Yearbook 11 -- 1986

WESTERN AUSTRALIAN NUT & TREE CROP ASSOCIATION (INC)

West Australian Nut & Tree Crop Association (Inc.) Year Book 11 -- 1986

West Australian
Nut and Tree Crop Association
(Inc)

WANATCA

Yearbook

Volume 11

1986

West Australian Nut and Tree Crops Association (Inc.)

The Association publishes a quarterly magazine Quandong and the Yearbook. The West Australian Nut Growing Society was incorporated into the Association from 1981.

For details of membership contact the Secretary, WANATCA, P0 Box 565, Subiaco, WA 6008, Australia. Members are welcomed from within and beyond Western Australia, indeed about one third of the current membership is from outside Western Australia.

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CONTENTS

Editorial

The status of the yearbook could only be described as healthy if the volume of material available and of potential interest is considered. An important aspect is to decide what can be left out without diminishing the meaning or content. This year the ten articles cover a wide range of species and interests and four come from authors residing outside Australia. I think this gives the yearbook an international flavour which we could develop.

The 1986 volume is the eleventh and a subject and author index has been included for vols 1 - 10. This will allow easier access to the material previously published.

Some of the articles in this edition challenge us to further develop our food and plant resources. This could be achieved by investigating some of the Australian species; by exploring the possibilities of an ancient crop - the palms; or by taking a fresh look at *Aleurites* species.

Who will accept the challenge?

David W. Turner
Editor

Potential nut crops of the Western Australian Santalaceae

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Summary
The most likely useful nut crop in the Western Australian Santalaceae (apart from *Santalum*) is probably *Anthobolus foeveolatus*. Members of the genera *Chorertum, Spirogardnera* (?) and most of *Leptomeria*, are probably only of decorative use. The genus *Exocarpus* and *Leptomeria* were used by the pioneers and aborigines for their succulent fruits, and may have continued use in this direction. *Leptomeria pauciflora* has reasonably large fruits, and could be studied further. Two species of *Santalum* are presently being investigated for commercial purposes, they are, *S. acuminatum* (Sweet Quandong) for its fruit and kernels, and *S. spicatum* for sandalwood production. Obviously the field is wide open for even the most simple studies. Hopefully this information may indicate what species could be successful where you live.

Introduction
The Santalaceae is a family of parasitic shrubs, found in tropical and temperate regions worldwide. The family has approximately 250 species distributed in 30 genera. Western Australia has 26 species distributed in 6 genera. All species bear numerous small, simple and very similar flowers (Figure 1). *Santalum* species have by far the largest flowers (to 15 mm across in *S. acuminatum*). Generally these flowers are bisexual, however, all members of the genus *Anthobolus* are dioecious. Most species flowers are visited by a wide range of small insects (bees, flies, wasps, beetles and butterflies) who obtain nectar and transfer pollen. Only in the larger flowered *Santalum* species are there more restricted vector lists. *Santalum spicatum* (Sandalwood) seems to be pollinated by large carrion flies (blowflies) only.

Despite a large range of pollinators visiting the flowers, seed set is often low. This is due to several factors, including an inability to set fruit following selfing (Table 1) which is widespread in the family, and sets physiological limits on fruit set. Most species of the Santalaceae will (per plant) set some fruit following selfing (Table 2), and this set often increases with age suggesting that as the size of the plant increases it is able to bear more fruit. Secondly there is considerable variation between plants in the amount of fruit set following selfing, suggesting that selection for selfing ability could increase fruit set. What this means is that one should always plant several trees (to ensure cross pollination), encourage the insect pollinators and always use high yielding plants for stock as there is considerable variation and little selection has been carried out.

