of riverine occurrence rainfall alone is no indication of the total moisture available . The incidence of the principal rain varies from a weak summer-autumn maximum in southern New South Wales to a strongly defined summer maximum in the north (monsoonal in the far north).

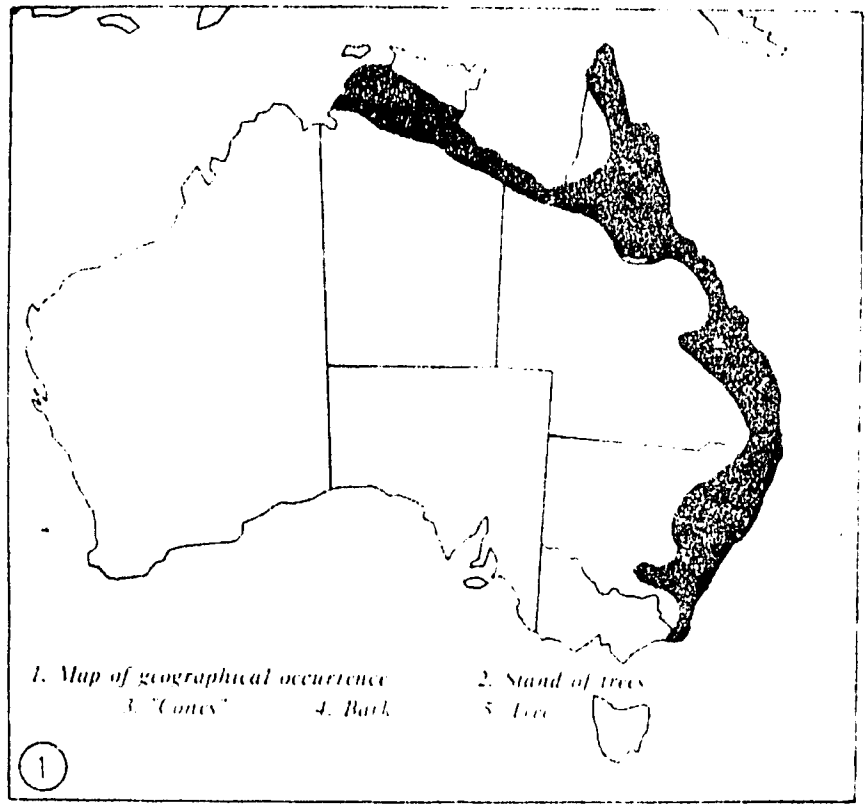
*Topography and soils:* River sheoak mainly grows on river and stream banks, especially in the belt between normal water level and maximum flood level and occasionally on adjacent river flats. The species may extend for a short distance up rocky hillsides, chiefly on limestone. The soils range from light textured sands through to gravels in terraces of old river courses.

*Vegetation type:* The species occurs as pure stands in narrow riverine belts.

*Fodder:* The foliage whilst not having a high nutritive value can be used by stock in times of drought.

*Wood:* The heartwood is dark reddish or purplish brown; fissile, close-grained except for the medullary rays, moderately strong and very tough when seasoned, comparatively durable for a casuarina, moderately heavy, density 900 kg $m^{-3}$. The timber is occasionally used for heads of casks, axe handles and ornamental turnery. Formerly it was used for shingles and bullock yokes. It is an excellent fuel and was used in the past for burning in baker's ovens.

*Other uses:* The tree is of handsome appearance and can be used for ornamental planting as well as for shade and shelter in suitable locations. It is fully protected in New South Wales.



1. Map of geographical occurrence  2. Stand of trees
3. "Cones"  4. Bark  5. Tree

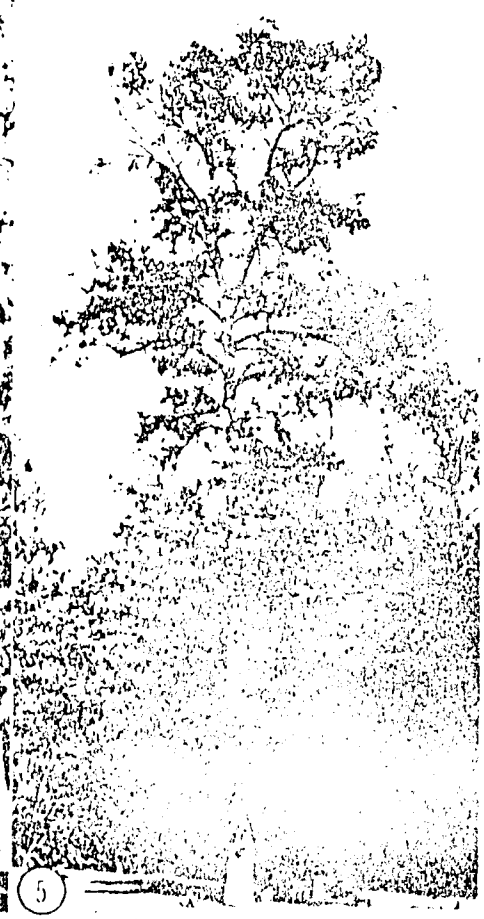
1

0  1
cm

3

4

2



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*Casuarina decaisneana* F.Muell. **DESERT SHEOAK**

*Principal features:* This is one of the remarkable species of the centre of Australia as it grows to 15 m height (though usually 9–12 m) in some of the hottest and driest conditions of the continent. The tree typically has an erect and straight main stem, which is often unbranched for half the total height and pendulous, branches and branchlets. The bark is very dark in colour, thick and deeply fissured.

The deciduous branchlets of desert oak are slender, wiry, articulate and about 1–2 mm in diameter. The leaf-teeth are in whorls of four and are 2–5 mm long. The "cones" are sessile or only shortly pedunculate and amongst the largest in the genus; ovoid-oblong, 3–5.5 x 2.5–3.5 cm, with conspicuous wooden bracts.

*Geographical occurrence:* Desert sheoak grows in central Australia extending from the south-western parts of the Northern Territory, for over 300 km into Western Australia and southwards into the far north-western corner of South Australia. Outside of this region there are several well-authenticated isolated occurrences. Altitude ranges from 250–700 m.

*Climate:* The distribution is in the arid climatic zone with very high summer temperatures, frosts (1–12) in winter and a potential evaporation in the range of 2500–3300 mm a year. The 50 percentile rainfall is 200–250 mm and the lowest on record 40–65 mm. Seasonal patterns of rainfall vary greatly between years although long term means give a summer maximum. Representative meteorological stations include Alice Springs and Giles.

*Topography and soils:* The part of the Western Shield where desert sheoak grows consists mainly of plains including the Great Sandy Desert and the Great Victoria Desert. There are also a number of small residual ridges, sometimes of sandstone, but on which desert sheoak only grows to a very limited extent.

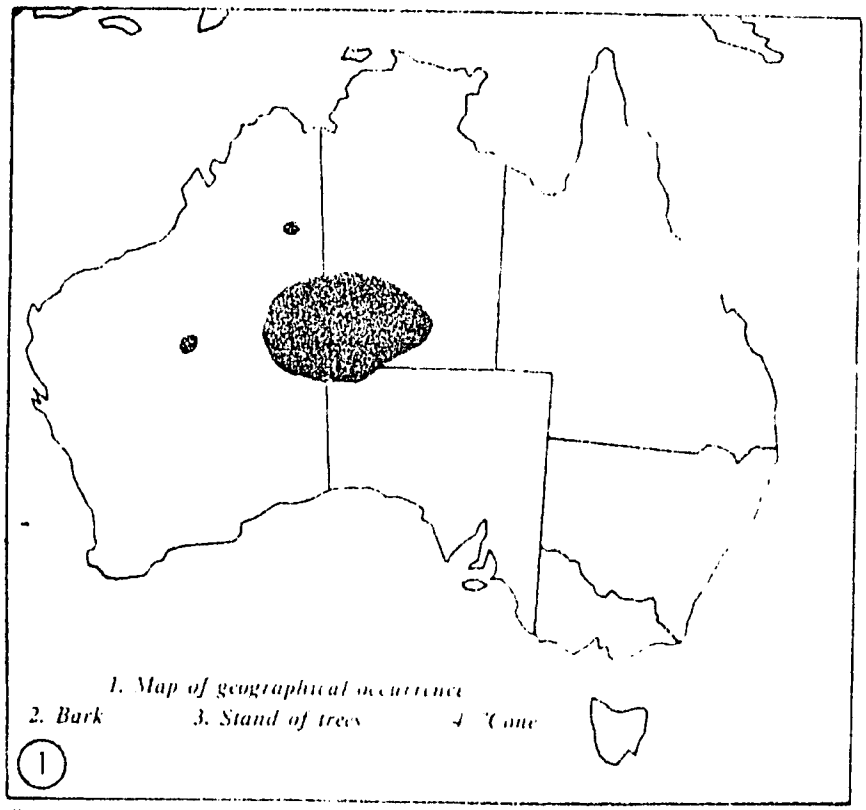
In the deserts the tree mainly grows on the interdune areas or on the lower slopes of the dunes and along relatively low-lying drainage lines which receive run-off from adjacent gentle slopes in times of the rare heavy falls of rain. Further to the east and also south of Alice Springs it may grow on low sand ridges. The soils are mainly deep sands, sometimes red, and occasionally deep coarse clayey sands.

*Vegetation type:* The broad vegetation types are hummock grassland, low open woodland and desert complex. In its area, desert sheoak is an impressive dominant and commanding tree of the landscape, occurring as scattered individuals or in groves of irregular size, density and distribution. It is frequently the only tree species present and even large shrubs are not common.

*Fodder:* The young foliage is rather sharp and hard and is unattractive as fodder. Nutritive value is low.

*Wood:* The heartwood is dark, red-brown, strong and moderately durable against termites and in the ground. Basic density is about 1050 kg m$^{-1}$. Local uses include exterior construction, fencing and fuel.

*Other uses:* This species has received little attention for amenity planting, but certainly merits consideration for park, avenue and shade planting in its climatic and soil environment.



1. Map of geographical occurrence
2. Bark
3. Stand of trees
4. Cone

(1)

0 1 cm

(4)

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(3)

*Casuarina dielsiana* C.A.Gardn. **DIELS SHEOAK**

*Principal features:* This sheoak is a small tree, commonly 5–8 m high, but sometimes reduced to 4 m on the top of dry gravelly ridges or attaining 9–10 m on moderately good sandy loams. The crown tends to be carried in the upper part of the trunk, whilst the lower parts are thinly branched. The bark is rough to the smaller branches, greyish and scaly in irregular plates.

The deciduous branchlets carry whorls of 6–8 small leaf-teeth. The woody "cones" are ellipsoidal to subglobose, about 2–3 x 1.75–2.5 cm in size. The back of the bracteoles of the individual fruit are prominently striate.

*Geographical occurrence:* This is a species of Western Australia, where it occurs in a belt about 750 km long and 150–200 km wide. The north-western end is just south of Shark Bay and the species is found near the coast from Kalbarri to Geraldton, from whence the belt extends south-east towards the northern side of Southern Cross. The range in altitude is 50–375 km.

*Climate:* Diels sheoak occurs in the warm semi-arid climatic zone, though very close to the arid zone on the inland side of the distribution, especially north of Southern Cross. Northern coastal areas are frost-free, but inland, and especially towards Southern Cross the values are 1–11 per annum. The 50 percentile rainfall is 275–400 mm, and the lowest on record 125–250 mm. There is a clearly defined winter maximum.

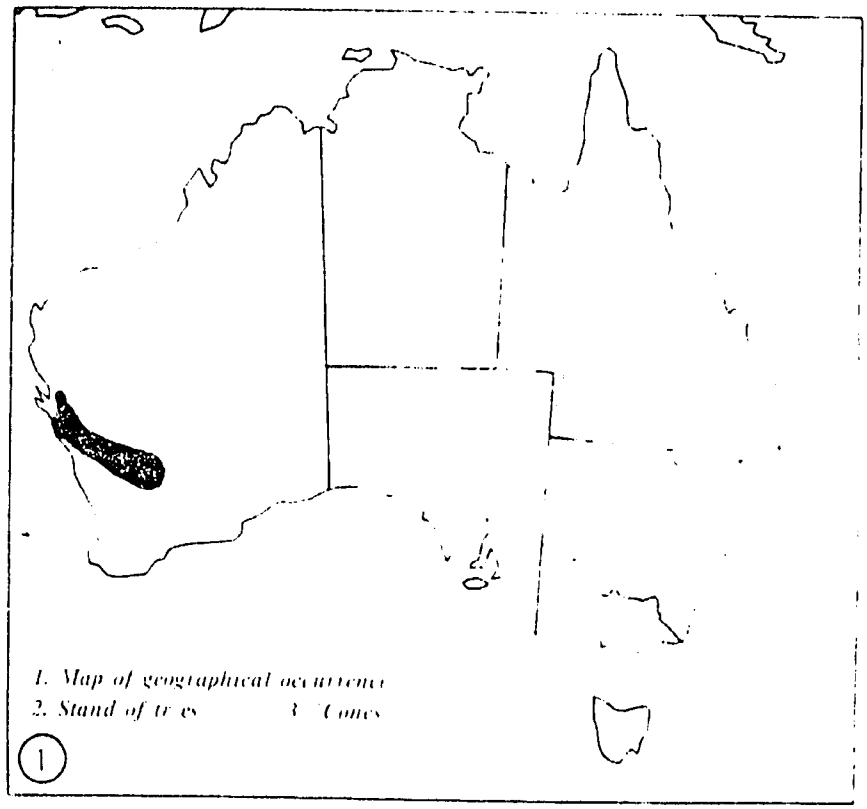
*Topography and soils:* The occurrence of *C.dielsiana* is on the Western Shield. This species is typically found around or on the more rocky and rugged sites and whilst it may edge sandplains it is rarely found on them. The soils are mainly sandy, sandy-loams or stony-skeletal. Other types include gravels on ironstone ridges and light red loams associated with granitic outcrops.

*Vegetation type:* Diels sheoak is mainly found in shrubland, sometimes with scattered trees, sometimes in areas approaching shrub steppe and only edging low open-woodland. Whilst this species may occur as an important constituent in small localised situations, it is nowhere a dominant species over large areas and is generally seen as scattered specimens.

*Fodder:* Unknown.

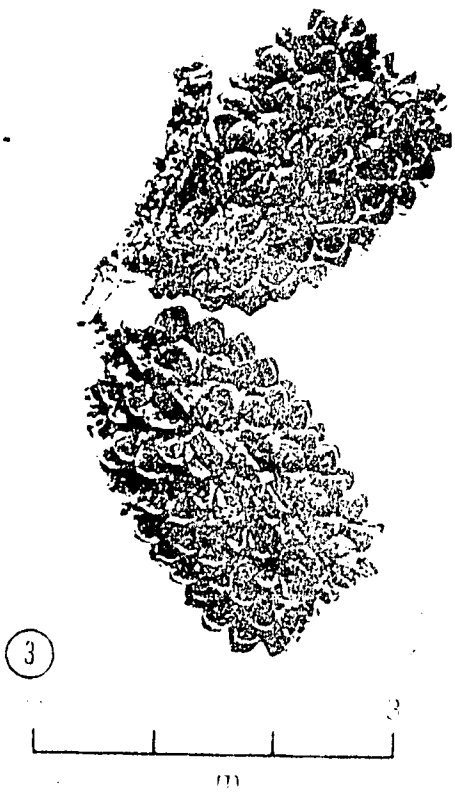
*Wood:* Unknown.

*Other uses:* Most casuarinas have a role in their climatic and soils areas for amenity planting or for the production of fuel-wood and timber but this species, possibly due to its area of occurrence, has received little attention. It is suggested that Diels sheoak merits small scale trials overseas where conditions are comparable to those of its native habitat. It will tolerate very high summer temperatures, a low and erratic rainfall and sites which are rocky and freely-drained.



1. Map of geographical occurrence
2. Stand of trees 3. Cones

(1)



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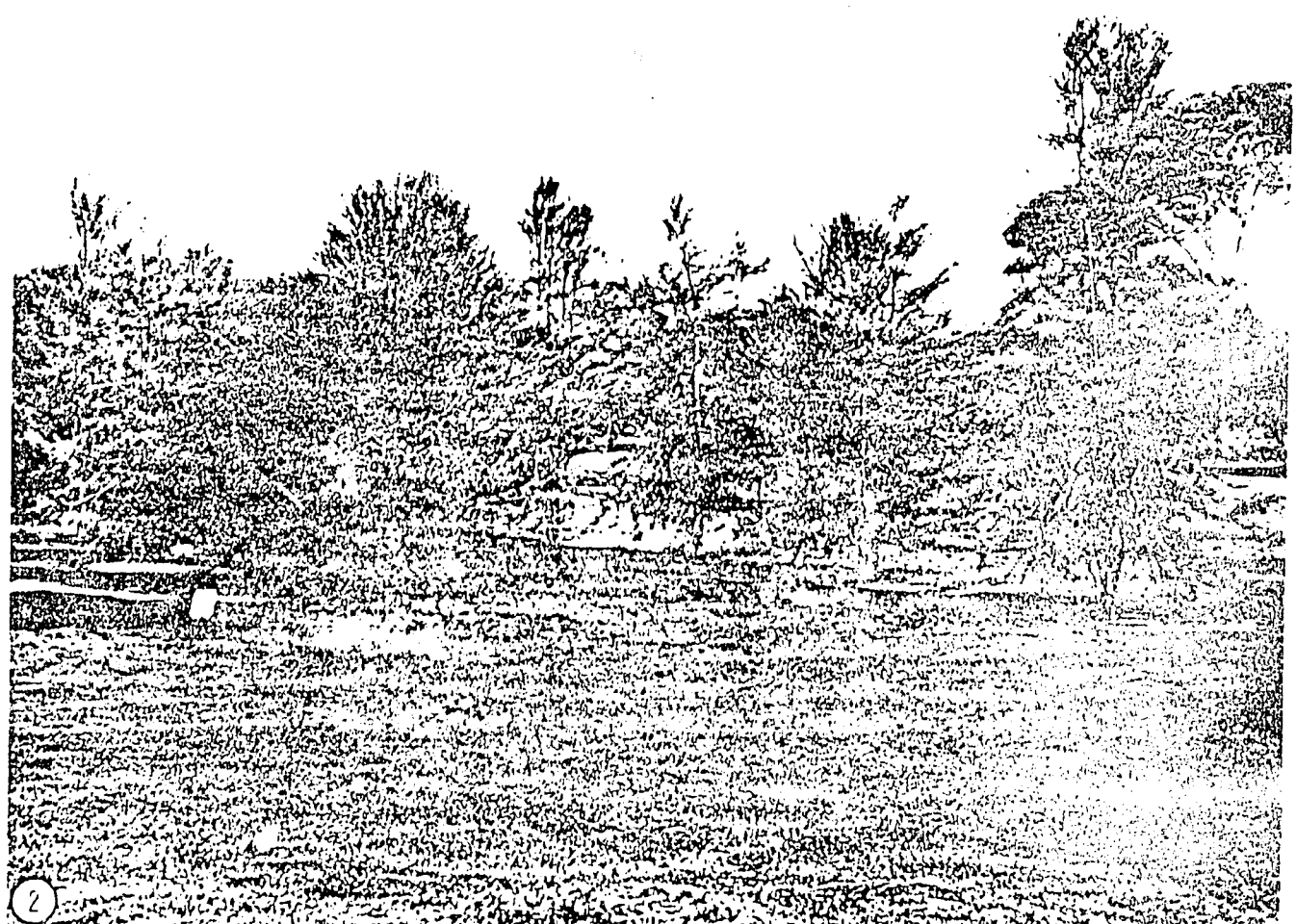


(2)

*Casuarina equisetifolia* Forst. var.*equisetifolia* and *C.equisetifolia* Forst. var.*incana* Benth.

## COAST SHEOAK

*Principal features:* In Australia the var. *equisetifolia* is mainly a smallish tree, 8–16 m high, usually with a somewhat bent stem of less than half total tree height. The crown is typically very open-branched and open-growing specimens may have a width nearly as great as the tree is high. The var. *incana* is not more than a small tree and may be only a large shrub 6–10 m high. Stem form is poor with a very open canopy. The bark is grey-brown, tight, with small lenticular protuberances on young branches.

The slender, pale green, deciduous branchlets are about 1.5–2.5 mm in diameter; they are drooping or semi-drooping. The minute leaf-teeth appear in whorls of 6–8 on the deciduous branchlets. In the case of var. *incana* the "cone", 1–2.3 x 1–2 cm, is covered in a fine white pubescence while green; bracteoles are acute and the bracts shield-like.

*Geographical occurrence:* The var. *equisetifolia* occurs in a narrow coastal strip from the Darwin area of the Northern Territory along the north coast of Queensland to the Cairns region. From Cairns to Mackay there is some intergradation with var. *incana*. The latter variety extends southwards to near Port Macquarie, New South Wales.

*Climate:* The var. *equisetifolia* occurs in the hot humid climatic zone with some extension into the hot sub-humid zone, whilst var. *incana* has its main distribution in the warm sub-humid zone. Frosts are absent on all of the coastal strand, though in the south there may be 1–3 a year, within a few kilometres of the sea. The 50 percentile rainfall is mainly 1000–1500 mm (Cairns, 2150 mm) and the lowest on record has a very wide range 175–1100 mm. Seasonal distribution varies from a moderate summer maximum in the south to a strong monsoonal pattern in the north.