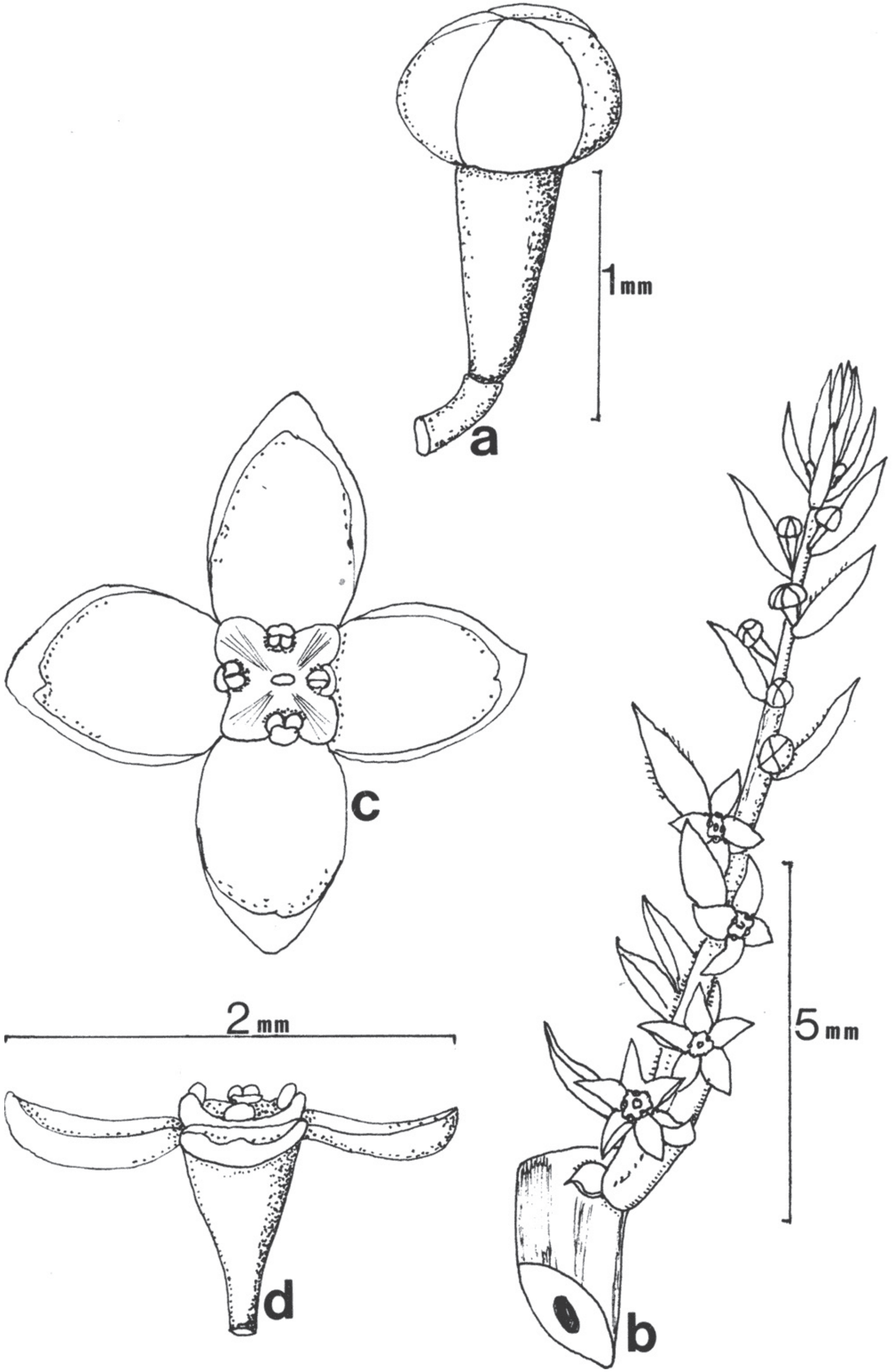


Table 1. Self fertility in Western Australian Santalaceae.

Species	Locality	Flowers Selfed	Fruit Set.
Exopcarpus sparteus R. Br.	City Beach	17	0
Leptomeria cunninghammii	Augusta	74	0
L. empetriformis	Gin Gin	33	0
L. spinosa	Yanchep	21	0
Santalum acuminatum	City Beach	31	0
Spirogardnera rubrescens	Badgingarra	21	14

Table 2. Whole plant fruit set following enforced selfing.

Species	Number of fruits set
Exocarpus sparteus	12
Santalum acuminatum	4
Leptomeria spinosa	14

Vegetative reproduction by root suckers is widespread in Western Australian members of the family, and this ability could be exploited as a means of increasing desirable plants.