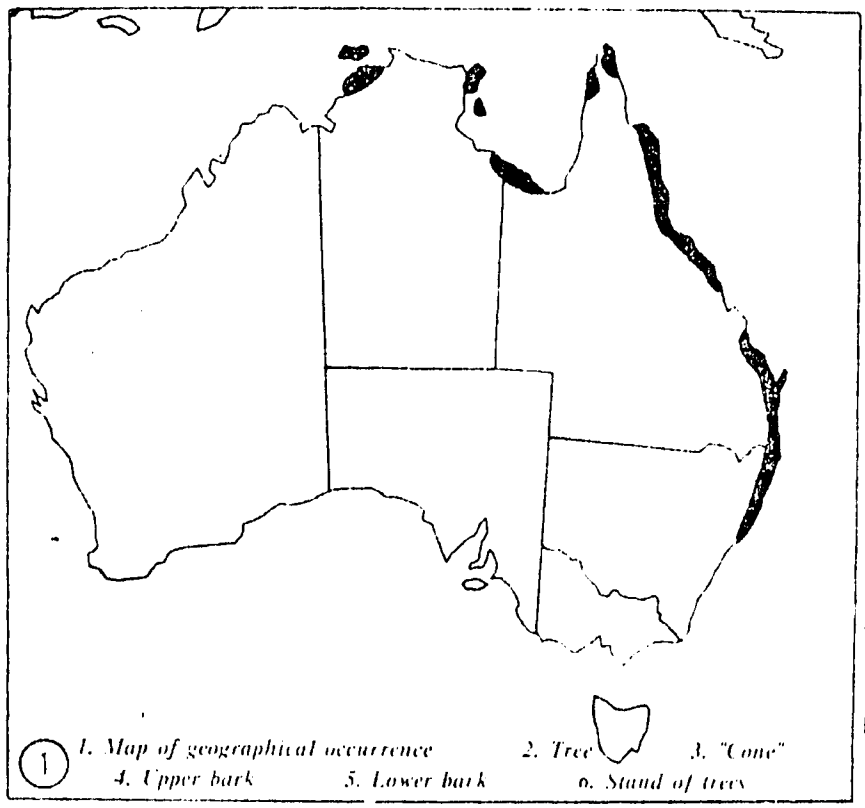
*Topography and soils:* The topography includes both dunes, sandy flats immediately behind frontal dunes and very gentle slopes near he sea. The var. *incana* may occur towards the bases of rocky headlands. The soils are typically of a sandy nature often 2 m or more of sand above a more retentive layer, sandy loams and var. *incana* has been recorded on conglomerate rock.

*Vegetation type:* In the strand vegetation where coast sheoak mainly occurs, it may be the only tree or shrub present, whilst the ground cover includes various grasses and herbs. The species may also grow in narrow belts immediately adjacent to mangroves, or scattered, but sometimes in small groups in open woodland where it may be associated with eucalypts.

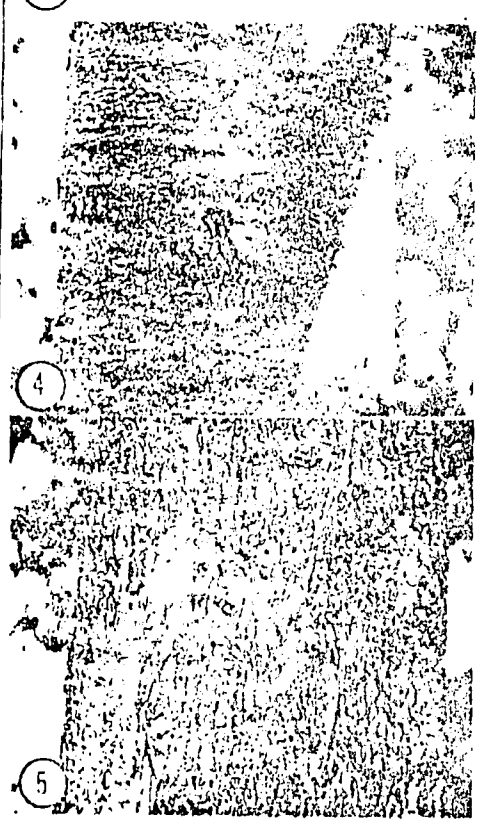
*Fodder value:* Probably of limited value during times of severe drought.

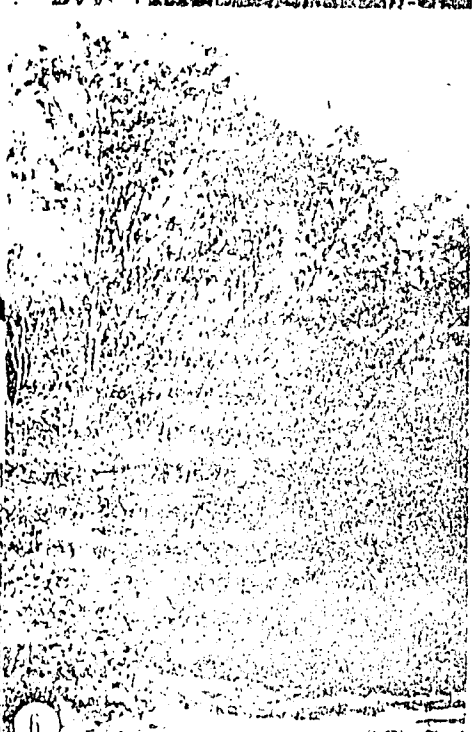
*Wood:* The heartwood is dark brown, very hard, very heavy (density 1000 kg $m^{-3}$), strong and durable in the ground or submerged in saltwater. It is one of the worlds best firewoods and burns satisfactorily even when green. It also makes an exceptionally fine charcoal. Shingles or small items such as oars may be produced. It is difficult to use for fine carpentry.

*Other uses:* Coast sheoak has been widely planted in the tropics for a variety of purposes which vary from amenity planting, reclamation work on coastal plains, medicinal purposes, tannin, dyes, pulp and timber production (used mainly in the round or partly squared). Given favourable conditions in coastal zones (rainfall of 1000–1500 mm a year) early growth may be remarkably good.



1. *Map of geographical occurrence* 2. *Tree* 3. *"Cone"*
4. *Upper bark* 5. *Lower bark* 6. *Stand of trees*





*Casuarina fraserana* Miq. **FRASERS SHEOAK**

*Principal features:* At its best in the jarrah forests this sheoak is an erect, somewhat pyramidal tree with straight bole for $\frac{1}{3}$ of the tree height, and a somewhat open crown. Under such conditions it is commonly 9–12 m high but in particularly favourable areas heights of 14–15 m occur. Even on lateritic clay the height may be 10 m but on poor sites such as dry sandy plains or rocky areas the height may be reduced to 2–5 m. The bark is smooth, grey in colour with a fine-textured surface.

The slender deciduous branchlets have whorls of 6–8 small, leaf-teeth. The woody "cones" are large, subglobose to cylindrical, 2–4 x 2–3 cm, on a stalk 0.5–3 cm long. The bracteoles are very thick, shortly exserted, ferruginously pubescent, dorsal surface rugose with multiple protuberances.

*Geographical occurrence:* This is a species of the coastal belt of southwestern Western Australia, from about 150 km north of Perth to less than 100 km east of Albany. The main belt is generally less than 75 km wide and in the Darling Range is predominantly on the seaward side, although some locations have been recorded a few kilometres on the inland side. The range in altitude is from 50 m to about 500 m.

*Climate:* This is typically a species of the warm humid climatic region of the far southwest of Western Australia, with only a minor extension into the higher rainfall parts of the adjacent warm sub-humid zone. Areas immediately adjacent to the sea are frost-free while at higher altitudes away from the sea frosts may average up to 11 per year. The 50 percentile rainfall is 900–1250 mm, and the lowest on record 500–750 mm. There is a well-developed winter maximum rainfall.

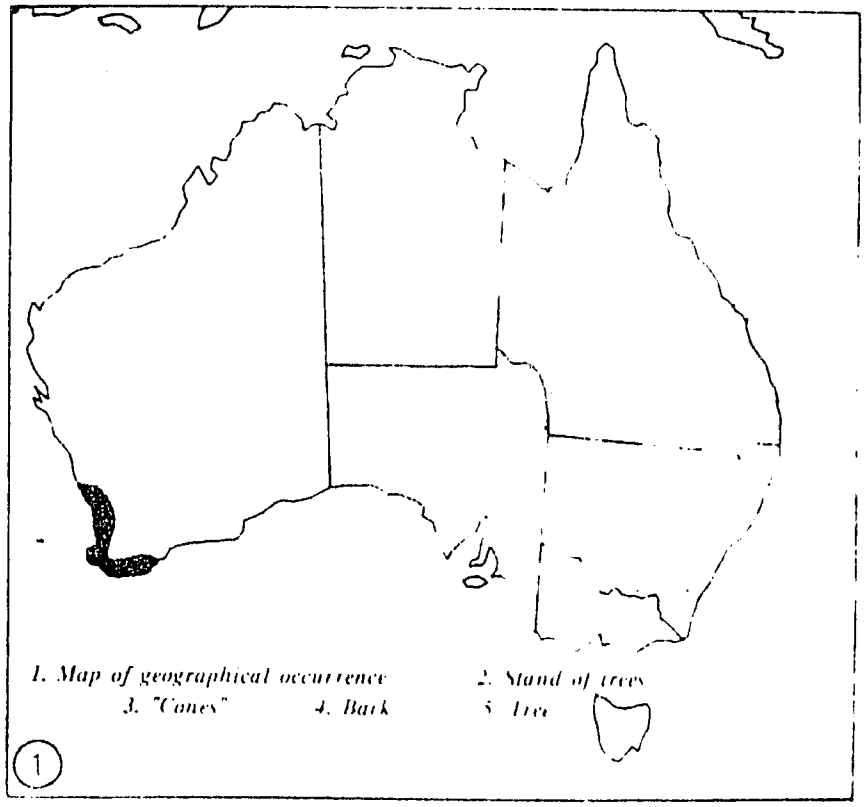
*Topography and soils:* Frasers sheoak occurs on the southwestern edge of the Western Shield. The topography is undulating to hilly, the latter especially in the Darling Range system. The species is also found on the coastal plain. Although it typically attains large sizes on lateritic clays and gravels of jarrah forests this sheoak is also found on a fairly wide range of soils which include deep white sands as well as extending in poor form to skeletal types on "ironstone" hills.

*Vegetation type:* The broad vegetation type is open-forest with limited extension to woodland and tall shrubland. Characteristic of the better and more extensive growth of the sheoak is eucalypt forest with *E.marginata* as the dominant species, but often with a significant mixture of *E.calophylla*. In such forest the sheoak grows as scattered specimens or in small groups. It is also found in casuarina-banksia shrubland.

*Fodder:* This species is not known to have any value for stock.

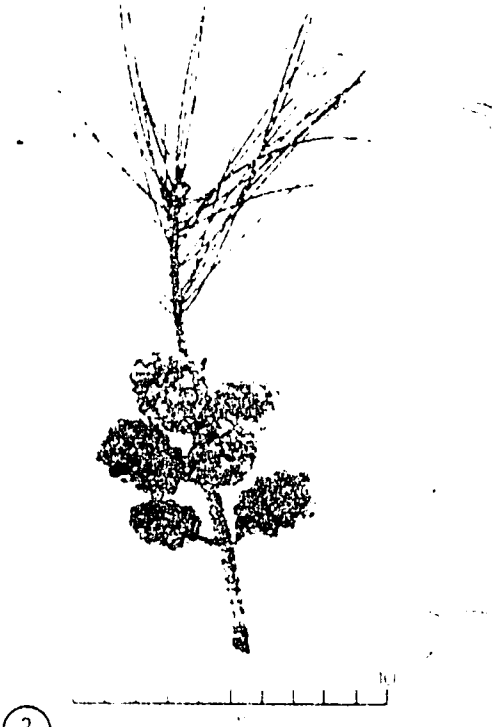
*Wood:* The heartwood is dark red in colour, density 830 kg $m^{-3}$. In 1981 there was only one licensed timber cutter for casuarinas in the southwest of Western Australia and the firm concerned was only utilising *C.fraserana*. The products were mainly wood turnery - goblets, plates, saucers, bowls, piano legs, with some roof shingles and veneer board for panelling. Another company used to take reject logs from the first and make dowelling, mouldings and picture frames. Firewood is still cut from this species for the Perth market.

*Other uses:* Frasers sheoak is little used for amenity planting in Western Australia. Other local and several eastern sheoaks have become better known in the State for this purpose.



*1. Map of geographical occurrence* *2. Stand of trees*
*3. "Cones"* *4. Bark* *5. Tree*

1



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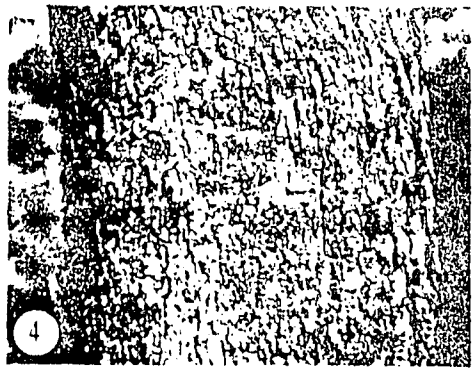

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*Casuarina glauca* Sieb. ex Spreng. **SWAMP SHEOAK**

*Principal features:* *C.glauca* is an erect, medium-sized tree, usually in the height range of 10–14 m, though sometimes reported up to 20 m. The main stem, which may be buttressed and fluted, is moderately straight and typically dominant for most of the tree height. Free-growing specimens have a somewhat sparse habit and narrow crowns. The bark is hard, greyish to light black with a tessellated appearance.

The slender deciduous branchlets (about 1 mm in diameter) carry 12–16 small leaf-teeth in widely spaced whorls. The permanent branches display peeling leaf-teeth. The "cones" are sub-globose to shortly cylindrical, often pubescent when young and mainly 1–2 x 1–1.5 cm in size.

*Geographical occurrence:* Swamp sheoak is found in a very narrow coastal belt in eastern Australia from Bega in southern New South Wales to Rockhampton in Queensland, with an insular occurrence on Fraser Island. In only two regions does it extend far inland; and these are in the Sydney region (about 50 km) and Singleton area (about 80 km). This casuarina is most common along the edges of tidal reaches and is often found in estuarine locations, though sometimes on or near beach fronts. Occasionally it may be found on low rocky and hilly slopes near the sea. The range in altitude is from sea level to 30 m.

*Climate:* The distribution is in the warm humid and sub-humid climatic zones. Whilst locations immediately on the sea front are frost-free, there may be 1–5 a year at places only a kilometre or so inland. The 50 percentile rainfall is 900–1150 mm, and the lowest on record 325–500 mm. The rainfall incidence varies from a weak summer-autumn maximum in the south to a strongly defined summer maximum at Rockhampton.

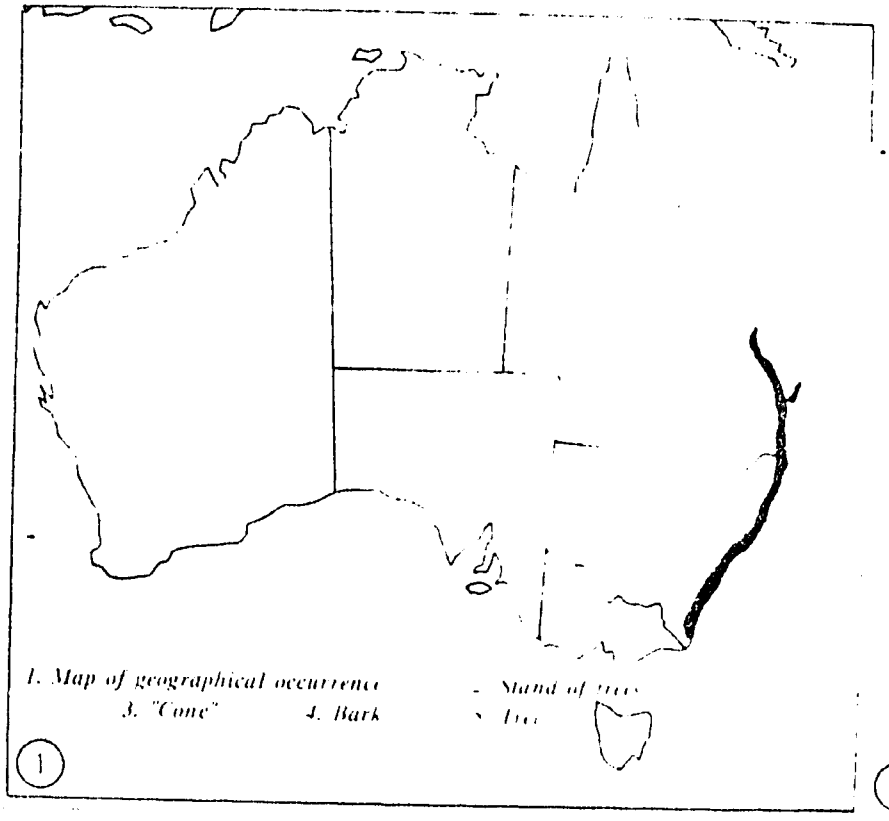
*Topography and soils:* The typical topography consists of swampy flats, often only 10–100 m wide, near estuaries and along tidal reaches of rivers. The flats may be only marginally above tidal limits and the water table is usually close to the surface. The soils are mainly dark with humus material and sand prominent in the top 0.1–0.2 m, below which it becomes clayey and influenced in many cases by the underlying parent rock. Salt content is higher then for "normal" soils. In complete contrast to this are occasional occurrences on rocky headlands with steep slopes and soils which may be almost skeletal.

*Vegetation type:* This sheoak typically occupies the coastal river flats fringing mangroves on the one hand and, where there is an abrupt change in topography and soils, edging woodland or open-forest types on the other. Where the topography remains flat there is often a transition from the brackish habitat of *C.glauca* to fresh-water swamps in which ***Melaleuca quinquenervia*** may grow in dense, pure stands.

*Fodder:* This species has little value as a drought fodder.

*Wood:* The heartwood is reddish brown coloured and has conspicuous rays, hard, tough and fissile, heavy, density 980 kg m$^{-3}$. Except for firewood for which it is excellent, this species is little used nowadays. In the past it was used for handles, fencing rails, rafters, shingles, stakes, small piles in sea water and for flooring and turnery. Whilst it was used for cabinet work, the timber does not season readily and has a tendency to warp.

*Other uses:* Swamp sheoak is an excellent tree for amenity planting and shelter belts, especially in coastal locations. The rooting system is believed to be relatively shallow.