Fruits of many species have a coloured succulent sweet tasting cover or base. This attracts birds, who eat the fruit, digest this material and disperse the hard fruit.

Before considering the Sandalwoods in greater detail, we would like to consider the other Western Australian members of the family briefly, and consider which may prove to be useful subjects for further study. Fruit of the Western Australian members of the Santalaceae, excepting *Santalum* are shown in Fig. 2.

Anthobolus
A genus of 5 species, confined to Australia. All are dioecious shrubs, with inconspicuous yellow-green flowers. One species which has been rarely cultivated (*A. foeveolatus*) is both highly decorative and bears large numbers of edible nuts.

A. foeveolatus F. Muell
A broom like shrub, to 2.5 m with yellow-green branches, it has also been reported to be semi-twining on larger shrubs. The species flowers in spring, and bears fruit in summer. The fruits have a bright red/orange fleshy exocarp, over a minutely pitted nut, which is 8-10 mm long by 5 mm wide. Wild populations occur on red sandy soils or calcareous sands (Map 1).

A. leptomerioides F. Muell
A compact twiggy or tangled shrub, to 2 m, branches green or yellow-green. Flowering sporadically, but chiefly in winter and spring, fruiting in late spring. The fruits are smaller, to 6 mm long by 3 mm wide. Wild populations occur on sandy soils (Map 2).

Choretrum
A genus of about 7 species, confined to Australia. All bear small bisexual flowers. Most are decorative for their foliage but are rarely grown. All species bear small globular fruits (to 5 mm diameter) which are crowned by a persistent perianth. The fruits of all species appear to be too small to be more than curiosity value.

C. chrysanthum F. Muell
An erect much branched shrub, to 2 m, branches yellow-green. Bears small yellow flowers in spring, fruits in late spring and summer. Occurs naturally on yellow or red sand (Map 4).

C. glomeratum R. Br.
A broom like shrub (often with weeping branches) to 2 m, with yellow-green branches. Flowers small, white, flowering recorded throughout the year with a peak in autumn. Fruiting similar. Wild populations found on a variety of soils, chiefly sandy clays (Map 3).