*1. Map of geographical occurrence* - *Stand of trees*
*3. "Cone"* *4. Bark* *5. Tree*

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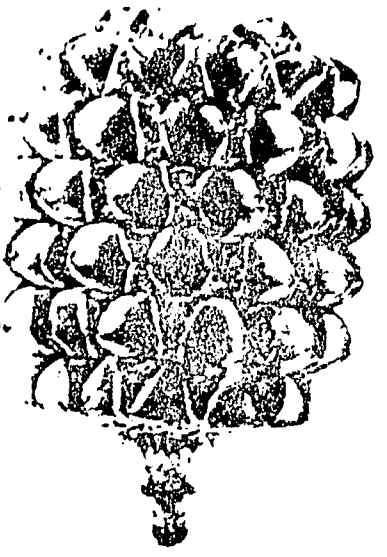

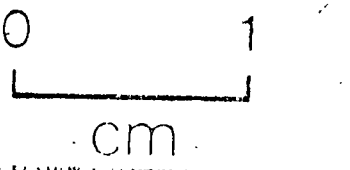


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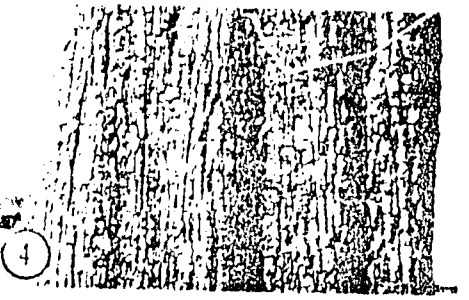

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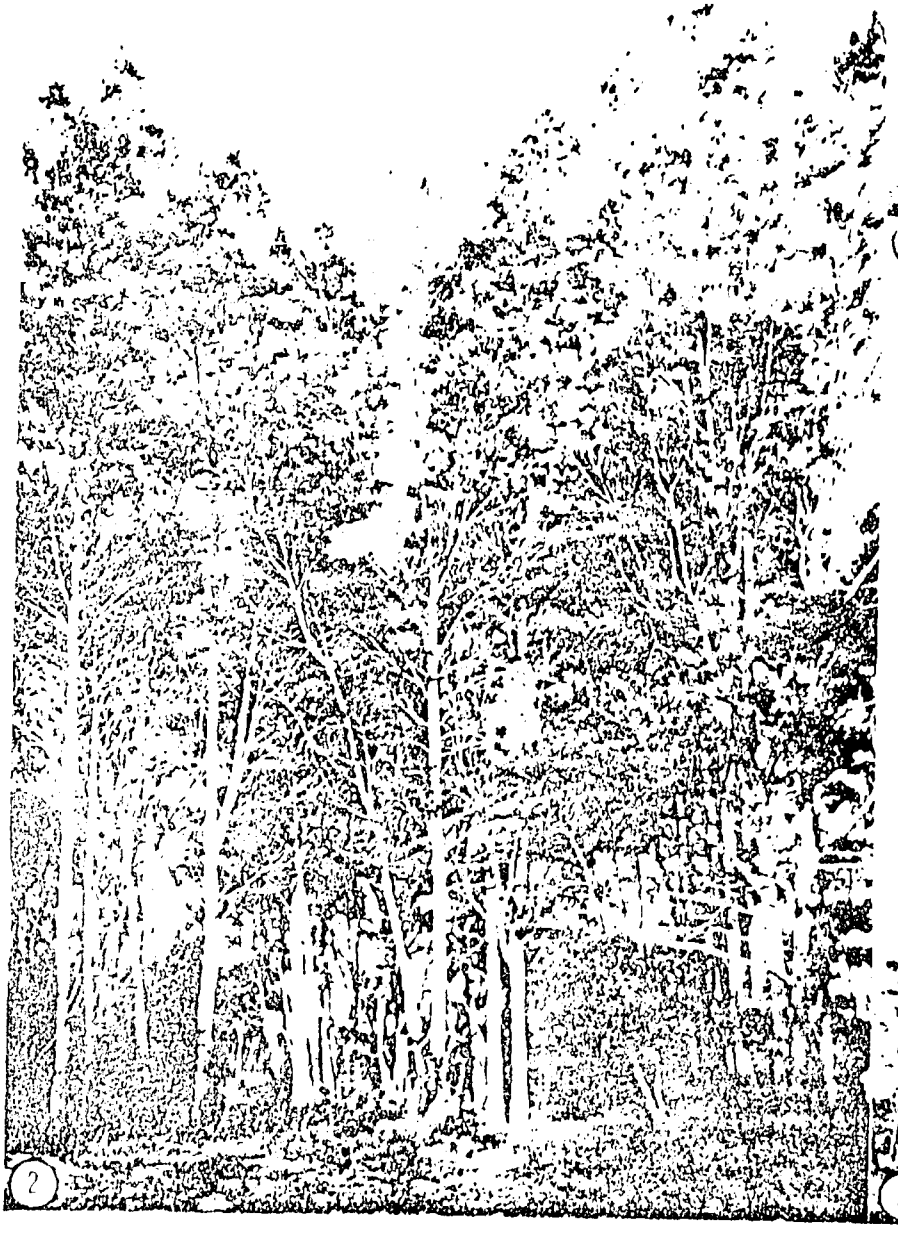

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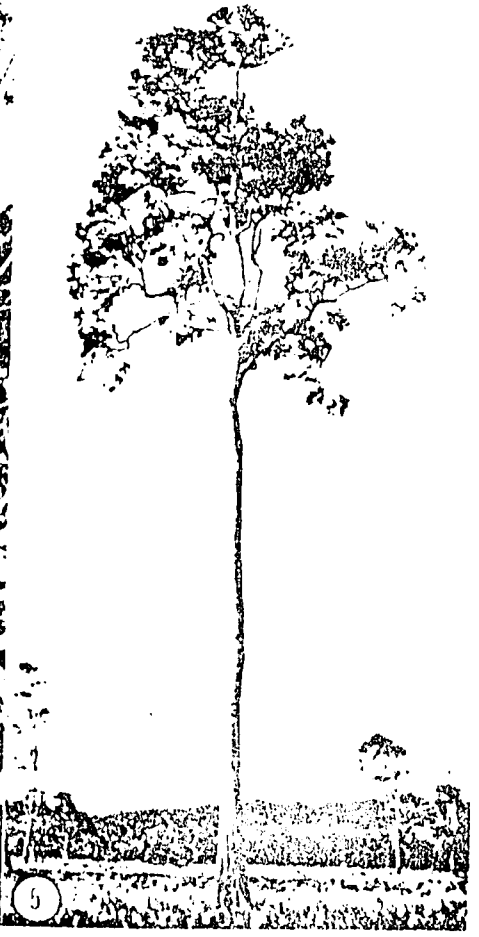

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*Casuarina huegeliana* Miq. **GRANITE SHEOAK**

*Principal features:* Granite sheoak is a small tree commonly in the height range of 5–12 m, though sometimes attaining 14 m under favourable conditions. On very adverse sites it may be reduced to 2–3 m. Young trees and mature ones in closed stands have a columnar habit while open-growing specimens have a wide crown and a main stem which divides at $\frac{1}{4}$–$\frac{1}{3}$ of plant height. The bark on the trunk is very hard, dark grey to almost black, rough, strongly fissured and sub-fibrous. The smaller branches are smooth.

The slender deciduous branchlets carry the whorls of 8–12 leaf-teeth, each about 1 mm long. The "cones" are truncate, cylindrical–subglobular, 1.4–3 x 1.4–2.4 cm with bracteoles, smooth surfaced, woody and rather blunt-tipped.

*Geographical occurrence:* This casuarina occurs in the southwest of Western Australia excluding the higher rainfall belt from Busselton to Pemberton and Denmark. It is locally common from Perth to Merredin and southwards to Albany and the Ravensthorpe areas. Eastwards it is found nearly to Coolgardie, Norseman and in the Israelite Bay area. North of Perth granite sheoak is not common for about 250 km, but is then found in several localities as far as the Murchison River gorge.

*Climate:* The greater part of the distribution is in the warm semi-arid climatic zone, but the belt from Perth to Albany is the warm sub-humid zone. An apparent disjunct occurrence near Leonora is in the warm arid zone. Areas on the coast and in the far north are frost-free, but elsewhere the average number of frosts are 1–6 per year. With the exception of Perth, Albany and Esperance which have relatively high rainfall, the 50 percentile is 300–500 mm and the lowest on record 175–225 mm. The whole area is in a winter rainfall zone with dry to very dry summers.

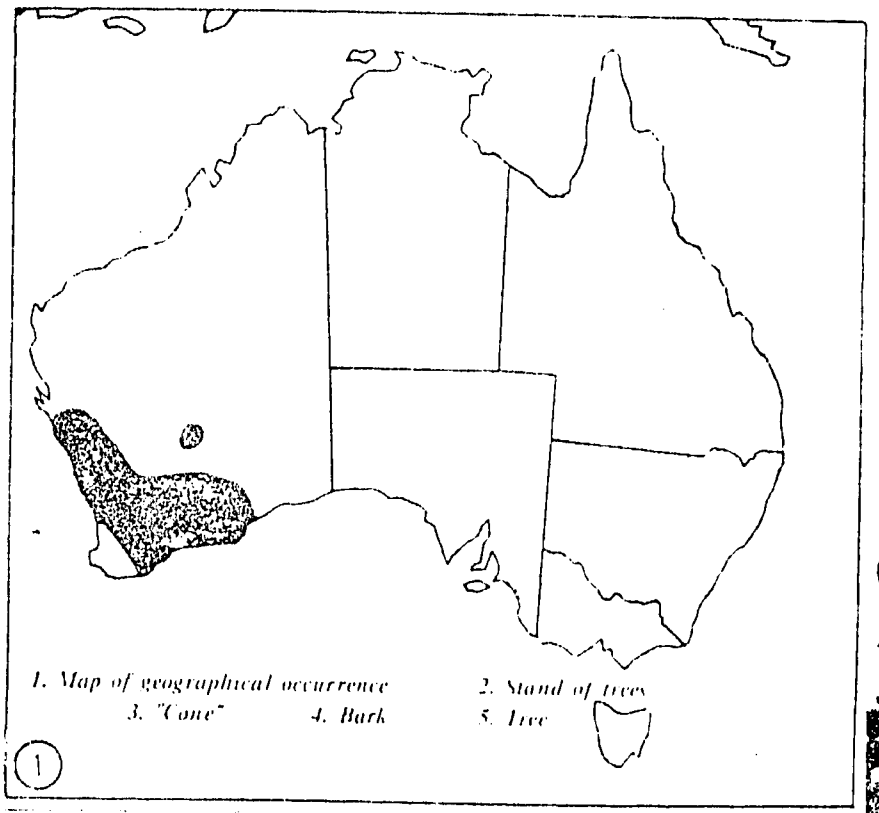
*Topography and soils: C.huegeliana* typically occurs on and around the scattered granitic outcrops of the Great Western Shield, but is also found on sand plains and on highly ferrugineous banded ironstone. Whilst this casuarina is often found on coarse granitic sands, it has been recorded from a wide range of soil types. These range from yellow clay-sands to sandy and gravelly loams, sandy clays, sandy types of all gradations and lateritic clays.

*Vegetation type:* The broad vegetation types include woodland in the main sheep–wheat belt east of Perth, and woodland in association with grassy open-shrub and some heath as well as a little shrubby open-shrub over the remaining area. Much of the area of occurrence is rich in species of small shrubs 1–5 m tall and there is a wide range of eucalypts.

*Fodder:* Unknown

*Wood:* Unknown

*Other uses:* The Forests Department of the State consider that this species merits greater attention than it has hitherto received for shade planting on poor, shallow sandy soils with a minimum rainfall of 380 mm. It is less suitable for shelterbelts since the moderately dense crown is carried on the upper part of the stem, though it can be used in association with lower storey shrubs such as *C.campestris*. The species also deserves consideration for ornamental planting on some difficult sites.



*1. Map of geographical occurrence* *2. Stand of trees*
*3. "Cone"* *4. Bark* *5. Tree*

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*Casuarina littoralis* Salisb. **BLACK SHEOAK**

*Principal features:* *C.littoralis* is usually a large shrub or small tree in the height range of 3–12 m. In forest and shrubland associations this species has an erect habit and narrow crown, but on windswept coastal heaths and very poor soils it may be reduced to a procumbent plant 0.1 m high, or a small shrub to 2 m where conditions are less severe. The bark is very dark in colour, hard but with somewhat corky layers, corrugated, up to about 3 cm thick.

The deciduous branchlets may be slender (0.5 mm diameter) or somewhat coarse (1–1.5 mm), usually erect but may be drooping on long thin permanent branchlets. They carry the whorls of 6–8 leaf-teeth. The "cones" are shortly ellipsoid to cylindrical, about 2–3 x 1.5–2 cm. The wooden bracts are conspicuous when open.

*Geographical occurrence:* Black sheoak has the widest geographic and altitudinal range of any Australian casuarina extending from Cape York at the northern tip of Queensland, southwards in a belt mainly within 100 km of the sea to Tasmania. In a few localities it extends to the inland side of the Divide and up to about 300 km from the sea. Whilst most plentiful under about 300 m altitude it is often common at elevations up to 1200 m (e.g. Mt.Warning, N.S.W.).

*Climate:* With such a wide geographical occurrence there is a correspondingly large variation in climate. Most of the occurrence is in the warm sub–humid and humid climatic zones. There are appreciable areas in the cool, sub–humid zone and some in the hot humid zone. Very little occurs in the cool humid areas. The incidence of frosts varies from 1–10 at southern, low altitudes to 30–70 at the highest altitudes in New South Wales. The 50 percentile rainfall is 650–1250 mm and the lowest on record 300–500 mm. In the far north rainfall follows a strong monsoonal pattern with very dry springs. This pattern changes southwards to a more or less uniform distribution in Tasmania.

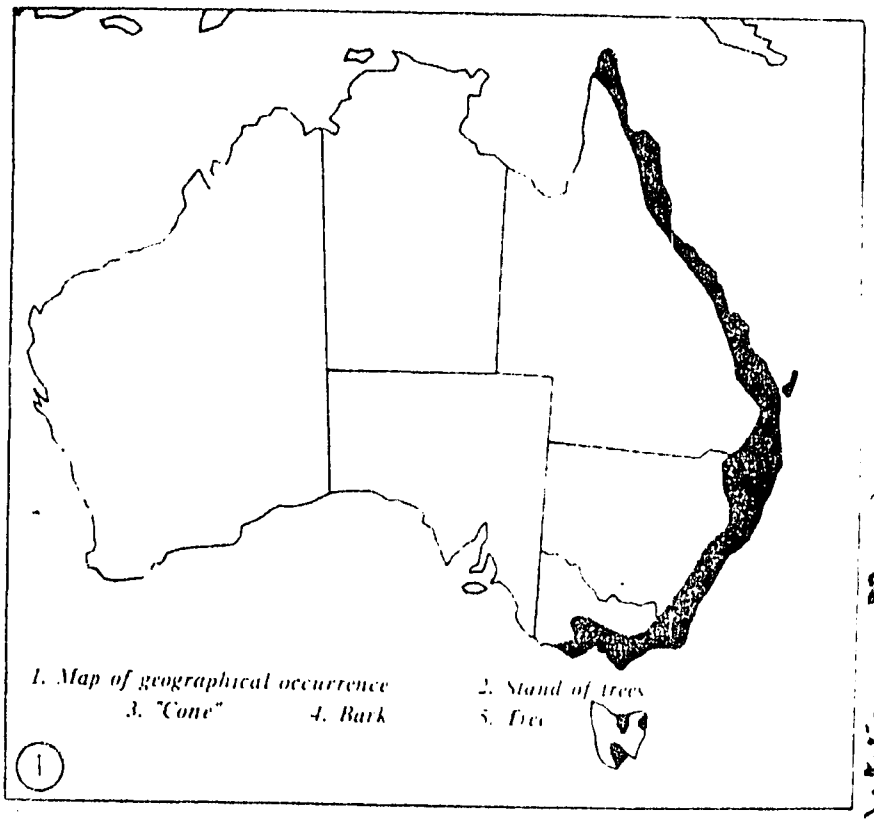
*Topography and soils:* Black sheoak grows on almost all sites from lowland flats to undulating topography and mountain peaks, though it is most common on well–drained hill and mountain slopes. It may be found in rocky gorges, near the edge of swamps, on heathlands and on sandy lowlands behind sandunes. The most common soils types are sands, podzolics, skeletals and rocky areas where soil is almost absent.

*Vegetation type:* This casuarina is mainly an understorey species of open–forest and tall open–forest, but occurs in woodland areas and in the more open patches with closed forest. It may also be present in both low and tall shrubland and in some mixed scrub may be a dominant species. Associated tree genera include *Eucalyptus, Angophora, Syncarpia,* and *Callitris* with a wide range of shrubs.

*Fodder:* The deciduous branchlets are eaten by stock only during times of major drought.

*Wood:* The heartwood is reddish brown, it is strong, moderately durable and very fissile due to the very prominent medullary rays. Density is about 960 kg $m^{-3}$. It is a first–class fuel. In the past black sheoak was used for a wide range of purposes including turnery, shingles, handles, yokes, rough furniture and in farm buildings.

*Other uses:* Black sheoak is an excellent tree for relatively low, narrow shelter belts and for use in avenues where larger trees are undesirable. Well–drained sites are preferred.



*1. Map of geographical occurrence* *2. Stand of trees*
*3. "Cone"* *4. Bark* *5. Tree*

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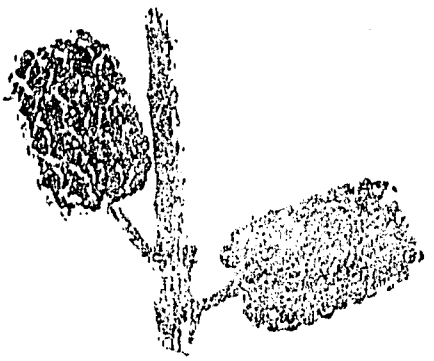

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*Casuarina luehmannii* R.T.Bak. **BULL SHEOAK**

*Principal features:* Bull sheoak is a small to moderate-sized tree usually in the height range of 9–15 m, though only 6–8 m on unfavourable sites. The trunk is erect and dominant for most of the tree height, and usually of moderately good form. The bark is blackish and furrowed.

The slender deciduous branchlets are more robust (mainly 1–1.5 mm diameter) than in most casuarinas, erect and rather wiry. They carry the whorls of 9–15 (often about 11) minute leaf-teeth (0.5–1 mm long). The leaf-teeth of the permanent branchlets remain characteristically adnate to the stem. The fruit are unusual in that they are crowded into squat cylindrical "cones" in which the length is distinctly less than the diameter, about 1–1.25 x 1.25–1.75 cm.

*Geographical occurrence:* The main distribution of bull sheoak is in a belt 60–150 km wide which extends from a small area in south-eastern South Australia, across central Victoria, along the Western Slopes of New South Wales into south-eastern Queensland as far as about 26°S latitude. In addition to this there is a large area where the species is relatively rare, including a disjunct occurrence in the far north (16–17$\frac{1}{4}$°S).

*Climate:* Throughout its range bull sheoak is mainly in the warm sub-humid climatic zone and with only a limited extension into the warm semi-arid zone in New South Wales and Victoria. Heavy frosts occur and average 4–18 (range 0–50) per year. The 50 percentile rainfall is 425–650 mm and the lowest on record 225–300 mm. The seasonal pattern varies from a slight winter maximum in the south to a weak summer maximum in central New South Wales and a well-developed summer peak in most of Queensland (monsoonal in the far north).

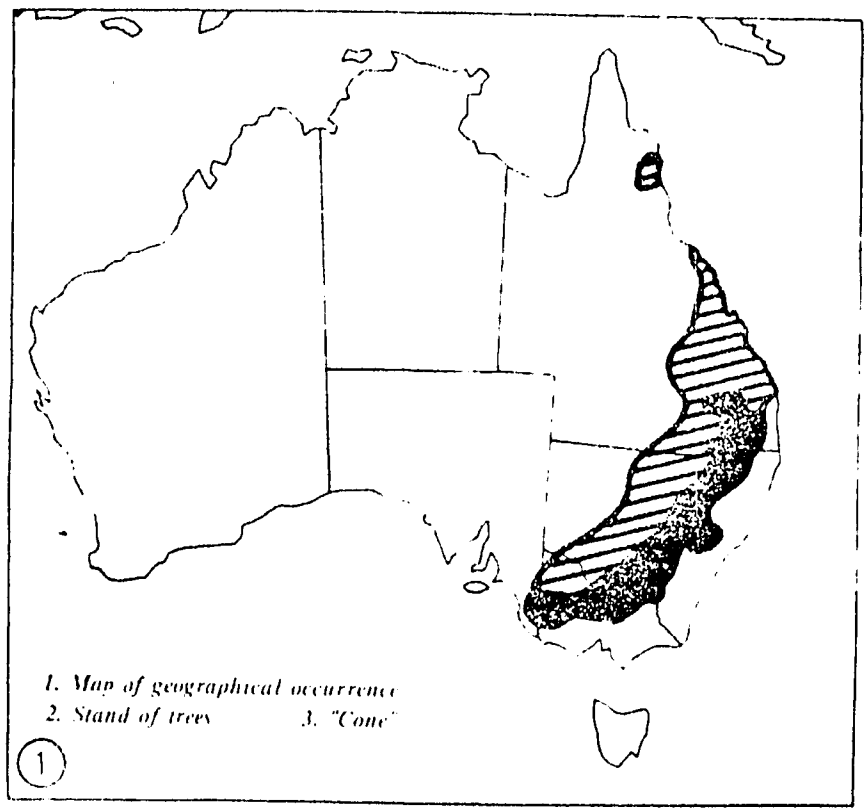
*Topography and soils:* Bull sheoak grows mainly on plains and gentle slopes, including the lower foothills of the Great Dividing Range. Only locally does it occur on ridges and other steep topography. Whilst the species mainly grows on sandy soils and light loams it has been reported from a wide range of soils including brown soils of heavy texture, stony and gravelly types and even inland sandhills.

*Vegetation type:* The broad vegetation type is mainly woodland, sometimes low open forest and, on marginal areas, sometimes tall scrubland. The main associated tree genera are *Eucalyptus*, *Callitris* and *Angophora* and a wide range of shrub species.

*Fodder:* The deciduous branchlets of this species are relatively coarse and wiry and are considered of negligible value for stock fodder.

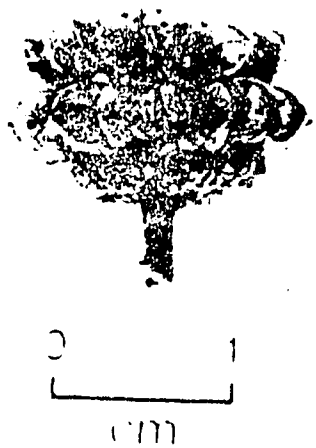
*Wood:* The heartwood is red, with rather coarse grain and prominent medullary rays. It is very heavy, hard and of moderate durability. Basic density is about 1100 kg m$^{-3}$. It does not season readily and is liable to splitting. The wood is an excellent fuel and has been used for many purposes in the past.

*Other uses:* Bull sheoak is suitable for amenity planting in parks or avenues in its climatic area. It will provide satisfactory but somewhat open shelterbelt protection and on moderately good sites early growth is relatively fast. Under some conditions the species develops a suckering habit and there are reports that it will withstand some seasonal inundation.

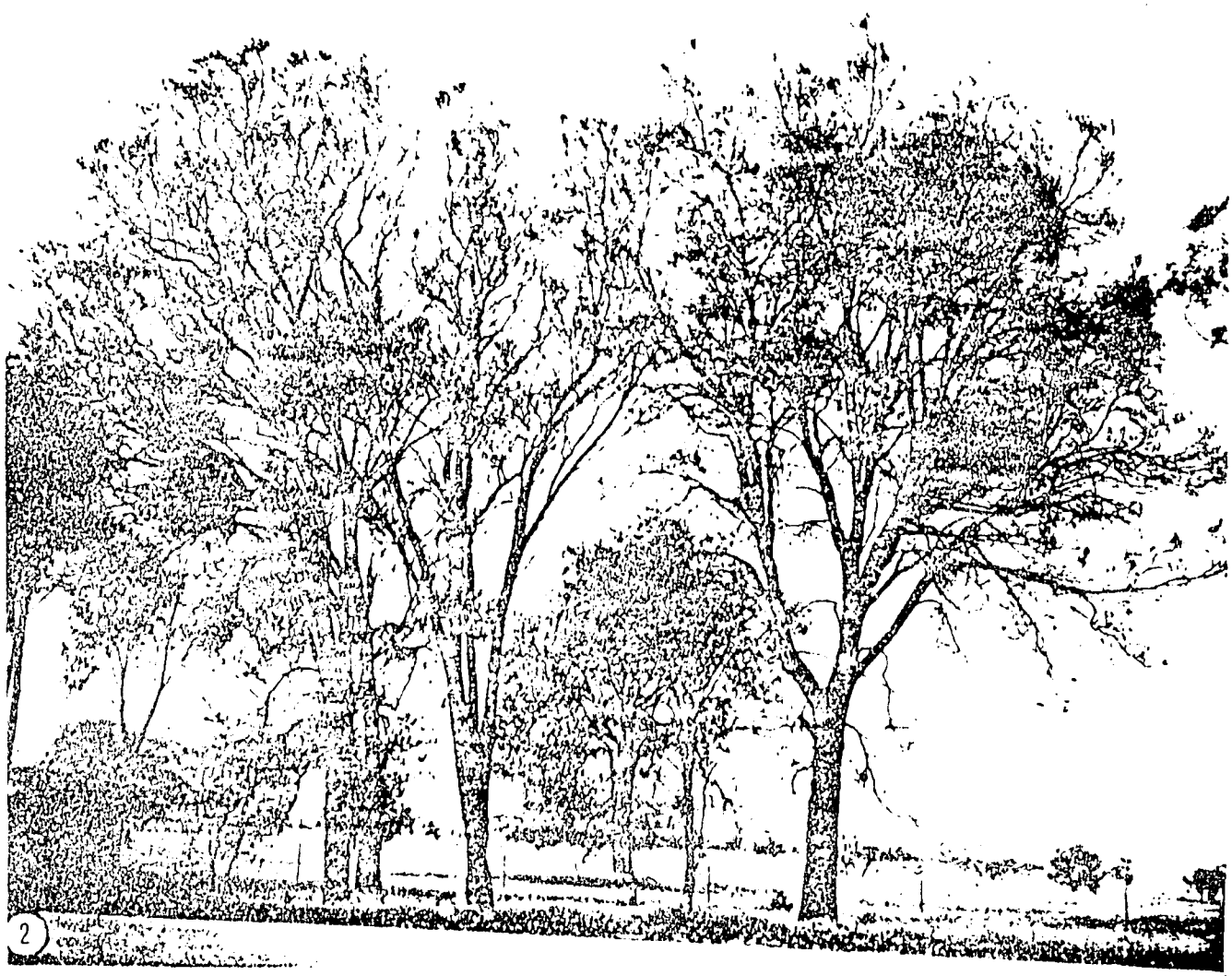


*1. Map of geographical occurrence*
*2. Stand of trees* *3. "Cone"*

1



3



2

*Casuarina obesa* Miq. WESTERN AUSTRALIAN SWAMP SHEOAK

*Principal features:* This casuarina varies from a shrub 1–2 m high on very unfavourable sites to a small tree 6–14 m high along stream banks and other sites with a favourable water regime. The main stem is branchless for much of the tree height and is usually moderately straight in closed stands in the better growing situations. The bark is hard, greyish with a tessellated appearance.

The deciduous branchlets may be erect and are of intermediate diameter for the genus (mainly 1–1.25 mm) and moderately flexible. The whorls of leaf-teeth are 9–11 in number and the individual teeth tend to be longer (1–2 mm) than in many of the Australian species of the genus. The leaf-teeth on permanent branches tend to peel off. The woody "cones" are globular, truncate, 1.5–2 x 1–1.5 cm, with thin, obtuse bracteoles.

*Geographical occurrence:* It appears possible that this casuarina had a much more extensive distribution in the past, than it has today. The main location is in southwestern Western Australia from the Murchison River to east of Esperance, and from near Perth to Kalgoorlie. This excludes the higher rainfall in the far southwestern corner of the State. In addition it has been collected in the drier and hotter parts of the State in what could be disjunct occurrences – near Cue south of Lake Carnegie and in the Lake Throssell area. Outside Western Australia it has been reported in western Victoria and in one small area in southern New South Wales. The range in altitude is from near sea level to about 300 m.

*Climate:* Most of the Western Australian distribution is in the warm sub-humid and warm semi-arid climatic zones, but there are what appears to be disjunct occurrences in the warm arid zone. Coastal areas, especially Perth northwards, are frost-free, but elsewhere there are 1–12 frosts per annum. With the exception of Perth and Esperance, which have higher than typical rainfall, the 50 percentile is 250–500 mm, and the lowest on record 125–275 mm. There is a strongly defined winter maximum.

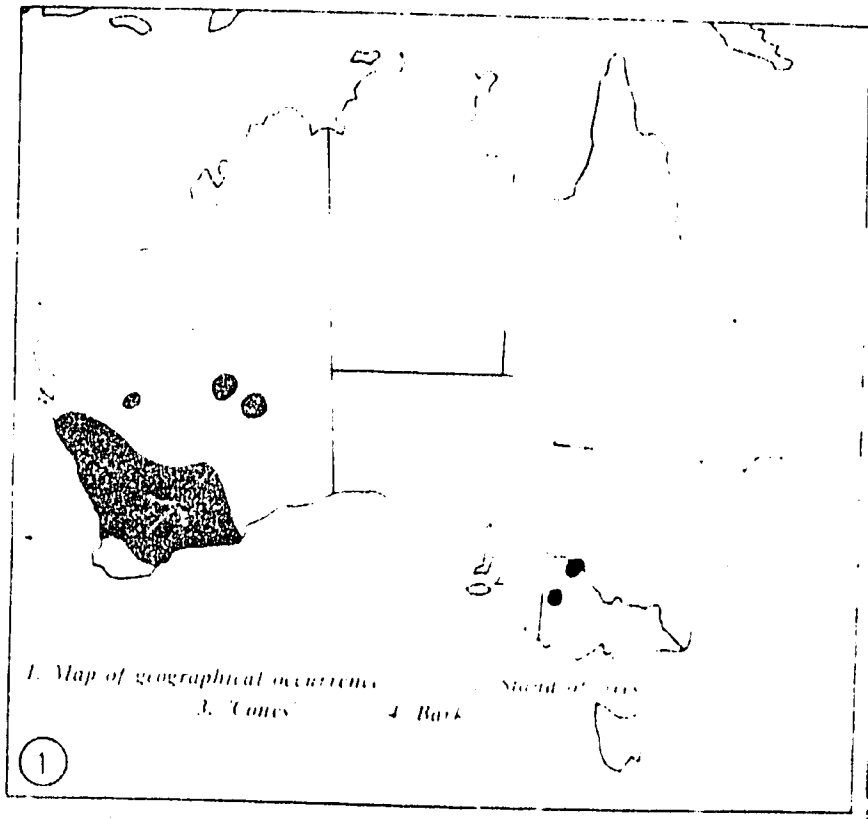
*Topography and soils:* The area of the Western Shield where *C.obesa* grows consists mainly of plains and gently undulating topography. The species has been collected from flats near high tide limits, river banks, the edges of salt (including gypsum) lakes and, somewhat atypically, from small hillsides. The soils include a wide range of sands and silts. Other types which have been recorded include pink granitic sands, stoney red soils, red clay loams and swampy soils. Only to a limited extent has it been noted on calcareous types.

*Vegetation type:* The broad vegetation types are mainly woodland and tall shrubland, but with smaller areas of grassy open-shrub and even some heath. Within these types *C.obesa* often occupies distinctive niches: low-lying seasonal swampy flats only just above high tide limits, along river banks as only a narrow belt often only 20–40 m wide and, inland, on the edges of salt lakes. In these areas it may grow as pure, dense thickets or as the principal large shrub/small tree with other trees.

*Fodder:* Unknown

*Wood:* It appears to possess the general attributes of the genus – striking medullary rays, very hard, heavy, somewhat difficult to work and a first class firewood.

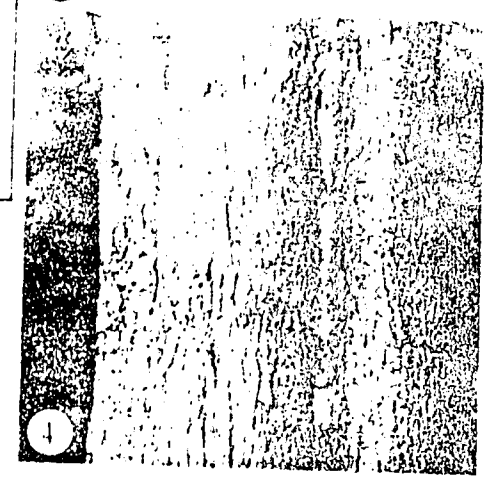
*Other uses: C.obesa* has a role in shelter belt, avenue and ornamental planting in its climatic area. In Western Australia it is in demand by farmers for planting on salt-affected lands.



1. Map of geographical occurrence
3. Cones 4. Bark

1

3



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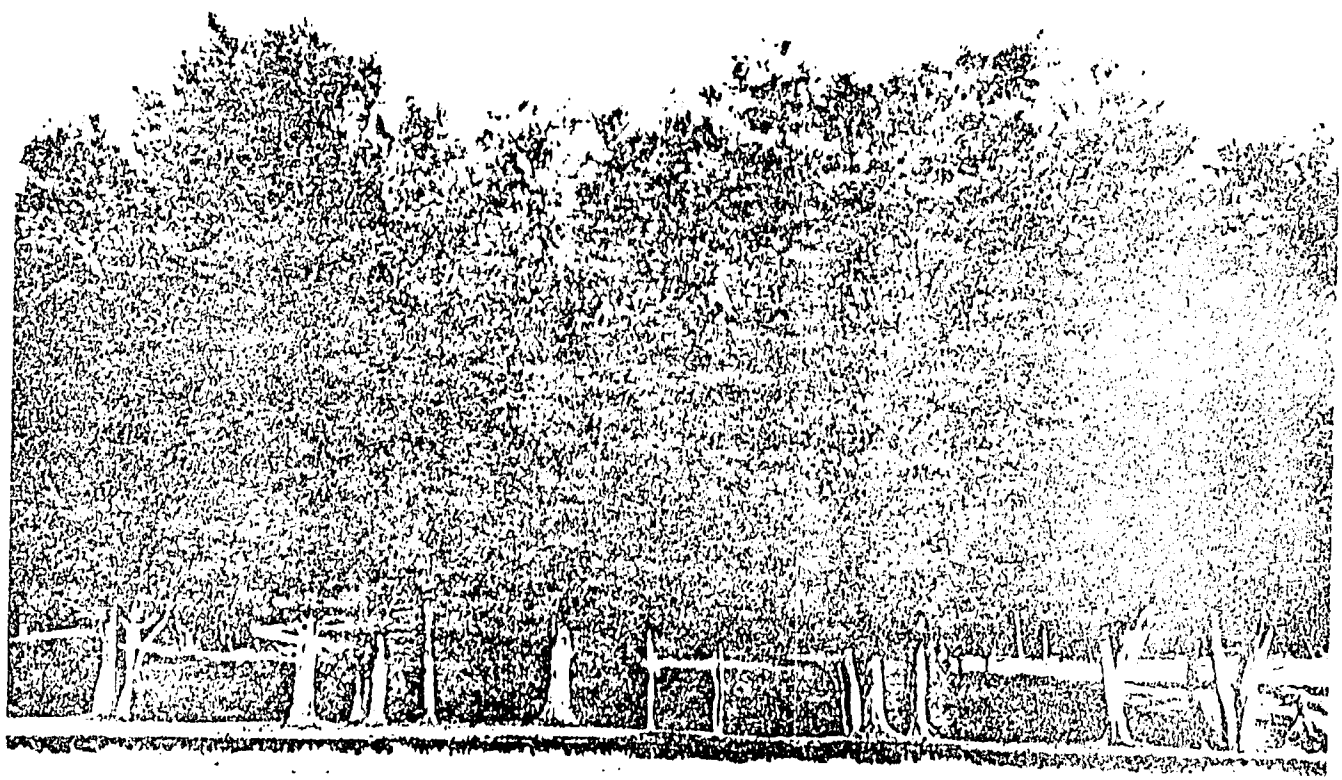


2

*Casuarina stricta* Ait. **DROOPING SHEOAK**

*Principal features:* This is typically a small tree with a straight but usually short main stem and a total height of 6–9 m. In the common, open-growing situation the crown is dense, deep and almost as wide as the tree is high. Occasionally *C. stricta* may be reduced to a bushy shrub of 2–3 m height. The bark is dark brown and fissured.

The deciduous branchlets are long, slender (about 0.75–1 mm diameter) and carry the whorls of 9–12 leaf-teeth. Typically the branchlets are drooping although this character is somewhat variable. The "cones" are large, 2–5 x 2–3.1 cm, with large acute bracteoles.

*Geographical occurrence:* Drooping sheoak occurs in the higher rainfall parts of South Australia from the Flinders Ranges to the south-east, most of Victoria (except the north-west and higher mountains), the Western Slopes, Southern Tablelands and Central and South Coast of New South Wales, and on the east coast and adjacent lowlands as well as parts of the north coast of Tasmania. The range in altitude is from near sea-level to about 750 m.

*Climate:* Most of the mainland distribution is in the warm sub-humid climatic zone but, on the inland side, edging the warm semi-arid zone. Both in Tasmania and at the higher altitudes on the mainland the climate is cool sub-humid. Immediately on the coast narrow strips are frost-free, but elsewhere the number of frosts per year are 2–40. The 50 percentile rainfall is 600–900 mm and the lowest on record 250–375 mm. Seasonal incidence varies from a nearly uniform distribution to a well-defined winter maximum.

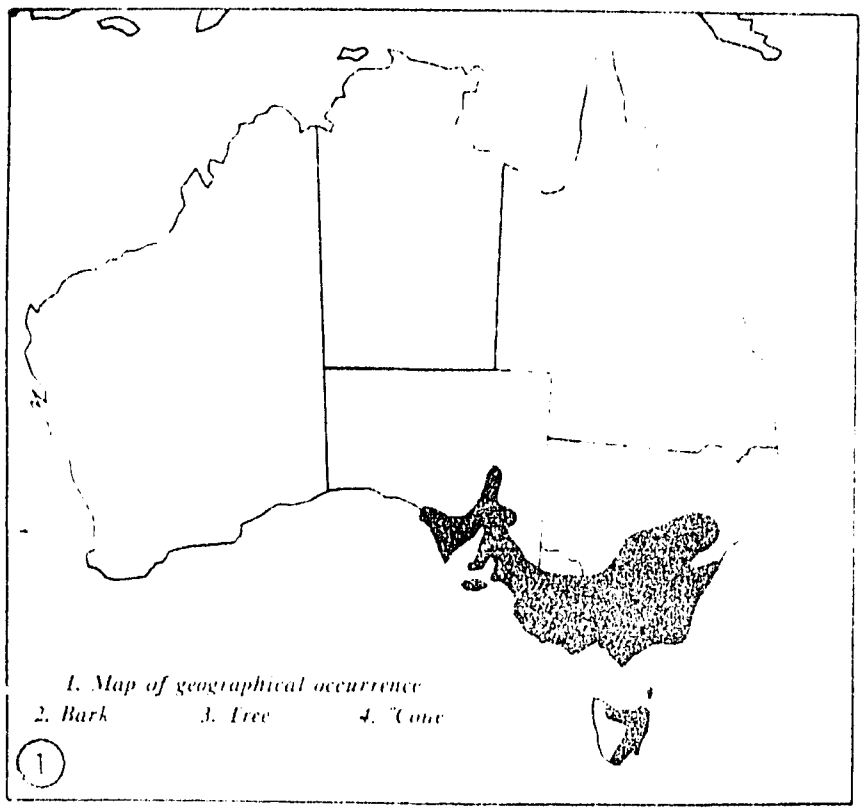
*Topography and Soils:* Drooping sheoak grows on a wide range of topography which varies from level or gentle countryside to exposed coastal headlands and cliffs, rocky gorges and ledges and mountain ridges. The generally poor soils show a wide range.

*Vegetation type:* The broad forest types include woodland and low woodland/tall shrubland as well as gaps in open-forest. Only occasionally is it the dominant plant, but it should be noted that many areas where it was once common have now been cleared or partly cleared for farming. Species with which it may be associated include many acacias, banksias, eucalypts and cypress pines.

*Fodder:* A useful fodder plant, attractive to stock. The trees stand lopping well and this allows most of the smaller branches of the crown to be cut off in times of severe drought without the trees dying.

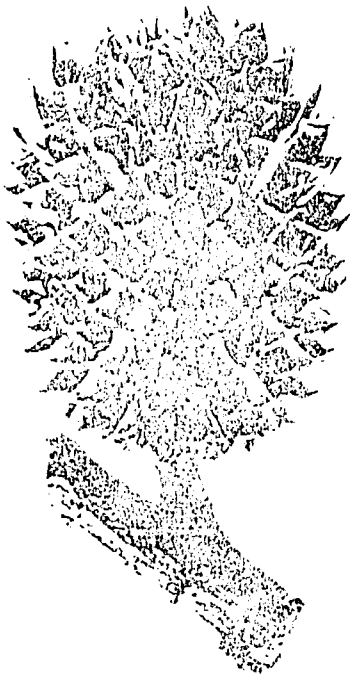
*Wood:* The heartwood is heavy, hard, fissile and with large medullary rays typical of the genus. It can be easily machined and takes a ready polish. Durability in the ground is sufficient for use as fence posts. Nowadays the timber use is restricted to fancy articles (turnery) and fuel for which it is outstanding. Formerly it was used for bullock yokes, wheel-spokes, axe-handles, staves and shingles.

*Other uses:* On even moderately-good soils open-grown specimens are useful for shade and ornament, as well as being available for drought fodder in areas where rainfall is as low as 350 mm, but preferably above 450 mm. Height growth for the first 3–5 years is usually excellent but plants must be protected from browsing by stock and rabbits.



*1. Map of geographical occurrence*
*2. Bark* *3. Tree* *4. Cone*

1



0 1
cm

4

2



3

*Casuarina torulosa* Ait. **FOREST SHEOAK**

*Principal features:* Forest sheoak is a medium-sized tree attaining 12–20 m in height and 0.3–0.6 m in diameter and is usually an understory species. On favourable sites trees attain about 25 m in height and 1 m in diameter. The bole is half or more of tree height, the main branches are spreading to erect and the crown has an open appearance. The bark is thick, very dark grey to almost black, sub-tessellate and deeply furrowed.

The slender, green (often coppery), drooping deciduous branchlets have whorls of 4(–5) small leaf-teeth. The woody "cone" is globular to sub-cylindrical with a flattish top, 2–3 x 1.8–2.3 cm, on a long, thin stalk.

*Geographical occurrence:* This is a species of the coastal ranges of eastern Australia from Coen in north Queensland to south of Nowra in central New South Wales. It occurs throughout the northern and central coastal, and coast range regions of New South Wales but only to a limited extent in the south, whilst in Queensland it is found in coastal areas and on the upper slopes of the Dividing Range. It also occurs on Fraser Island, Blackdown Tableland and the Eungella Range. The altitudinal range is from near sea level to 1100 m.

*Climate:* The distribution is in the warm sub-humid and humid climatic regions. For the northern areas the number of frosts are 1–5 per year at high altitudes but absent at sea level, whilst further south the number is about 5–20. The 50 percentile rainfall is 950–1250 mm and the lowest on record 400–600 mm. Maximum precipitation is in the summer.

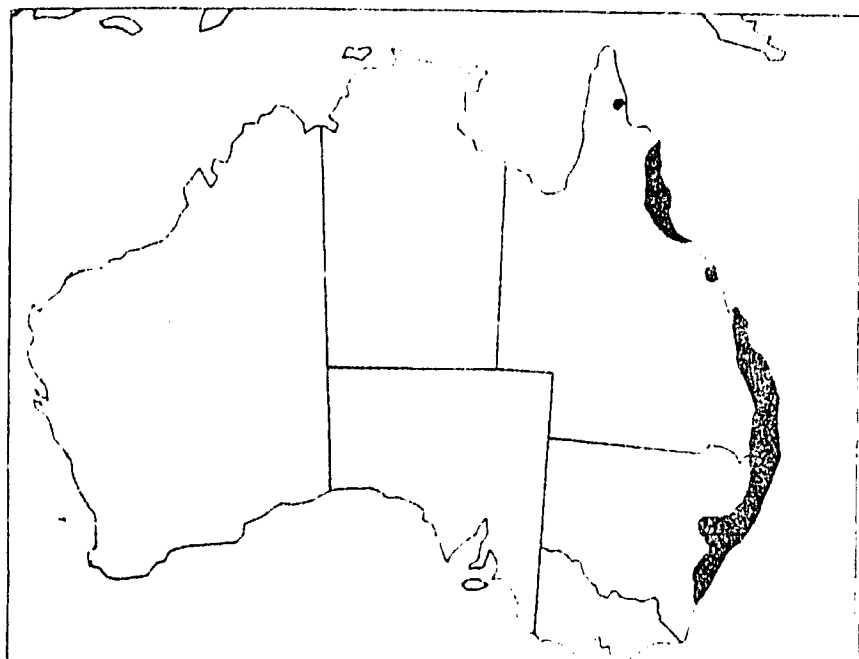
*Topography and soils:* The major land form in which this species occurs is the geologically complex Eastern Uplands. Forest sheoak has been recorded on steep slopes, moderate hillsides, tablelands, and undulating lowlands, whilst rock types noted include tertiary basalts, rhyolite, quartzite, various sedimentary rocks, sandstone and shale. Apart from deep podsols, the soils vary from sandy alluvials to rather heavy clays.

*Vegetation type:* Forest sheoak is typically an understory species in open-forest to tall open-forest formations. Over such a wide geographical occurrence, it is not surprising that it is often associated with a large number of trees which include the major commercial species of eastern Australia. Apart from a wide range of *Eucalyptus* species it is often associated with *Syncarpia, Tristania, Alphitonia, Angophora* and *Acacia* species.

*Fodder:* Unknown but unlikely to be of value.

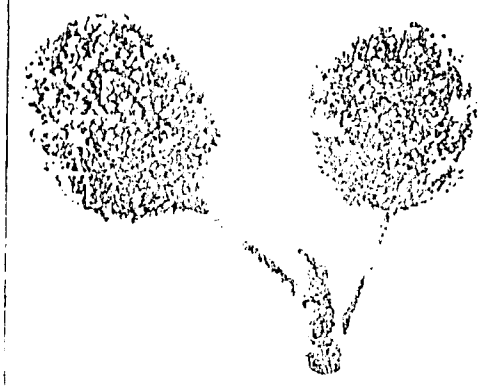
*Wood:* The pale sapwood is narrow (only a few centimetres) whilst the dark red heartwood has very large medullary rays of a darker colour. It is heavy, density 1000 kg $m^{-3}$, hard, strong, fine-grained other than for the rays, very fissile and machines and turns well. It dries slowly and is prone to checking on back-sawn boards. Wherever suitable logs are available in current logging areas it is milled and used for flooring, parquetry, small cabinet work, fancy turnery and special veneers. It is still used for shingles required for restoration of historic buildings. This species was rated very highly for burning in baker's ovens.

*Other uses:* Forest sheoak should be considered for amenity planting in suitable areas. It can be used for single-row shelter belts, with spacing between trees of 3–4 m, or in staggered two-row belts.



1. Map of geographical occurrence 2. Stand of trees under eucalypts
3. "Cones" 4. Bark 5. Tree

1




3

4



2

ACKNOWLEDGEMENTS

We are pleased to acknowledge the assistance of Dr.L.A.S. Johnson and Mrs.K. Wilson of the National Herbarium, Sydney and Dr.R. Johnson of the Queensland Herbarium, who gave permission for one of us (N.H) to examine specimens of the genus. We thank Mr.D.G. Boland for his comments on the manuscript and Mr.B.A. Rockel and Mr.P.N. Martensz for technical support.

GLOSSARY

*bract:* . . . . A modified leaf that supports the flower. In casuarina "cones" it is usually a small, thin, laterally disposed structure beneath the bracteoles.

*bracteoles:* . . . . Of casuarina flowers and fruit. Each samara is enclosed by one laterally disposed bract and two vertical bracteoles. It is the bracteoles that are usually most conspicuous on mature "cones". The backs of the bracteoles are either smooth or have markings that often characterise a species e.g. markings may be striations, tessellations, rounded or long awl-like protuberances.

*"cones":* . . . . . These have been also called "infructescences". In casuarina they consist of compact, attenuate whorls of female flowers (consisting of one bract plus two bracteoles and a samara). The arrangement of flowers is homologous with the arrangement of leaf-teeth on the branchlets; the number of flowers per whorls being often closely similar. When flowers are fertilised (by wind) the "cones" become very woody. The cone is supported by a short stalk. "Cones" may fall early or persist over several seasons depending upon species.

*deciduous branchlets:* . . . These are the branchlets of determinate length that are borne on the permanent branchlets and carry out to the main photosynthetic role. As the tree ages these branchlets die and fall (usually lasting 1, 2, or 3 years) as whole units.

*kg m $^{-3}$:* . . . . . Of wood density. Kilograms per cubic metre, determined at 12% moisture content (air dried).

*leaf-teeth:* . . . . Of casuarina leaves. Small scale-like triangular projections collectively forming a whorl at the joints on the branchlets. Easily observed by breaking the deciduous branchlets at any joint. The leaf-teeth are considered to be the true leaves (or the extremity of a leaf adnate to the stem) of casuarinas. The juvenile leaf-form of some species e.g. *C.campestris* and *C.acutivalvis* produce quite elongated succulent leaves. The adult leaf-form of all casuarinas is much reduced.

*medullary ray:* . Thin, vertical plate of parenchyma cells, one to several cells wide, running radially through the tissues of the stele. The function of the medullary rays is in storage and radial conduction of synthesized food material. Very prominent in casuarina being darker than surrounding wood and being many times taller than wide.

*permanent branches/ branchlets:* Of casuarinas. These are the branches (in older trees) of determinate length that bear the deciduous branchlets. As branchlets they may be similar or quite distinct from deciduous branchlets. As permanent branchlets age the photosynthetic role is lost and they become very enlarged and woody. Very distinctive in the *C.glauca* and *C.cunninghamiana* group of species.

*seed:* . . . . . Of casuarina seed. Really a samara or winged achene. A dry, one-seeded, winged fruit formed from a single carpel, with no special method of opening to liberate the seed. In *Casuarina* the seed are usually smooth-sided but "seed" in a few species are hairy e.g. *C.grevilleoides*. The wing is usually thin with the remains of the style, being centrally and longitudinally located and embedded in the wing.

*sheoak:* . . . . . The word "she" has been attributed to various origins. One is the occurrence of female (as well as male) trees in the genus *Casuarina*. Another suggestion is the sound (shee) that the branchlets make as the wind gently tosses the tree crowns. The term "oak" refers to the resemblance of the figure of the casuarina wood (with medullary rays etc.) to that of the oaks (*Quercus* spp.)

*striate:* . . . . . Used in reference to the back of the bracteoles in the "cone". Marked with fine longitudinal more or less parallel lines; as grooves or ridges.

TABLE - A SUMMARY OF THE MAIN CHARACTERISTICS AND USES OF FIFTEEN AUSTRALIAN *CASUARINA* SPECIES.

*Reference Code*

1 = very suitable for the purpose.

2 = can be used for the purpose, but may be subject to limitations as indicated in the text.

R = recommended for trial planting (in many cases species are considered suitable, e.g. for amenity planting but have not been used for such purposes or only to a limited extent in Australia).

X = not suitable for the purposes listed (as far as is known). Where there is no entry it means there is no reported use of the species for such purposes and also does not fall into category 'R'

| *Botanical name, common name* | *Geographical occurrence* | | | *Climatic summary* | | |
|---|---|---|---|---|---|---|
| | *Lat. °S* | *States* | *Alt. m* | *Meteorological reference stations* | *Climatic zones* | *No. of Frosts per year* |
| *Casuarina campestris* a sheoak | 27–34½ | WA, s'western, but not in wettest SW | 0–375 | Geraldton, Merredin, Esperance | Warm semi-arid<br>Warm arid | 0–12 |
| *C. cristata* subsp. *cristata* belah | 22½–34½ | Qld, NSW, mainly on inland side of coastal ranges | 175–325 | Emerald, Miles, Narrabri, Dubbo | Warm semi-arid<br>Warm sub-humid | 2–50 |
| *C. cristata* subsp. *pauper* black sheoak | 26–36 | WA, SA, W of NSW, edges of Qld & Vic | 25–400 | Kalgoorlie, Kimba Mildura, Bourke | Warm arid<br>Warm semi-arid | 1–17 |
| *C. cunninghamiana* river sheoak | 12½–37 | Coastal streams of NT, Qld & NSW | 0–1000 | Katherine, Bundaberg, Casino, Canberra | Warm sub-humid<br>Warm semi-arid | 0–50 |
| *C. decaisneana* desert oak | 21½–27 | Southern NT, adjacent SA & WA | 250–700 | Yuendumu, Alice Springs Curtin Springs | Arid | 1–12 |
| *C. dielsiana* | 26½–31 | Western WA, near Sharks Bay to Southern Cross | 50–375 | Geraldton, Southern Cross, Mullewa | Warm semi-arid | 0–11 |
| *C. equisetifolia* var. *equisetifolia* coast sheoak | 11½–19 | Coastal NT, Qld | 0–100 | Darwin Cairns | Hot humid<br>Hot sub-humid<br>Warm sub-humid | 0 |
| *C. equisetifolia* var. *incana* coast sheoak | 19–31½ | Coastal Qld, NSW | 0–100 | Bundaberg, Kempsey | Hot sub-humid | 0–3 |
| *C. fraserana* frasers sheoak | 31–35 | Coastal belt of southwestern WA | 50–500 | Pemberton, Perth | Warm humid<br>Warm sub-humid | 0–11 |
| *C. glauca* swamp sheoak | 23–36½ | Coastal strip, Rockhampton Qld, to Bega NSW | 0–30 | Bundaberg, Parramatta, Bega | Warm humid<br>Warm sub-humid | 0–5 |
| *C. huegeliana* granite sheoak | 27½–35½ | Southwestern WA | 0–450 | Merredin, Norseman | Warm semi-arid<br>Warm sub-humid | 0–6 |
| *C. littoralis* black sheoak | 10½–43 | Coast & near ranges, C York Qld to NSW, Vic, Tas | 0–1200 | Atherton, Ingham, Brisbane, Dorrigo, Orbost, Hobart | Hot/warm humid<br>Warm sub-humid<br>Cool sub-humid | 0–70 |
| *C. luehmannii* bull sheoak | 16–37½ | Eastern Qld, central NSW, northern Vic, edges of SA | 0–800 | Inglewood, Dubbo, Bendigo, Bordertown | Warm sub-humid<br>Warm semi-arid | 0–18 |
| *C. obesa* Western Australian swamp sheoak | 26–37 | Southwestern WA minor occurrence in SA | 0–360 | Geraldton, Kalgoorlie, Norseman | Warm sub-humid<br>Warm semi-arid<br>Warm arid | 0–12 |
| *C. stricta* drooping sheoak | 31½–38½ | Southern Australia – SA, Vic, NSW, Tas | 0–750 | Keith, Horsham, Bendigo, Hobart Canberra, Dubbo | Warm sub-humid<br>Warm semi-arid<br>Cool sub-humid | 0–40 |
| *C. torulosa* forest sheoak | 15½–39½ | Coast & near ranges, Cairns to Nowra area NSW | 0–1100 | Atherton, Brisbane Dorrigo, Taree Pennant Hills | Warm sub-humid<br>Warm humid | 0–20 |

| Rainfall | | Size | The more important uses which have been reported | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | The living tree | | | | | | | Timber | | | | |
| Range of 50 percentile values | Season | Range of mature height(m) | Tolerance to salt | Shelter and windbreaks | Soil conservation | Shade | Ornament | Street planting | Drought fodder | Sawlogs | Poles | Fencing material | Turnery and special items | Firewood |
| 225–400 | W | 2–3 | | 1 | 1 | | 2 | | | X | X | X | | |
| 550–650 | U–S | 10–20 | | 1 | | 2 | 1 | 1 | 2 | 2 | 2 | 2 | 1 | 1 |
| 175–275 | W–S | 10–16 | 2 | 2 | | 2 | 2 | 2 | 2 | 2 | | 2 | 1 | 1 |
| 500–1500 | S | 10–35 | | 1 | 1 | 2 | 1 | | | 2 | | 2 | 1 | 1 |
| 250–700 | U–S | 9–15 | | | | R | R | R | | 2 | | 1 | 1 | 1 |
| 275–400 | W | 4–10 | | 2 | 2 | 2 | 2 | | | | | | 2 | |
| 1000–2150 | S | 9–16 | ? | | 2 | | | | | | | | | 1 |
| 1000–1500 | S | 6–10 | 2 | X | 2 | 2 | 2 | 1 | | | | | | 1 |
| 900–1250 | W | 5–15 | | R | | R | R | R | | 2 | | 2 | 1 | 1 |
| 900–1150 | S | 10–14 | 1 | 2 | | 2 | 1 | 1 | | 1 | 2 | 1 | 1 | 1 |
| 300–500 | W | 5–12 | | 2 | | 2 | 2 | 2 | | | | | | 1 |
| 650–1250 | U–S | 4–12 | | 1 | | 2 | 1 | 2 | | 1 | 2 | 1 | 1 | 1 |
| 425–650 | W–U–S | 9–15 | | 2 | | 2 | 1 | 1 | 2 | 2 | 2 | 1 | 1 | 1 |
| 250–500 | W | 6–14 | 1 | | | | 1 | 1 | | | | | | 1 |
| 600–900 | W–U | 6–9 | | | | 1 | 1 | 2 | 1 | 1 | | 2 | 1 | 1 |
| 950–1250 | S | 12–20 | | 2 | | 2 | 1 | 1 | | 1 | | 2 | 1 | 1 |

*Season*
S – summer
W – winter
U – uniform

# SECTION II

## REPORT ON CASUARINA OLIGODON IN THE HIGHLANDS OF PAPUA NEW GUINEA (EASTERN HIGHLANDS PROVINCE)

# *REPORT ON CASUARINA OLIGODON*

# *IN THE HIGHLANDS OF PAPUA NEW GUINEA*

# *(EASTERN HIGHLANDS PROVINCE)*

*CASUARINA MEETING*

*17 - 19 AUGUST 1981*

*CANBERRA - AUSTRALIA*

*ANDREW ATAIA*

*DEPARTMENT OF THE EASTERN HIGHLANDS*

*OFFICE OF FORESTS*

*GOROKA EHP*

# *CASUARINA OLIGODON*

## *IN THE EASTERN HIGHLANDS PROVINCE*

## *PAPUA NEW GUINEA*

### 1 *INTRODUCTION*

*The Office of Forests association with casuarina oligodon dates back to the early 1950's when the Forests Department advised the Patrol Officers to set up nurseries throughout the Highlands, especially in the Eastern Highlands Province, which provided a source for distribution of seedlings of casuarina oligodon, and at the sametime the local people were taught the value of "YAR" (casuarina oligodon) and so the previously known "YAR" culture of the Chimbu Province was spread.*

*This had come about due to the predominance of grasslands, mainly Kangaroo grass (Themeda australis) with various species of kunai grass (Imperata species), all maintained by frequent firing carried out by the local people during hunting and for safety purposes where hostile neighbouring tribes were prevented from hiding in the bushes and ambushing them.*

*The process of burning off the grass killed off any young trees and shrubs from growing, causing the valleys to be short of wood as a source of fuel wood, housing, fencing materials, etc and this in some cases caused people to do their cooking with dried pitpit (Saccharum species).*

*Seeing the problem of wood shortage the Patrol Officers discouraged the annual burnings of the grasslands and the change in social behaviour with regard to tribal warfare helped the extension programme by both the Patrol Officers and the Office of Forests of casuarina oligodon together with many Pinus, Araucaria and Eucalyptus species both native and exotic, to change the landscape which about thirty (30) years ago was mainly grassland to an attractive and varied landscape with trees and shrubs of many kinds, with casuarina oligodon being the dominant species, dotting the landscape and every village to have its share of trees.*

E. Fruit - Fruit proper is a small samara; it is held by the enlarged and hardened scales which are fused into a small woody cone less than 1cm in diameter.

It must be noted that the species in Papua New Guinea are similar in most aspects but Casuarina oligodon differs by having smaller cones (diameter less than 1cm) (7mm) and widely spaced broad rays in the wood.

## 2.2 NATURAL DISTRIBUTION

### 2.2.1 Climate

The species grows in areas where the rainfall ranges from 1 900mm to 2 600mm with high relative humidity throughout the year.

### 2.2.2 Soil

Casuarina oligodon is mostly found in sandy soils along creeks and rivers but grows well in colluvial soils, humic brown clay soils, alluvial and meadow soils.

### 2.2.3 Topography

The species is found mostly in the Highland valleys at altitudes ranging from 1 500m to 1 800m and occurs commonly on stream banks and ridge tops and on old garden and village sites.

### 2.2.4 Associates

Casuarina oligodon forms extensive pure stands along river beds but at times is seen to be associated with C. Papuana.

## 2.3 VARIATION

i Provenance differences in growth.

ii Form

* With regard to this no research has been done, however, there seem to be no noticable difference between provenances.

MISSING PAGE NO. 7

2.5.3 Competition

What can be seen with casuarina oligodon is that it can do well even with competition from grass (Imperata exaltata, saccharum robustum, themeda australis etc) and trees and shrubs found in old garden sites, river beds, etc.

2.5.4 Wind

The species ability to withstand high winds is high except in cases where branches being too heavy causes them to snap off.

## 3 AFFORESTATION WITH CASUARINA OLIGODON

As the Office of Forests in the Eastern Highlands Province does not carry out afforestation through plantations of C. oligodon, the following information is related only to extension plantings.

### 3.1 SITE

Most sites in the Highland valleys which are mostly covered by grass are ideal for afforestation with the species, however, afforestation in pure grasslands areas on steep mountain slopes might provide limitations and needs looking into.

### 3.2 SEED SOURCES

3.2.1 Provenance

At present our seed collections are from any available/free tree sources that can be found in the Province as no provenance trials have been made of the species.

3.2.2 Storage

Storage of casuarina oligodon seeds are in household refrigerators where they are kept till needed for sowing in seedling beds.

3.2.3 Testing

No testing is done of seeds as all seeds are germinated on a seed bed and pricked after they are ready for transplanting into black polythene tubes.

3.4.6 Special Features

Since the Highland valleys are mostly grasslands any natural regeneration of c. oligodon is welcomed and, therefore, has not created any problems as a weed.

## 4 USES OF CASUARINA

### 4.1 ANIMAL FEED

The species has not been used as a feed source for animals in the Highlands which could be due to sufficient grass species available for use as animal feed.

### 4.2 WOOD PRODUCTS

i Durability

Casuarina oligodon is moderately durable to durable with regard to resistance of untreated heart-wood to attack by wood-destroying fungi and termites.

ii Preservatives

With regard to treatment of timber of casuarina oligodon, it has been found by the Forest Research Centre in Port Moresby that the permeability of preservatives of the species is not good mainly with the heart-wood with the exception of the sap wood and so is generally considered as untreatable.

iii Uses

Round posts for construction, poles, fences suitable for use in the ground and for unprotected extension use in buildings, protected extension and intension work.

Speciality uses of c. oligodon include tool handles, shuttles and permanently submerged freshwater piles.

### 4.3 FUEL WOOD

The demand for fuel and the fact that many Highland areas have gone to grasslands make c. oligodon, which is a good source of firewood, to be very useful.

No research on the calorific value of the species has been done by Forest Research in Port Moresby, but has been recommended as a good source of charcoal.

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# SECTION III

# EXCERPTS FROM AN UPCOMING NATIONAL ACADEMY OF SCIENCES PUBLICATION ON CASUARINAS

Casuarina equisetifolia

Botanic Name Casuarina equisetifolia L.

Synonyms Casuarina littorea

Common Names Casuarina, she-oak, horsetail oak, Australian beefwood, Australian pine, ironwood, whistling pine, agoho (Philippines), ru (Malaysia), filao, nokonoko (Fijian)

Family Casuarinaceae

Main Attributes Almost all of the approximately 35 Casuarina species produce top-quality firewood. There are rapid-growing, carefree species for sites and climates as varied as coastal sand dunes, high mountain slopes, the hot humid tropics, and semiarid regions. They tend to be salt tolerant, wind resistant, and adaptable to moderately poor soils. Although they are not legumes, they do have the ability to fix atmospheric nitrogen.

Casuarina equisetifolia is, perhaps, the most widely used so far, but other Casuarina species deserve more attention and testing.

Description Viewed from a distance, casuarinas look like somber pine trees with long, drooping, gray-green needles and small cones. They are medium to lofty evergreens with open, feathery crowns that appear to be leafless. The leaves are actually reduced to small sheaths on the needle-like branchlets. By dispensing with leaves, the plants have reduced the surface exposed to the elements and this makes them adaptable to dry sites and salt spray.

Casuarina equisetifolia can attain heights of up to 50 m, with diameters of up to 18 cm. However, it is commonly only 15 - 25 m tall.

Distribution Casuarina species are native to the Southern Hemisphere from tropical India to Polynesia. Most are native to Australia where they occur in subtropical and tropical coastal regions as well as in the arid central areas.

Casuarina equisetifolia is indigenous to north and northeast Australia, some Pacific Islands, and from Indonesia and Malaysia to India and Sri Lanka. It has been introduced for firewood, beautification, and other purposes to India, Pakistan, East, Central, and West Africa, and West Indies, as well as to Florida and the Gulf of Mexico area in the United States.

Use as Firewood The wood of Casuarina equisetifolia burns with great heat and has been called "the best firewood in the world." It is used for both domestic and industrial fuel. In India, it fuels some railroads and in the State of Karnataka, for example, it is the major species planted for firewood. It burns readily, even when green, and the ashes retain heat for a long time. It makes exceptionally fine charcoal. It has a specific gravity of 0.8 - 1.0 and calorific value of 4,950 kcal per kg.

Yield On good sites in Malaysia and the Philippines the tree commonly grows 2 - 3 m a year. In general, the yield per ha varies from 75 - 200 t, on a rotation of 7 - 10 years, with a spacing between plants of about 2 m. In the Philippines,

even higher yields have been noted.

Other Uses

° Wood. Timber is generally dark colored, fissile, strong, heavy, and very tough. It is used for house posts, rafters, electric poles, mine props, roofing shingles, tool handles, oars, yokes, and wagon wheels.

° Erosion control. Because it is salt tolerant and can grow and reproduce in sand, Casuarina equisetifolia is used to control erosion along coastlines, estuaries, riverbanks, and waterways.

° Windbreak. An abundance of switchy twigs absorb wind amazingly well. A wind strong enough to blow hats off can be stripped of its force by a belt of casuarinas 2 or 3 deep, leaving the leeward air heavy and still.

° Dye, tanning. The bark contains 6 - 18 percent tannin and has been used extensively in Madagascar for tanning purposes. It penetrates the hide quickly and furnishes a fairly plump, pliant, and soft leather of pale reddish-brown color.

° Pulp. The wood has been found to make a good pulp by use of the neutral sulfite semi-chemical process.

Environmental Requirements

° Temperature. This is a species for warm to hot subtropical and tropical climates. The monthly mean maximum temperature in its native areas are 10° - 33°C, but it is adapted to a wide range of temperatures. It is not frost-hardy, although some

other Casuarina species are.

° Altitude. This is a lowland tree which can be planted from sea level up to 1,500 m.

° Rainfall. In its natural habitat, rainfall is from 700 to 2,000 mm annually, often with a dry season of 6 - 8 months. However, it has been planted successfully in areas with as little as 200 - 300 mm rainfall or as much as 5,000 mm annually.

° Soil. Casuarina equisetifolia trees have root nodules containing nitrogen-fixing actinomycetes bacteria. They are therefore not dependent on soil nitrogen for good growth. The species tolerates calcareous and slightly saline soils, but it grows poorly on heavy soils such as clays. It can withstand partial waterlogging for a time.

Establishment The trees produce seed plentifully. Normally, seedlings are raised in a nursery for transplanting to the field. Transplanting is carried out at the onset of the rainy season, 4 - 18 months after sowing. In dry sites, irrigation may be needed immediately after transplanting and as long as the first 3 years.

° Seed treatment. When seeds are planted outside their natural range, the soil should be inoculated with crushed nodules from natural stands. They should also be treated to repel ants.

° Ability to compete with weeds. Initially poor, especially in dense grass cover.

Pests and Diseases Seedlings are vulnerable to attack by ants, crickets, and other insect pests. They are also susceptible to root rot.

Main Limitations Casuarina equisetifolia can exhaust the moisture in the soil, lower the water table of the site, and restrict growth of a healthy understorey, leaving the soil exposed. The tree is fire sensitive and can be browsed only lightly without being damaged. Although other Casuarina species coppice readily, C. equisetifolia does not.

In some cases casuarinas tend to be aggressive plants. C. cunninghamiana and C. glauca have invaded Florida displacing much native vegetation and are proving nearly impossible to control.

Related Species

Other Australian species worth testing as firewood crops are:

| | Adaptation |
|---|---|
| ° Casuarina cristata Miq. (syn. C. lepidophloia) | Arid and semiarid zones; prefers moderately heavy soils; tolerates alkalinity |
| ° C. cunninghamiana Miq. | Coastal tablelands and higher elevations |
| ° C. decaisneana F. Muell | Arid sandy soils |
| ° C. glauca Sieb. ex Spreng. | Saline and swampy ground; tidal flats; heavy soils; warm temperate and tropical coasts |

| | |
|---|---|
| ° *C. leuhmannii* R.T. Bak | Arid and semiarid zones; saline, clay soils |
| ° *C. littoralis* | Infertile, tropical and temperate acid soils |
| ° *C. stricta* Dryand. | Warm temperate zones; poor coastal sands and clays; calcareous and saline soils |
| ° *C. torulosa* Ait. | Tropical and subtropical coastal tableland and high-altitude regions |

Papua New Guinea species for firewood include:

| | |
|---|---|
| ° *Casuarina oligodon* | High elevations, including ultrabasic rocks |
| ° *C. papuana* | |

Indonesian species include:

| | |
|---|---|
| ° *Casuarina junghuhniana* Miq. (syn. *C. montana*) | High elevations |
| ° *C. sumatrana* Jungh. (syn. *Gymaostoma nobilis nomen*) | Lowland podsols |

Fiji species include:

| | |
|---|---|
| ° *C. nodiflora* (Forst) | Wetter areas (2,000 - 3,000). A larger tree used for firewood and posts. A potential timber but so far little used as such. |

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# SECTION IV

# CASUARINAS IN FLORIDA (USA) AND SOME CARIBBEAN ISLANDS

10/27/81

# CASUARINAS IN FLORIDA (USA) AND SOME CARIBBEAN ISLANDS

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Paper presented to International Casuarina Workshop
17-21 August 1981, CSIRO Division of Forest Research
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# CASUARINAS IN FLORIDA (USA) AND SOME CARIBBEAN ISLANDS

by T. F. Geary

Casuarinas are ubiquitous in the Florida peninsula from its southern tip at 24°30'N latitude to about 29°N. Elevations are rarely more than 30 m and most are less than 15 m above sea level. Australian-pines, as the casuarinas are known locally, are very common on the coast, along roads and property lines, on ditch and canal banks, and around buildings. Despite their conspicuousness, casuarinas occupy a very small percentage of the total land in the region.

The casuarinas have not been studied in detail in Florida. Identification of the species that occur is uncertain, but it appears that almost all, if not all trees, are C. equisetifolia, C. glauca, C. cunninghamiana, or their hybrids. Trees are found that seem to have characteristics of all three species. C. cristata (syn C. lepidophloia) is reported as widely planted in Florida (Little, 1979), but this may be a misidentification of C. glauca.

Casuarinas were once highly regarded for landscaping, windbreaks, and shade, because they grow well on acid and alkaline soils, sand dunes, calcareous rocky soils, muck and many other soils (Conover and McElwee, 1971). Now plantings are regarded as a mixed blessing.

C. equisetifolia is the only species that is truly naturalized. It regenerates and spreads by seed. It is common along the coast, where it is appreciated for its shade and the pleasant sensation produced by the wind "whispering" through the foliage. However, on fore-shore dunes C. equisetifolia roots can prevent sea turtles from digging nests for their eggs, and sometimes turtles are trapped by the roots.[1/] On coastal areas subject to wave erosion, toppled casuarinas act as groins, increasing loss of sand.[1/]

A key concern of those who discourage planting in coastal areas is public safety. C. equisetifolia is the largest coastal tree, with heights to 30 m. Trees of this size if toppled by hurricanes, to which Florida is prone, can cause substantial property damage. The major fear, though, is that C. equisetifolia planted along roads and on causeways may fall and block evacuation routes from low-lying coastal areas during hurricanes. This species has a bad reputation in some cities in the northern part of its range, because large trees killed by a record freeze became a public nuisance due to falling limbs and tops. Removal of dead trees and debris was costly. C. equisetifolia is not common inland, as it cannot survive the harder inland freezes. Its tolerance of fire also limits its ability to spread uninhibited in the fire-dominated environment of southern Florida.

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[1/] Personal communication from Richard W. Workman, Thomas M. Missimer & Assoc., Inc., Cape Coral, Florida.

C. glauca is found in coastal areas, usually around brackish waters, but it is more prominent inland as an ornamental, windbreak, and grove for cattle shade. The species is propagated by transplanting root suckers of male trees, and it is uncertain if there are any females of genetically pure C. glauca in Florida. Prolific root suckering characterizes stands of this species. This property has caused C. glauca to be considered a pest, and some counties legislated against planting it and other members of the genus (Conover and McElwee, 1971). Because of the desirable ornamental value of the dense, dark green crown of C. glauca, it is sometimes grafted onto rootstocks of C. equisetifolia, which does not have root suckers, and sold for landscaping (Conover and McElwee, 1971).

Planting of C. glauca as an agricultural windbreak has fallen into disrepute, because reductions in crop yields at field margins due to shading and root feeding exceed benefits of the windbreak. Windbreaks have been felled because of this. Old plantings along roads, so common in southern Florida, are slowly disappearing as roads are widened. Planting of trees near road edges is now discouraged to prevent collision of cars with trees.

C. cunninghamiana is the least common of the three species in Florida, even though it is the most cold hardy and is the least objectionable to environmentalists. The species' lack of popularity may be caused by its relatively low visual appeal as an ornamental, its intolerance of coastal sites, and relatively slow growth.

Casuarina stands, particularly those of C. glauca, appear impressive in standing volume compared to native forest. But the timber is not used commercially. Interest has developed in growing casuarinas in Florida as a source of fuelwood for industrial boilers, but experimental plantings have been disappointing. The growth rate of casuarinas has been substantially less than that of eucalypts. Lack of nodulation of the experimental plants may have caused the unexpectedly slow growth. If commercial plantations of casuarina are established, Clitocybe root rot could be a serious problem (Rhoads, 1952).

The Dominican Republic is on the island of Hispaniola at about 18°N latitude. Trees of C. equisetifolia were very common in the coastal city of Santo Domingo until hurricanes in 1979 blew them down. Trees 20 to 25 cm diameter at breast height snapped off from 3 to 5 m above ground, while larger trees were uprooted.[1/] Streets were clogged with debris from these downed trees, and cleanup was costly. C. equisetifolia is being replanted in some sections of the city, but whether the tree again becomes a common ornamental remains to be seen.

Casuarinas are rare outside of Santo Domingo. But trial plantings by a private company, Falconbridge Dominicana, of C. equisetifolia on strip-mined land in a humid climate zone have grown faster than eucalypts of unknown species and Pinus caribaea var. hondurensis. In the dry zones of the island, on alkaline soils, there are a few trees of casuarina of unknown species that have grown to a large size. Because the Dominican Republic is heavily dependent on charcoal and wood for home cooking, and the existing forests have been heavily exploited, casuarina plantations could become important to the fuelwood industry of the island.

In Puerto Rico, an island just east of the Dominican Republic, C. equisetifolia is the only casuarina commonly planted. It is found along the coast, and less commonly in the lower mountain regions (Little and Wadsworth, 1964). It is recommended as an outstanding species for beaches and windbreaks (Schubert, 1979). Planting close to buildings is not recommended because a disease, probably Clitocybe root rot, sometimes kills old trees, and there is danger of the trees being blown over by hurricanes. Natural regeneration is rare in Puerto Rico because ants eat nearly all the seeds (Little and Wadsworth, 1964).

In screening trials of trees for commercial timber production on granitic uplands in Puerto Rico, C. equisetifolia grew faster in height than Pinus caribaea var. hondurensis and a variety of other gymnosperms and angiosperms (Geary and Briscoe, 1972). Only Eucalyptus tereticornis grew faster. As in Florida, the trees' timber is rarely utilized, if at all. Utilization of the wood of casuarina in Puerto Rico is not anticipated; in contrast to the Dominican Republic, fuelwood and charcoal use of any species in Puerto Rico is negligible.

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# SECTION V

# CASUARINA: ACTINORHIZAL DINITROGEN-FISING TREE OF THE TROPICS

PREPRINT FROM:

Proceedings of the International Workshop on Biological Nitrogen Fixation Technology for Tropical Agriculture, CIAT, Cali, Colombia. March 1981.

# CASUARINA: ACTINORHIZAL DINITROGEN-FIXING TREE OF THE TROPICS

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## ABSTRACT

*Casuarina* is the most important actinorhizal plant of the tropics. The genus comprises well over sixty species of woody, dicotyledonous plants whose roots are capable of symbiotic association with the filamentous bacterium *Frankia* of the Actinomycetales. The root nodules which develop contain the dinitrogen-fixing endophyte whose activities lead to nitrogen accretion in the soil environment at rates equivalent to herbaceous legumes. A review is presented of the published literature on nodulation and dinitrogen fixation in *Casuarina* and an assessment is made of experimental and practical measures which should be taken to understand the symbiosis better and to improve the contributions made by *Casuarina* to agriculture and forestry in tropical and subtropical countries where *Casuarina* can be grown. The following topics are discussed: early studies on symbiotic nitrogen fixation, the ecological role in the nitrogen economy, laboratory studies of nitrogen fixation, nodule initiation and development, the ultrastructure of nodules, handling the microorganism in culture and in nodule suspensions, inoculation of nursery seedling stock and the distribution of *Casuarina* and its actinomycetous endophyte.

# INTRODUCTION

Casuarina is a woody dicotyledonous plant native to Australia but widespread in tropical and sub-tropical countries around the World where it has been disseminated by the activities of man. Its roots are nodulated following invasion of the filamentous soil bacterium, Frankia of the Actinomycetales and this symbiosis results in dinitrogen fixation at rates comparable to nodulated legumes (Torrey 1978). These trees occupy a diversity of sites ranging from tropical rain forests to arid deserts or sandy coastal dunes. The genus encompasses more than sixty species, only a few of them at present of economic significance. In Australia Casuarina cunninghamiana, the river sheoak, grows along fresh water river banks, reaches a height of up to 36 meters and produces a straight, hard wood trunk useful as timber. Casuarina equisetifolia is distributed around the world in the tropics and in many countries is in common use for shelter belts, for erosion control, land reclamation and as a forage and fuel tree. The species diversity and adaptability to climatic variability and harshness of habitat within the genus have hardly been explored. By virtue of their symbiotic nitrogen fixing capacity, many members of the genus Casuarina serve as pioneer species in diverse localities preceding and making possible the establishment of forested stands.

An effort has been made to bring together here the available information on nodulation and dinitrogen fixation in Casuarina in the hope of developing a better understanding of the significance of the genus in its present habitats and to explore the possibilities for better utilization of these plants in world-wide tropical agriculture and forestry

## EARLY STUDIES ON SYMBIOTIC NITROGEN FIXATION

Although Janse (1897) reported the presence of nodules on roots of Casuarina and later Miehe (1918) and McLuckie (1923) inferred that root nodules on Casuarina were implicated in fixation of atmospheric nitrogen, the first direct studies of symbiotic nitrogen fixation in Casuarina were made by Aldrich-Blake (1932) and Mowry (1933).

Working in Dehra Dun, India, Aldrich-Blake surface-sterilized seeds of C. equisetifolia, planted them in sand in pots watered with nutrient solution lacking nitrogen, and inoculated them with ground nodule suspensions from mature plants collected in the field. Uninoculated plants were carried as controls and watered with nutrient solution lacking nitrogen or supplemented with $NH_4NO_3$. The experiment lasted about 15 months.

Uninoculated plants showed no nodules on the roots. Inoculated roots showed numerous root nodules ranging up to 3.8 cm in diameter and nodules represented 11.7% of the dry wt of the whole root system. Height growth of nodulated plants was more than triple that of uninoculated plants and the dry wt per shoot more than 50x the control plants. Kjeldahl analyses of the plants showed that the average nitrogen content per shoot was more than 100x that of the uninfected control plants not provided fixed nitrogen.

Mowry (1933) reported successful inoculation of nine different species of Casuarina seedlings grown in pots in sterile soil by inoculation of the soil with small pieces of fresh nodules taken from plants growing in the field. From these studies he concluded that a single strain of the infective organism was effective in causing nodulation of all the species. From comparative growth studies of inoculated and uninoculated plants, Mowry concluded that fixation of atmospheric

nitrogen occurred in the nodules resulting from a symbiotic relation between host and soil microorganism which he believed to be a bacterium. The trees grew vigorously in Florida on sand dunes and other sites of low fertility. In 20 different locations in Florida, he found no trees of any size which did not have nodules on the roots.

Other early workers reported the occurrence of root nodules on Casuarina (Kamerling 1915, Narashimhan 1918, Rao 1923, and Parker 1932) and most of these observers made the connection between the presence of root nodules and satisfactory plant growth, probably related to nitrogen fixation. These nodules were presumed to be produced by a soil microorganism (Chaudhuri 1931) and early efforts were made to isolate and culture it (Shibata and Tahara 1917, Narashimhan 1918).

In his review Becking (1977) attempted to list the earliest account in the literature of nodulation in each of the Casuarina species reported. He noted that 18 species of a total of 45 (as then interpreted) had been reported nodulated. The list could doubtless be extended but this effort becomes a fruitless exercise in the face of the uncertain and changing view of the taxonomy of the group. In field collections of Casuarina nodules in Florida, Hawaii and Australia, including some 10-15 species (Torrey, unpublished), in only one situation was it not possible to find nodulated roots. It is to be presumed that all of the species of the genus are capable of root infection and nodulation by the appropriate Frankia. Whether one or more strains of Frankia are involved remains to be demonstrated.

## ECOLOGICAL ROLE IN THE NITROGEN ECONOMY

Evidence for a significant ecological role of Casuarina in the nitrogen economy of a given environment can be traced back to reports of agricultural practices involving Casuarina plantations. Silvester (1976) cited the role of Casuarina

in traditional rotational agricultural practise in highland New Guinea in which Casuarina is planted in cleared areas, grown for 5-20 years, then cleared for firewood or timber and the land planted to yams or other crops which profit from the nitrogen accretion attributable to nitrogen fixation and litter fall from Casuarina.

Estimates of the contribution to the nitrogen status of sandstone soils near Sydney, Australia made by Casuarina littoralis were reported by Hannon (1956). Analyses of the plants of the low scrub forest showed 10,000-12,900ppm nitrogen on a dry-weight basis. Litter fall and dry-matter increment represented 29.0 tons per hectare per year which at 1% nitrogen content represented an accretion of 290 kg N/ha/yr, largely attributable to symbiotic dinitrogen fixation.

Dommergues (1963, 1966) reported the nitrogen fixation by Casuarina equisetifolia in sandy soils of the Cape Verde Islands off Portugal. By measuring soil nitrogen and plant nitrogen, he was able to estimate a yearly increment of about 58 kg N/ha/yr, mostly derived from dinitrogen fixation by the nodulated plants. Beadle (1964) referred to Casuarina sp. in reference to the nitrogen economy of arid areas in Australia.

Silvester (1977) reviewed the descriptive evidence for the importance of Casuarina equisetifolia in the revegetation of Krakatau Island, Indonesia following volcanic destruction of the vegetation. On a small scale, a similar sequence of revegetation involving Casuarina equisetifolia can be observed on the island of Hawaii. Opportunities for quantitative studies of establishment and succession of Casuarina equisetifolia exist at the Punha site near Hilo where volcanic ash wiped out a stretch of vegetation from the volcano to the sea in 1960. New seedlings and young trees of Casuarina which invaded the site were well nodulated and flourishing together with small sedges in a location otherwise devoid of vegetation

(Torrey, unpublished observations).

## LABORATORY STUDIES OF NITROGEN FIXATION

Careful laboratory and greenhouse studies of symbiotic nitrogen fixation by Casuarina are relatively sparse. Bond and his associates in Glasgow, Scotland contributed significantly to our understanding of the symbiosis over a period of about twenty years. Casuarina cunninghamiana and C. equisetifolia were grown in water culture or in sand provided a modified Crone's inorganic nutrient solution and inoculated with nodule suspensions from field-collected nodules provided from natural sites around the World.

Bond (1957a) determined shoot height, dry weight and total nitrogen values for nodulated and non-nodulated plants and showed from growth data the importance to plant development of dinitrogen fixation by nodules. Bond (1957a) calculated that a mean fixation of 50 mg atmospheric nitrogen per plant occurred in seedlings of C. cunninghamiana over a period of six months in water culture. In similar studies Rodriguez-Barrueco (1973/74) reported that plants of C. torulosa showed accumulation of 430 mg N per plant in twelve months. Bond (1957b, 1964) showed further using $^{15}N_2$ provided in the atmosphere that detached nodules of Casuarina incorporated the dinitrogen into fixed nitrogen. Nodules showed a nitrogen content of nodule dry matter of 3.0 percent and an increase in $^{15}N$ content of up to 0.368 atom percent of total nitrogen over the normal value during a 19-hr period. In these experiments (Bond 1961) the inhibition of dinitrogen fixation in detached nodules by molecular oxygen at concentrations above 20% was demonstrated. In other experiments with detached nodules of Casuarina Bond (1960) showed that fixation of dinitrogen in root nodules was inhibited by gaseous hydrogen at 20 percent (~50% inhibition) and higher, showing a sensitivity comparable to dinitrogen

fixation in nodules of legumes.

Using water culture or sand culture, Bond and his colleagues demonstrated the essentiality for dinitrogen fixation by Casuarina of molybdenum (Hewitt and Bond 1961), cobalt (Bond and Hewitt 1962, Hewitt and Bond 1966) and copper (Bond and Hewitt 1967) provided in the inorganic nutrient solution.

Studies on the effects of combined nitrogen on nodulation and nitrogen fixation have been made by Stewart (1963) and by Rodriguez-Barrueco, Macintosh and Bond (1970) Stewart showed that ammonium nitrogen provided as $(NH_4)_2SO_4$ at 10 ppm nitrogen facilitated the nodulation and development of young seedlings inoculated with a nodule suspension. $NH_4^+$ nitrogen up to 100 ppm did not significantly reduce the number of nodules formed. Stewart concluded that under most field conditions Casuarina nodulation would not be affected by levels of nitrogen usually in the soil Rodriguez Barrueco (1972) also reported that low levels of ammonium nitrogen did not interfere with nodule development in seedlings of C. cunninghamiana although the ammonium ion became inhibitory at high levels. Fixation of $^{15}N_2$ was less efficient in the presence of the ammonium ion.

Rodriguez Barrueco et al. (1970) studied the effect of combined nitrogen on dinitrogen fixation by Casuarina plants already nodulated. Plants grown in nutrient solutions containing different levels of $(NH_4)_2SO_4$ were provided $^{15}N_2$ in the atmosphere. After 14 weeks plants were harvested and analyzed for total nitrogen and isotopic nitrogen. Plants provided ammonium nitrogen grew well, more or less in proportion to the ammonium supplied. The presence of fixed nitrogen however reduced dinitrogen fixation of all plants even at 10 ppm nitrogen. Nodule growth was likewise reduced. Plants provided no fixed nitrogen, although well nodulated, did not grow as well as those provided ammonium nitrogen, suggesting that nitrogen fixation itself utilizes photosynthate which might otherwise go to growth.

Coyne (1973) reported that combined nitrogen as $Ca(NO_3)_2$ provided at 56 ppm N inhibited nodule formation by as much as 75% under optimum pH conditions in water culture. According to Coyne nitrogen-fixation was negligible in nodulated plants provided with nitrate nitrogen in the nutrient solution.

Bond and Mackintosh (1975) studied daily rates of fixation by detached nodules incubated in $^{15}N_2$. They found that fixation varied diurnally, showing a low rate in early morning, reached a relatively high level for several hours in mid to late afternoon and then decreased. Light intensity and temperature together influenced fixation rates. According to these authors the rate of dinitrogen fixation increased steadily from 10 to 36°C with the maximum rate of fixation by nodules of Casuarina cunninghamiana at 36° C. Waughman (1977) also observed a simple exponential response in nitrogenase activity in C. equisetifolia to increasing temperature. Rodriguez Barrueco (1973/74) found that detached nodules of C. torulosa showed the highest fixation rates in late afternoon and early evening rather than in mid morning.

## NODULE INITIATION AND DEVELOPMENT

Structural studies of root nodules of Casuarina were directed first at attempts to localize and identify the endophyte. Thereafter attention was paid to the modification of root structure and the anomalous form and development of root nodules. More recently ultrastructural studies have made possible a demonstration of root hair infection, root cortex invasion and the proliferation of multilobed modified lateral root branches to form the typical nodules with nodule roots. Miehe (1918), McLuckie (1923) and Aldrich Blake (1932) all made anatomical studies of young nodules. A review of these early anatomical studies has been written (Torrey 1976).

Bond (1956, 1957a) first called attention to the presence of vertically-upward growing nodule roots on Casuarina nodules. These nodule roots can be quite striking in young plants grown in water culture. In field-collected nodules, nodule roots may have dried up and shrivelled so that their presence is totally missed or ignored.

The present evidence supports the view that infection by the soil organism causing root nodules on roots of C. cunninghamiana occurs by root hair invasion (Callaham et al. 1979), as has been shown as well in Alnus, Myrica and Comptonia. The endophyte within the root hair shows multiple filaments, each of which is surrounded or encapsulated by a polysaccharide capsule formed by the host plant cytoplasm.

The filaments invade the cortical cells of the root, dissolving the cell walls and middle lamella, often forming wide strands of invading filaments (Torrey 1976, Tyson and Silver 1979). Filaments are septate and branched, ramifying through the cells of the root cortex, causing cortical cell proliferation followed by cell hypertrophy (Torrey 1976). The structure of the microorganism is that of a filamentous bacterium of the group Actinomycetales.

Coincident with the first invasion by the actinomycete, the root at the site of invasion is stimulated to form multiple lateral root primordia which are in turn invaded in the newly formed cortex tissues, forming swollen lobes where the actively fixing association of host and endophyte is presumed to occur (Torrey 1976, Kant and Narayana 1977). Only after the hypertrophy stage when the endophyte has filled the cortical tissues does the nodule root elongate from the pointed tip lobe of each successively formed nodule root. The result is the formation of a cluster of swollen nodule lobes at each infection site with upward-elongating nodule roots. The nodule roots remain uninfected by the bacterium. Silver et al. (1966)

attempted to interpret the peculiar negative geotropism of nodule roots in terms of abnormal metabolism of the plant growth hormone indole-3-acetic acid within the developing nodules.

## ULTRASTRUCTURE OF NODULES

There are few reports of the ultrastructure of Casuarina root nodules. Enough work has been published using transmission electron microscopy to conclude that the microorganism in the nodule cortical cells is an actinomycete of the Frankia type. The septate filaments of approximately 1 µm diameter are branched and ramified. All filaments are surrounded by a polysaccharide capsule and internally show the characteristic nucleoid regions along the filament (Newcomb, Pankhurst and Torrey 1981).

In nodules of actinorhizal plants vesicles are the demonstrated site of the nitrogen-fixation enzyme, nitrogenase (see Tjepkema et al. 1980, 1981) and have been reported to occur in mature nodule cortical cells in almost all actinorhizal plants studied structurally. According to studies by Tyson and Silver (1979), Dart (personal communication), Torrey (1976) and Newcomb et al. (1981), Casuarina nodules do not show these typical terminal swollen filamentous structures termed vesicles.

There exists one report illustrating nodule vesicles in Casuarina - a report by Gardner (1976) which included an ultrastructural survey of a large number of different genera and species. In her paper, she pictured a section of a nodule of Casuarina (Plate 34.4a) in which she designated a vesicle. The identification of this structure is confused by the fact that in her Table 34.1 she gave the average dimensions of club-shaped vesicles in C. cunninghamiana as 1.0 µm in diameter and 2.0µ m long while the vesicle illustrated was about 3.6 µm in diameter. If

her figure is in fact taken from a nodule of Casuarina, it seems more likely that the septate swollen structure is a sporangium. No other illustrations of sporangia in nodules of Casuarina have been published although Gardner has described Fig. 34.5b in the same paper as a section of Casuarina showing "bacteroids", which would be the products of sporangial release. Clearly, more work on the ultrastructure of nodules of Casuarina is needed. As noted by Gardner and others, the presence of polyphenols and tannins in uninfected cells of root nodules makes fixation and sectioning for light and electron microscopy difficult, especially with older mature nodules.

The lack of convincing evidence for the presence of vesicles in the endophyte in root nodules of Casuarina raises the very interesting question as to the locus of nitrogenase activity in the nodules of this genus. One must reserve judgment on this question, pending a more comprehensive and careful ultrastructural study of nodules fixed for microscopy at a time when nitrogenase activity is demonstrable.

The evidence is good that the normal vesicle structure of cultured Frankia provides protection of the oxygen-labile enzyme nitrogenase from inactivation by ambient $O_2$ concentration (Tjepkema et al. 1980). In the absence of a typical vesicular structure in Casuarina, how would nitrogenase be protected? An intriguing possibility is that special modifications have evolved in this case. Davenport (1960) reported the occurrence of haemoglobin in root nodules of C. cunninghamiana. Efforts of others to confirm this observation have not been successful. Here is another area needing further study.

## HANDLING THE MICROORGANISM

Efforts to isolate Frankia from nodules and grow it in culture: - The ideal

situation for the study of host-microorganism symbiosis is to be able to cultivate each of the components separately and to understand the behavior of each independen of the other. One can germinate seeds of Casuarina, grow them in water or sand culture and provide them with essential macro- and micro-nutrient salts and grow the host plants independent of Frankia.

Unfortunately, it is not yet possible to grow in pure culture the Frankia which causes nodulation of Casuarina roots. Thus far, the effective endophyte has resisted isolation efforts. Uemura (1961, 1964) attempted isolation of the microorganism from nodules of C. equisetifolia and was able to grow a Streptomyces-like actinomycete in sterile culture. He failed to achieve reinfection of axenically grown seedlings inoculated with this isolate. Using methods developed and applied successfully in the isolation of Frankia species from Alnus, Comptonia, Elaeagnus and other genera, Torrey (unpublished) has been unable thus far to isolate the endophyte from nodules of a number of species of Casuarina, collected in Florida, in Hawaii and in Australia. Baker (unpublished) has applied sucrose layered-gradient methods to nodule suspensions of Casuarina without success.

Gauthier et al. (1981) used microdissection methods and serial dilution to isolate an organism from Casuarina nodules which when grown in culture showed Frankia-like characters. The Frankia organism cultured by Gauthier et al. (1981) is of considerable interest since when grown in vitro it produces terminal vesicles and can be shown to reduce acetylene, presumably due to nitrogenase activity. Unfortunately, attempts to demonstrate infection of Casuarina seedlings with this organism have failed. The reasons for failure in these efforts are not clear and further attempts at isolation and culture must be made.

Inoculation using nodule suspensions: - In lieu of inocula prepared from the cultured organism, methods have been devised to achieve inoculation of seedlings from nodules collected in the field or from nodulated plants propagated in the greenhouse. Bond (1957a) reported successful inoculation with the following method, used also by Torrey (1976). Seeds were germinated in sand and watered with nutrient solution, then transferred to water-culture vessels containing modified Crone's solution, either at full strength or one-quarter strength. Nitrogen was provided as ammonium sulfate at 20 mg N. At the time of inoculation, plants were transferred to nutrient solutions lacking nitrogen at about pH 6.4. The healthy condition of the seedlings at the time of inoculation was critical to success.

Fresh nodule material was ground in distilled water at a ratio of about 1 g/20 ml water, filtered through muslin and the nodule suspension brushed on to the seedling roots. Plants were grown in the greenhouse under natural light conditions. Young nodules were apparent in approximately 4-5 weeks. Others have reported similar procedures for experiments conducted in water or sand culture.

Coyne (1973) studied the importance of certain variables affecting successfu inoculation of plants grown in water culture. Initial pH of the solutions at the time of inoculation was critical; almost no nodulation occurred in plants at pH 4.0 or at pH 9.0. Optimum pH for nodule formation in two species (C. glauca and C. cunninghamiana) was pH 6.0 with good nodulation still at pH 7.0 and 8.0 but poor at pH 5.0. Bond (1957a)reported good nodulation in C. cunninghamiana at pH 6 and 7. According to Coyne, the presence of combined nitrogen in the form of nitrate [$Ca(NO_3)_2$ at 56 ppm N] reduced the number of nodules initiated but did not influence the optimum pH for nodulation. The effects of combined nitrogen on nodulation and nitrogen fixation were discussed earlier. Kitamura et al. (1965) also studied the effect of pH on the growth of several actinorhizal trees grown in water

culture, including Casuarina.

In his later studies with Casuarina Bond and Mackintosh (1975) started Casuarina seedlings in water culture with modified Crone's solution lacking nitrogen but supplemented the first month with 10 mg/l ammonium nitrate nitrogen. Plants were transferred to nitrogen-free solutions at the time of inoculation; thereafter nodules appeared after 3-4 weeks. Using this procedure, Torrey (1976) observed first visible nodules at the earliest at 19 days.

Preparation of nodule suspensions: -- Alternative methods for preparing the inoculum have been described or discussed but no systematic study has been published. From accounts of inoculation of other genera, the following modifications could be expected to prove effective. Following the methods used with Rhizobium, Torrey (unpublished) found it possible to inoculate successfully with dried nodule preparations. To prepare the nodules, he placed small field samples of nodules of C. equisetifolia in a vial containing silica gel which caused rapid dessication of the nodule. Dry storage of nodules up to three months over silica gel could still be followed by inoculation with a dry powder prepared from the dessicated nodules, causing successful infection and nodule development in water-cultured seedlings of the same species. How long nodules can be safely stored in this way remains to be determined.

When ground in distilled water fresh nodules rapidly turn brown and then gray, presumably due to the release of polyphenols and/or tannins. In order to prevent the damage due to release of such potentially toxic substances, nodules can be ground up in the presence of polyvinylpyrrolidone (PVP). We have used 1% PVP-40 and found that its presence retards the blackening reaction. Similarly, activated charcoal can be used as an adsorbent. We have tested 10% activated charcoal (wt/vol) in distilled water and found the nodule suspension after filtratic

to be clear. Another method described by Lalonde for Alnus nodules (1979) is to use 0.6-1% sodium chloride for the grinding solution. This also results in a clear light yellow fluid after filtration. No systematic study of the relative effectiveness of these methods has been made.

These empirical tests all suffer from the common difficulty that we do not know for certain the nature of the infective particle which must be present in the inoculum and whose activity we are attempting to preserve.

Inoculation of nursery seedling stock: -- There seems to be no published account of procedures for inoculation of seedlings of Casuarina grown for nursery stock. Observations made of operations in government forestry nurseries in Hawaii and in Australia and New Zealand suggest that little attention has been paid by growers to assuring that the effective organism for nodule formation is present in the soil. Since most nursery operations routinely use sterilized soil mixes for seedling plantations, one cannot expect the infective actinomycete to be present in the root environment. Some arrangement must be made to introduce the organism into the rooting medium. Foresters have become most familiar with this problem in working with mycorrhizal fungus introductions.

Soil or leafy litter from around effectively nodulated plants may serve as an adequate inoculum for seedlings planted in soil mixes in the nursery. More likely to be effective would be inoculation from ground up nodules from field collections or nodulated plants in the plantation area.

Choice of inoculation material presents uncertainties at our present state of knowledge. The most likely procedure for successful infection following inoculation is to prepare a ground-up inoculum from freshly collected field nodules of the same species. We have reports of successful cross-inoculations among species as described for example, by Mowry (1933). This question was reviewed interestingly

by Allen and Allen (1965). We still do not know whether a single Frankia strain from Casuarina will infect all species or whether there may be more than one strain. Some authors (e.g., Coyne 1973) have suggested there may be more than one type of Frankia, specific to different Casuarina host species. This question can only be resolved when an infective Frankia isolate is available in pure culture.

Ideally, one would like to be able to culture a Frankia species isolated from Casuarina nodules which could be used to prepare an inoculum to be introduced at will to seedling stock grown in the nursery. Then one should be able to select the most infective strain to assure nodulation and also the most effective in nitrogenase activity to assure maximum rates of dinitrogen fixation and thus most effective plant growth and dry matter production.

In nursery practise, as in the laboratory, successful inoculation of seedlings and nodulation in container-grown plants depends upon sustaining the seedlings in a healthy condition by providing fixed nitrogen to the seedling until the induced nodules are actively fixing and can provide nitrogen directly from dinitrogen incorporation. One must provide fixed nitrogen at low levels for plant maintenance but not at levels or in forms inhibitory to nodulation. From the earlier discussions one can conclude that a container mix supplemented with $NH_4^+$-nitrogen in amount not in excess of 100 ppm nitrogen should meet these needs. Nitrate nitrogen should be avoided in the soil mix. It might be possible to provide seedlings with a foliar spray of urea to sustain seedling growth while nodulation proceeds in inoculated soil mix.

Once seedlings are planted out, they respond to adequate water supply. Kant and Narayana (1978) reported experiments with young plants of Casuarina watered every day, every other day or every third day. After six months they measured height, weight of shoots and roots, number, size, weight and nitrogen content of

nodules. All measured parameters decreased in relation to the reduced water supply

## DISTRIBUTION OF CASUARINA AND ITS ACTINOMYCETOUS ENDOPHYTE

Casuarina species are wide spread throughout the tropics and sub-tropics wherever it has been taken by man beyond its origins in Australia. Success in establishment of Casuarina depends upon plants obtaining sources of fixed nitrogen provided naturally or added as inorganic or organic nitrogen fertilizer or from symbiotic dinitrogen fixation when Frankia forms root nodules and the enzyme nitrogenase develops.

Many reports from around the world show that Casuarina has adapted to many ecological sites in many countries. Most evidence from laboratory research demonstrates that the actinomycete is not transmitted with the seed - either within it or on the surface. Rather, Frankia is transported in nodule material or in the soil in a form which we do not yet know for certain. The presumption, based on structural evidence, is that spores are the most resistant form and presumably can survive in dessicated state for long periods and/or distances. The interesting question is how the effective Frankia species reached the many distant lands where Casuarina now occurs One can find no reports in the older accounts suggestin that soil samples or nodules should accompany seeds for successful establishment. I is possible that Frankia spores can be circulated by the winds and this explanation seems a reasonable one for situations such as the Punha volcanic site in Hawaii where existing stands of nodulated Casuarina plants are only a few hundreds or thousands of meters away. Greater distances provide great difficulties and puzzles.

In recent travels in New Zealand (Torrey, unpublished) it was interesting to study the occurrence of Casuarina in planting sites or in forestry nurseries in the North and South Island. New Zealand winter minimum temperatures are sufficientl: mild to allow Casuarina to survive even as far south as Dunedin (at least in pro-

tected sites). With the cooperation of personnel of the Forest Research Institute (FRI) at various locations in New Zealand samples of roots of Casuarina trees were made. In some cases excavations of whole root systems (in nursery plantations were made in Rangiora near Christchurch, in the nurseries and field plots of the Aokauterre Science Center, Palmerston North, at the FRI at Rotorua and in urban plantings, some of considerable age, in Auckland (with the help of Jack Rattenbury). Several different species of Casuarina were examined including C. cunninghamiana and C. stricta. In no case were root nodules observed! Plants were surviving on fixed nitrogen available in the nurseries of field sites. Some plants were not very healthy.

Accounts were given of fairly extensive efforts in the North Island of New Zealand to develop Casuarina stands as a wind-break or fence rows but experimentation was abondoned as the plants failed to establish successfully. One would assume this failure occurred because the plants did not form nodules and therefore could not perform as they do in countries where the endophyte occurs. New Zealand has very strict laws concerning soil and plant material importation and it may be that Frankia, effective on an imported genus such as Casuarina, has never reached that country. Examination of root systems of Elaeagnus and Alnus species at the nursery at Rotorua showed abundant nodulation by those Frankia species so it seems unlikely that soils in New Zealand are deleterious to Frankia. New Zealand offers an interesting experimental situation for the careful and systematic introduction of the appropriate Frankia strains for use with Casuarina plantations. Other reports are scattered through the literature of areas in which Casuarina occurs but in which nodules have not been found or occurred only sporatically. Bond (1976) quoted reports of studies made in Indonesia showing that of 83 trees of C. equisetifolia growing in a latosol soil only 3 plants were nodulated. Of 72 trees of C.

sumatrana examined in another location, all were nodulated. Bond (1957a) also noted that specimens of Casuarina in Botanical Gardens in the British Isles seemed to lack nodules, a fact noted by Miehe (1918) for Botanic Gardens in Germany and also Italy. These exotic plants were presumably sustained by regular nitrogen fertilization. The failure of nodulation suggests the difficulty of transport of Frankia by seed and the lack of distribution in soils in the temperate climatic areas.

Casuarina may also show mycorrhizal infection in addition to nodulation by Frankia. The fungal associations have been little studied. Dommergues (1976) reported such association in Casuarina. Recently studies have been initiated by Bamber et al. (1980) in Australia. Effective mycorrhizal association may offer another mechanism to assure survival and adequate mineral nutrition.

## ACKNOWLEDGEMENTS

This research was supported in part by the Maria Moors Cabot Foundation for Botanical Research of Harvard University and by research grant No. DEB 77-02249 from the National Science Foundation. The author expresses his appreciation to members of the staff of the Forestry Division and the Division of Plant Industry, CSIRO, Canberra, Australia for help in the literature search and for discussions about Casuarina in Australia.

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# SECTION VI

# INOCULATION METHODS FOR CASUARINA

UNIVERSITY OF FLORIDA
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES
SCHOOL OF FOREST RESOURCES AND CONSERVATION
GAINESVILLE, FLORIDA 32611

118 NEWINS-ZIEGLER HALL
TELEPHONE: 904-392-1797

APR 2[illegible] REC'D

April 26, 1982

Dr. Tom Geary
Southeastern Forest Experiment
Station
P.O. Box 938
Lehigh Acres, FL 33936

Dear Tom:

Enclosed is a summary of methods that have been successful for inoculating Casuarina.

Sincerely yours,

Donald L. Rockwood
Associate Professor

DLR/mp
encl

# Inoculation Methods for Casuarina

The methods used to inoculate Casuarina with the root infecting endophyte will depend upon how the seedlings are handled, and whether or not the seedlings are already growing in containers. I am assuming here that containers are styroblocks. If seed are planted directly into styroblocks, or seedlings initially germinated in flats and then transplanted to styroblocks, the following inoculation methods can be used.

There are three sources of the endophyte that infects Casuarina. These are leaf litter, soil, and the root nodules themselves. For leaf litter and soil to be effective inoculums, they must be collected within 5 feet of the trunks of well-nodulated, mature Casuarina. Root nodules are most abundant in this zone. Beyond this distance the number of root nodules declines, and therefore, the endophyte is assumed less abundant.

Leaf litter, soil, or root nodules are mixed directly into the potting medium prior to filling the styroblocks. Finely chop leaf litter or root nodules to aid mixing. If leaf litter or soil are used they should constitute at least 10 percent of the potting medium by weight. Root nodules are a more effective inoculum, but are more

difficult to collect. If root nodules are to be stored for longer than 30 days before being used, we recommend drying them at 70 C to avoid rotting during storage. Drying at moderate temperatures does not adversely effect the infecting ability of the endophyte.

If fresh nodules are used as the inoculum source they should comprise at least 1 percent of the potting medium. If dried nodules are use, at least 0.1 percent of the potting medium by weight should be nodules.

If seedlings are already growing in styroblocks, and need to be inoculated use root nodules as the inoculum source. Collect root nodules and finely chop . Preweigh chopped root nodules into 8 pound lots. Mix one lot root nodules with 20 gallons water in a large, shallow container, (a childs wading pool works great). Dip whole styroblocks into the solution, submersing the block for at least one minute to allow for saturation of the soil. Stir the mixture frequently to insure maximum contact between potting medium and the chopped root nodules. Add more water and root nodules as needed, preferably in batches of 8 pounds root nodules to 20 gallons water to maintain the proper ratio. This proceedure , if performed 2 months prior to outplanting resulted in approximately 50 percent nodulation in treated seedlings. Good luck.

*END

*GO

# SECTION VII

# AUSTRALIAN SEED SOURCES FOR CASUARINAS

CSIRO

Division of Forest Research
Banks Street Yarralumla Canberra A C T

A Division of the Institute of Biological Resources

P O Box 4008 Canberra A C T 2600
Telephone (062) 81 9211
Telegrams Foresearch Canberra Telex 62755

Casuarina file

FILE COPY

FILE COPY

JCD/VB
OUR REF: 74/609

14 October 1980

Mr Michael D. Benge,
DS/AGR/TSWM, 420, SA-18,
Office of Agriculture,
Bureau of Development Support,
Agency for International Development,
WASHINGTON, D.C. 20523, U.S.A.

Dear Mr Benge,

Your letter of 5 September 1980 refers.

Sorry for the omission of our leaflet 'Australian Suppliers of Tree Seed' from my letter of 26 February 1980.

Since writing in February, this Division has undertaken field trips in an attempt to improve our seed stocks of Casuarina species and provenances. We now hold good stocks of a wide range of provenances of E. cristata, C. cunninghamiana, C. leuhmannii, C. stricta, C. torulosa and other species not on your list such a C. glauca, C. decaisneana and a comprehensive range of Western Australian seedlots. Our work so far has concentrated on arid zone, temperate and sub-tropical provenances and we are yet to undertake collections in the far north (planned for 1981).

If it is not already too late, I would like this Section included in your list of contacts for research and seed supply. We can provide seed samples for research or refer buyers of large quantities of seed to appropriate private suppliers (eg. Australian Tropical Plant Supplies for seed of C. equisetifolia and tropical provenances of C. cunninghamiana).

For advice on the availability of C. oligodon seed you might wish to write directly to the Director, Office of Forests, P.O. Box 5055, Boroko, Papua New Guinea and for C. junghuhniana seed to the Chief, Direktorat Reboisasi danRehabilitasi, Sub. Direktorat Benih, Kompleks SKMA, P.O. Box 42, Bogor, Indonesia.

Yours sincerely,

J. C. Doran

J.C. Doran
Seed Section

recommended suppliers of Casuarina seed

# AUSTRALIAN SUPPLIERS OF TREE SEED

provided with the compliments of

Division of Forest Research, CSIRO
PO Box 4008, Canberra ACT 2600
Australia

A note to potential purchasers -

Most commercial seed collectors can specify the origin of the seed they supply. *There is however no tree seed certification scheme operating in Australia,* and it is recommended that the purchaser ascertain details of the seed origins before entering into any purchase agreement. *Purchasers should not assume that the seed of eucalypts or other Australian genera will necessarily be supplied from trees growing in Australia. Seed from exotic plantations is now common in the seed trade.*

# AUSTRALIAN SUPPLIERS OF TREE SEED

## Federal Government:

research samples – wide range of species

Seed Section, CSIRO Division of Forest Research
PO Box 4008, Canberra, ACT 2600

Telephone (062) 818211 Telex: 62751 Telegrams: FORESEARCH Canberra

The Seed Section of the CSIRO Division of Forest Research provides a central seed supply service and acts as a national seed coordinating centre for Australia.

Limited quantities of seed are available for research. Seeds of about 400 Eucalyptus species, other Australian native trees and some exotic species are held in stock. For most eucalypt species a range of seed origins (provenances) or individual tree collections is available. All seed lots are tested for germination capacity, and fumigated prior to despatch. Seed certificates and phytosanitary certificates are issued. Information and advice on the choice of species and other aspects of the growing and utilisation of eucalypts will be provided on request.

Prices: A service charge of $5 per seedlot plus $3, $4 or $5 for each 10 g of seed depending on species (includes postage or airfreight, as appropriate). Some seed is available for exchange with government research organizations.

A catalogue is not available, quotations are provided on request.

Terms of trade: Payment in advance by bank draft.

---

## State Governments:

Forestry Commission of New South Wales
GPO Box 2667, Sydney, N.S.W. 2001

Telephone (02) 20236 Telegrams: NEWFORESTS Sydney

Seeds of a wide range of tree species (both Australian and exotic) are available. A price list is available on request.

Terms of trade: Prices include all handling charges and delivery costs within Australia. Postage on overseas orders is free of charge by surface mail, but where air postage is specified payment should be included in remittance.

Payment in advance is requested.

---

Forests Commission, Victoria
GPO Box 4018, Melbourne, Vic. 3001

Telephone (03) 6179222 Telex: PREMVIC AA32636
Attention FORESTS COMMISSION

Telegrams: FORESTCOM MELB.

Seeds of trees native to Victoria.

Seed prices on request, no catalogue available.
Terms of trade: cash in advance.

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Queensland Forestry Department
Mineral House
41 George Street, Brisbane, Qld 4000

Postal: Box 944 GPO Brisbane, Qld 4001

Telephone: (07) 2240515 Telegrams: FORESTRY, BRISBANE

Seeds of a wide range of tree species, both exotic and native are available.

Orchard grade seed of Pinus elliottii var. elliottii and Pinus taeda is available; also seed of Pinus caribaea var. hondurensis.

A price list is available on request.

Terms of trade: Payment in advance is required.

---

Woods and Forests Department, South Australia
135 Waymouth Street, Adelaide

Postal: Box 1604 GPO Adelaide, S.A. 5001

Telephone: (08) 2170402 Telegrams: WOODFOREST, ADELAIDE
Telex: AA82231

Material available: only Pinus radiata

Standard grade - unsupervised collection
Select grade - multiple-thinned stands over c.40 years old
Orchard grade - polycross orchard collections.

Collected from departmental plantations or orchards in the Mount Lofty Ranges or Lower Southeastern Region of South Australia.

Prices: Standard grade $34 per kg
*Select grade $42 per kg
(1980) *Orchard grade $91 per kg

*Available only when surplus to Departmental requirements.

---

Forests Department, Western Australia
54 Barrack Street, Perth, W.A. 6000

Telephone (092) 258077

Seeds of tree species native to Western Australia.

A catalogue and price list is available post free, on request.

Terms of trade: remittance or letter of credit with order.

---

Forestry Commission, Tasmania
GPO Box 207B, Hobart, Tas. 7001

Telephone: (002) 302014

Seeds of Tasmanian eucalypts and acacias.

Price list is available on request.

Terms of trade: Cash, 30 days.

---

**Private:**

Tasmanian Forest Seeds
'Summerleas Farm', Kingston, Tas. 7150

Telephone: (002) 296387

A wide range of trees and shrubs native to Tasmania. Many species cannot be held in stock and orders for these are met by seasonal collection.

A price list is available on request.

Terms of trade: Charges for postage and customs certificates will be added where applicable. Payment may be made by bank draft to Commercial Bank, Hobart.

large quantities temperate species

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Western Wildlife Supply
'Terrara'
PO Box 90, Gilgandra, N.S.W. 2827

Telephone: (068) 472473
Telegram and Cable: EUCOSEEDS, Gilgandra, N.S.W.

Specialises in Eucalyptus, but has a range of other Australian species, including cycads and palms. Minimum quantities 250 g. Bulk orders may require some time, as many species do not set large crops of seed each year.

Price list is available. Where clients require collections from specific provenances, prices subject to negotiation.

Terms of trade: Bank draft or letter of credit.

Australian Seed Company Pty Ltd
Robertson, N.S.W. 2577

Telephone: (084) 851274

This company specialises in bulk orders for tree, snrub, ground-cover and erosion control seeds. It has a good range of native species, mostly from temperate regions, and a limited range of non-native species.

A catalogue is available.

Terms of trade: Cash or letter of credit. Prices include packing and handling charges.

---

large quantities tropical species/ provenances.

Australian Tropical Plant Supplies
Pinnacle Road, Julatten, Qld 4880

Seeds of indigenous tropical Queensland trees, chiefly economic and commercial species. Mainly eucalypts but will quote for special collections of any tropical Queensland tree species. Normal area of operation is from about 15°S to 18°S and inland to about 144°E.

Terms of trade. 30 days from receipt of invoice; overseas customers by bank draft.

---

large quantities tropical species/ provenances

North Australian Native Seed Supplies
PO Box 40003, Casuarina, N.T. 5792

Telephone: Darwin (089) 852410

Seeds of plant species native to the Northern Territory and the Kimberleys, Western Australia (north of 18°S), specialising in palms and cycads.

Price list is available on request.

Terms of trade: Letter of credit against presentation of invoice and airway-bill.

---

H.G. Kershaw
Postal: PO Box 88, Mona Vale, N.S.W. 2103
Business: 'HighView', Cabbage Tree Road, Bayview, N.S.W.
Telephone: 9976239

Has a large range of ornamentals, including many Australian trees and shrubs, mostly from temperate regions.

A catalogue is available.
Terms of trade: Cash with order. Postage or carriage extra.

---

Nindethana Seed Service
Narrikup, W.A. 6326

Telephone: (098) 466205

Has a wide range of native trees and shrubs, most of which are from temperate regions. A good selection of Acacia species and ornamental trees.

A catalogue is available.

---

Seeds for Preservation
Lot 6, Badgerup Road, Wanneroo, W.A. 6065
Telephone: (092) 4051032

Supplying seeds of Western Australian native plants, specialising in Proteaceae (Banksia, Dryandra, Hakea) Myrtaceae (Eucalyptus, Melaleuca, Beaufortia) but covering many other plant varieties. Wholesale only.

Catalogue is available on application.

---

Southern Seed Sales
35 Wilhelmina Avenue, Launceston, Tas. 7250

Telephone (003) 319187

Suppliers of Tasmanian Eucalypt and Acacia seed. Provenance collections a speciality. A catalogue is available.

Terms of Trade: Existing clients, 30 days credit. New clients Bank draft or letter of credit.

---

A.P.M. Forests Pty Ltd
Technical Section,
129 Argyle Street, Traralgon, Vic. 3844

Telephone: (051) 741274

Details of seed available -

A. Pinus radiata

1. Late thinnings and clearfellings - seed from selectively thinned stands. Combined selection intensity for vigour, stem straightness and branching approximately 1 in 10.

2. Seed Production Area - seed from two areas specially thinned to 100 trees per hectare. Combined selection intensity of c. 1 in 20.

3. Seed Orchards - seed available from Golden Gully; Saxton's and Balook orchards. The composition and development of each orchard and expected gains are described in a seed sales brochure.

B Eucalyptus regnans - seedling seed orchard

Details of availability and price supplied on request.

A seed sales brochure including price list is available on request.

Terms of trade: Payment by cash or bank draft prior to despatch, except for approved customers where 30 day payment on invoice will apply.

---

Flamingo Enterprises Pty Ltd
PO Box 1037, East Nowra, NSW 2540

Telephone: (044) 24876, International: 61 44 24876
Telex: AA 21025 (SHLTVL).

Seeds of a wide range of palms, trees, shrubs, indoor plants and climbers are offered.

A catalogue is available.

Terms of trade: Cash with order unless prior credit arrangements are made.

---

H. Grant
2 Sandra Place, Dubbo, NSW 2830

Seeds of Australain trees; also shrubs, herbaceous and ground-cover plants. Western New South Wales a speciality.

Catalogue posted on application (enclose 2 postage stamps).

Terms of trade: Cash with orders for packets (50c each), 30 days for bulk supplies. Postage payable on all orders.

---

Silvan Improvements Pty Ltd
PO Box 42, Watson, ACT 2602

Telephone: (062) 411075 or 474328
Telegram and Cable: 'Silvan, Canberra'

A wide range of trees and shrubs native to Australia are available. Many species are not held in stock but, if available, can be met by collection. Seed from South Africa together with provenance details and germination test results can be supplied if required.

Quotations are provided on request.

Terms of trade: Bank cheque for small orders. Letter of Credit

Dendros Seed Supplies
59 Mirrool Street
Duffy ACT 2611

Telephone: (062) 881490

Specialising in bulk or provenance collections of Eucalyptus.

Prices available on request.

Terms of trade: Bank draft or letter of credit.

UNIVERSITY OF FLORIDA
INSTITUTE OF FOOD AND AGRICULTURAL SCIENCES
SCHOOL OF FOREST RESOURCES AND CONSERVATION
GAINESVILLE, FLORIDA 32611

118 NEWINS-ZIEGLER HALL
TELEPHONE 904-392-1792



April 26, 1982

Dr. Tom Geary
Southeastern Forest Experiment
Station
P.O. Box 938
Lehigh Acres, FL 33936

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Sincerely yours,

Donald L. Rockwood
Associate Professor

DLR/mp
encl

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*END

*GO

# SECTION VII

# AUSTRALIAN SEED SOURCES FOR CASUARINAS

CSIRO

Division of Forest Research
Banks Street Yarralumla Canberra A C T

Casuarina file

FILE COPY

A Division of the Institute of Biological Resources

P O Box 4008 Canberra A C T 2600
Telephone (062) 81 9211
Telegrams Foresearch Canberra Telex 62735

FILE COPY

JCD/VB
OUR REF: 74/609

14 October 1980

Mr Michael D. Benge,
DS/AGR/TSWM, 420, SA-18,
-Office of Agriculture,
Bureau of Development Support,
Agency for International Development,
WASHINGTON, D.C. 20523, U.S.A.

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Yours sincerely,

J. C. Doran

J.C. Doran
Seed Section

recommended suppliers
+ Casuarina seed.

# AUSTRALIAN SUPPLIERS OF TREE SEED

provided with the compliments of

Division of Forest Research, CSIRO
PO Box 4008, Canberra ACT 2600
Australia

A note to potential purchasers -

Most commercial seed collectors can specify the origin of the seed they supply. *There is however no tree seed certification scheme operating in Australia,* and it is recommended that the purchaser ascertain details of the seed origins before entering into any purchase agreement. *Purchasers should not assume that the seed of eucalypts or other Australian genera will necessarily be supplied from trees growing in Australia. Seed from exotic plantations is now common in the seed trade.*

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research samples - wide range of species

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The Seed Section of the CSIRO Division of Forest Research provides a central seed supply service and acts as a national seed coordinating centre for Australia.

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Prices: A service charge of $5 per seedlot plus $3, $4 or $5 for each 10 g of seed depending on species (includes postage or airfreight, as appropriate). Some seed is available for exchange with government research organizations.

A catalogue is not available, quotations are provided on request.

Terms of trade: Payment in advance by bank draft.

---

## State Governments:

Forestry Commission of New South Wales
GPO Box 2667, Sydney, N.S.W. 2001

Telephone (02) 20236 Telegrams: NEWFORESTS Sydney

Seeds of a wide range of tree species (both Australian and exotic) are available. A price list is available on request.

Terms of trade: Prices include all handling charges and delivery costs within Australia. Postage on overseas orders is free of charge by surface mail, but where air postage is specified payment should be included in remittance.

Payment in advance is requested.

---

Forests Commission, Victoria
GPO Box 4018, Melbourne, Vic. 3001

Telephone (03) 6179222 Telex: PREMVIC AA32636
Attention FORESTS COMMISSION

Telegrams: FORESTCOM MELB.

Seeds of trees native to Victoria.

Seed prices on request, no catalogue available.
Terms of trade: cash in advance.

---

Queensland Forestry Department
Mineral House
41 George Street, Brisbane, Qld 4000

Postal: Box 944 GPO Brisbane, Qld 4001

Telephone: (07) 2240515 Telegrams: FORESTRY, BRISBANE

Seeds of a wide range of tree species, both exotic and native are available.

Orchard grade seed of Pinus elliottii var. elliottii and Pinus taeda is available; also seed of Pinus caribaea var. hondurensis.

A price list is available on request.

Terms of trade: Payment in advance is required.

---

Woods and Forests Department, South Australia
135 Waymouth Street, Adelaide

Postal: Box 1604 GPO Adelaide, S.A. 5001

Telephone: (08) 2170402 Telegrams: WOODFOREST, ADELAIDE
Telex: AA82231

Material available: only Pinus radiata

Standard grade - unsupervised collection
Select grade - multiple-thinned stands over c.40 years old
Orchard grade - polycross orchard collections.

Collected from departmental plantations or orchards in the Mount Lofty Ranges or Lower Southeastern Region of South Australia.

Prices: Standard grade $34 per kg
*Select grade $42 per kg
(1980) *Orchard grade $91 per kg

*Available only when surplus to Departmental requirements.

Forests Department, Western Australia
54 Barrack Street, Perth, W.A. 6000

Telephone (092) 258077

Seeds of tree species native to Western Australia.

A catalogue and price list is available post free, on request.

Terms of trade: remittance or letter of credit with order.

---

Forestry Commission, Tasmania
GPO Box 207B, Hobart, Tas. 7001

Telephone: (002) 302014

Seeds of Tasmanian eucalypts and acacias.

Price list is available on request.

Terms of trade: Cash, 30 days.

---

Private:

Tasmanian Forest Seeds
'Summerleas Farm', Kingston, Tas. 7150

Telephone: (002) 296387

A wide range of trees and shrubs native to Tasmania. Many species cannot be held in stock and orders for these are met by seasonal collection.

A price list is available on request.

Terms of trade: Charges for postage and customs certificates will be added where applicable. Payment may be made by bank draft to Commercial Bank, Hobart.

large quantities temperate species

---

Western Wildlife Supply
'Terrara'
PO Box 90, Gilgandra, N.S.W. 2827

Telephone: (068) 472473
Telegram and Cable: EUCOSEEDS, Gilgandra, N.S.W.

Specialises in Eucalyptus, but has a range of other Australian species, including cycads and palms. Minimum quantities 250 g. Bulk orders may require some time, as many species do not set large crops of seed each year.

Price list is available. Where clients require collections from specific provenances, prices subject to negotiation.

Terms of trade: Bank draft or letter of credit.

Australian Seed Company Pty Ltd
Robertson, N.S.W. 2577

Telephone: (084) 851274

This company specialises in bulk orders for tree, shrub, ground-cover and erosion control seeds. It has a good range of native species, mostly from temperate regions, and a limited range of non-native species.

A catalogue is available.

Terms of trade: Cash or letter of credit. Prices include packing and handling charges.

---

large quantities tropical species/ provenances

Australian Tropical Plant Supplies
Pinnacle Road, Julatten, Qld 4880

Seeds of indigenous tropical Queensland trees, chiefly economic and commercial species. Mainly eucalypts but will quote for special collections of any tropical Queensland tree species. Normal area of operation is from about 15°S to 18°S and inland to about 144°E.

Terms of trade. 30 days from receipt of invoice; overseas customers by bank draft.

---

large quantities tropical species/ provenances

North Australian Native Seed Supplies
PO Box 40003, Casuarina, N.T. 5792

Telephone: Darwin (089) 852410

Seeds of plant species native to the Northern Territory and the Kimberleys, Western Australia (north of 18°S), specialising in palms and cycads.

Price list is available on request.

Terms of trade: Letter of credit against presentation of invoice and airway-bill.

---

H.G. Kershaw
Postal: PO Box 88, Mona Vale, N.S.W. 2103
Business: 'HighView', Cabbage Tree Road, Bayview, N.S.W.
Telephone: 9976239

Has a large range of ornamentals, including many Australian trees and shrubs, mostly from temperate regions.

A catalogue is available.
Terms of trade: Cash with order. Postage or carriage extra.

Nindethana Seed Service
Narrikup, W.A. 6326

Telephone: (098) 466205

Has a wide range of native trees and shrubs, most of which are from temperate regions. A good selection of Acacia species and ornamental trees.

A catalogue is available.

Seeds for Preservation
Lot 6, Badgerup Road, Wanneroo, W.A. 6065
Telephone: (092) 4051032

Supplying seeds of Western Australian native plants, specialising in Proteaceae (Banksia, Dryandra, Hakea) Myrtaceae (Eucalyptus, Melaleuca, Beaufortia) but covering many other plant varieties. Wholesale only.

Catalogue is available on application.

Southern Seed Sales
35 Wilhelmina Avenue, Launceston, Tas. 7250

Telephone (003) 319187

Suppliers of Tasmanian Eucalypt and Acacia seed. Provenance collections a speciality. A catalogue is available.

Terms of Trade: Existing clients, 30 days credit. New clients Bank draft or letter of credit.

A.P.M. Forests Pty Ltd
Technical Section,
129 Argyle Street, Traralgon, Vic. 3844

Telephone: (051) 741274

Details of seed available -

A. Pinus radiata

1. Late thinnings and clearfellings - seed from selectively thinned stands. Combined selection intensity for vigour, stem straightness and branching approximately 1 in 10.

2. Seed Production Area - seed from two areas specially thinned to 100 trees per hectare. Combined selection intensity of c. 1 in 20.

3. Seed Orchards - seed available from Golden Gully; Saxton's and Balook orchards. The composition and development of each orchard and expected gains are described in a seed sales brochure.

B Eucalyptus regnans - seedling seed orchard

Details of availability and price supplied on request.

A seed sales brochure including price list is available on request.

Terms of trade: Payment by cash or bank draft prior to despatch, except for approved customers where 30 day payment on invoice will apply.

Flamingo Enterprises Pty Ltd
PO Box 1037, East Nowra, NSW 2540

Telephone: (044) 24876, International: 61 44 24876
Telex: AA 21025 (SHLTVL).

Seeds of a wide range of palms, trees, shrubs, indoor plants and climbers are offered.

A catalogue is available.

Terms of trade: Cash with order unless prior credit arrangements are made.

H. Grant
2 Sandra Place, Dubbo, NSW 2830

Seeds of Australain trees; also shrubs, herbaceous and ground-cover plants. Western New South Wales a speciality.

Catalogue posted on application (enclose 2 postage stamps).

Terms of trade: Cash with orders for packets (50c each), 30 days for bulk supplies. Postage payable on all orders.

Silvan Improvements Pty Ltd
PO Box 42, Watson, ACT 2602

Telephone: (062) 411075 or 474328
Telegram and Cable: 'Silvan, Canberra'

A wide range of trees and shrubs native to Australia are available. Many species are not held in stock but, if available, can be met by collection. Seed from South Africa together with provenance details and germination test results can be supplied if required.

Quotations are provided on request.

Terms of trade: Bank cheque for small orders. Letter of Credit

Dendros Seed Supplies
59 Mirrool Street
Duffy ACT 2611

Telephone: (062) 881490

Specialising in bulk or provenance collections of Eucalyptus.

Prices available on request.

Terms of trade: Bank draft or letter of credit.