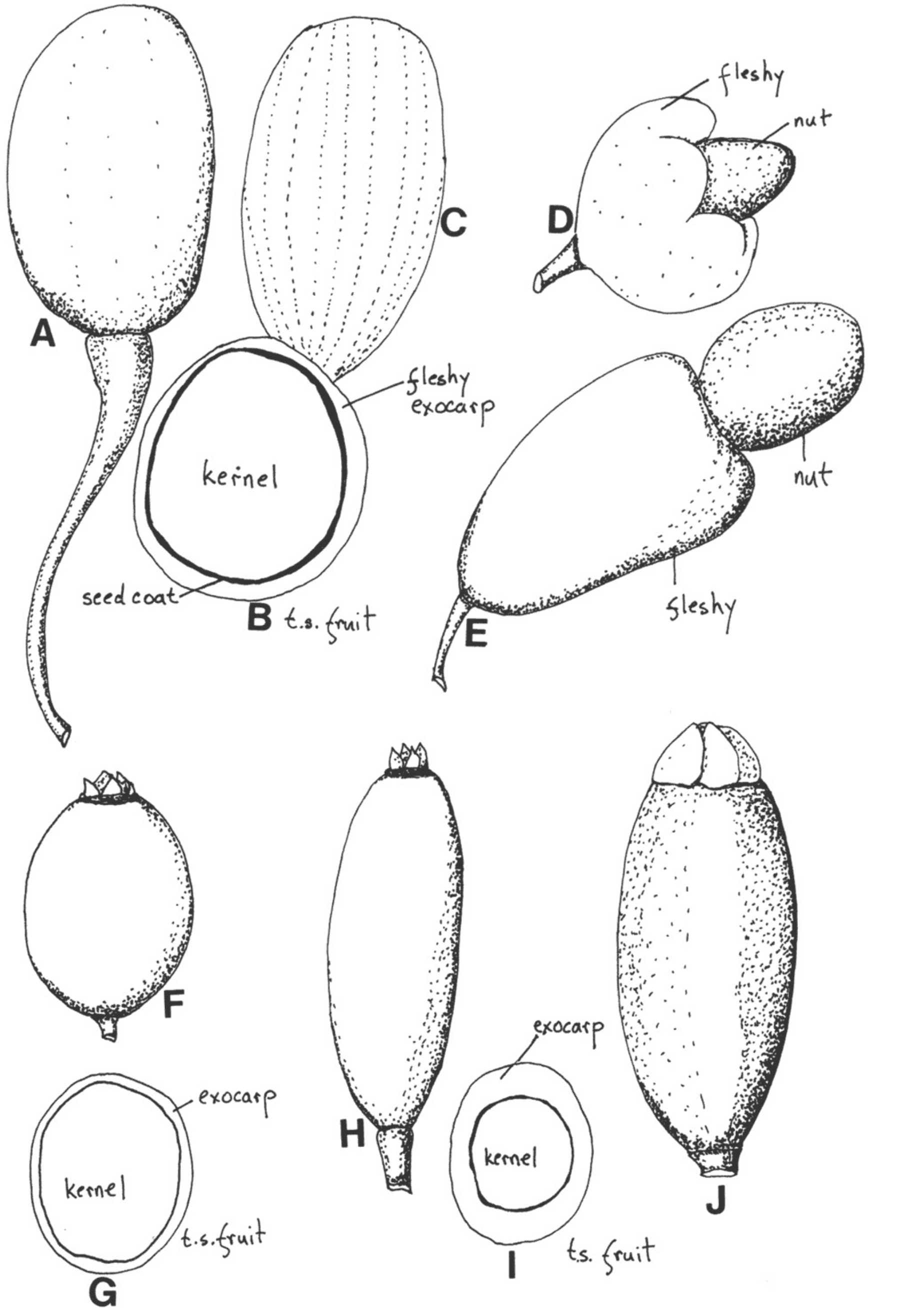
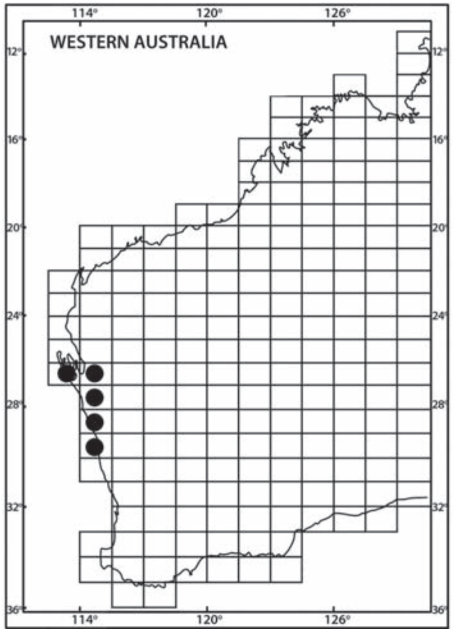


Fig. 2. Representative fruits of Western Australia Santalaceae.

Anthobolus foeveolatus fruit (A), section through fruit (B), seed (C); *Exocarpus aphyllus* fruit (D); *Exocarpus sparteus* fruit (E); *Choretrum laterifolium* fruit (F), section through fruit (G); *Leptomeria pauciflora* fruit (H), section through fruit (I) and *Spirogardnera rubrescens* fruit (J).

1



Anthobolus foeveolatus

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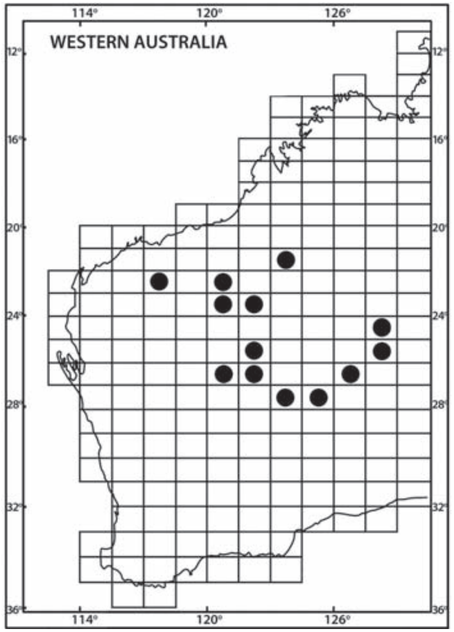
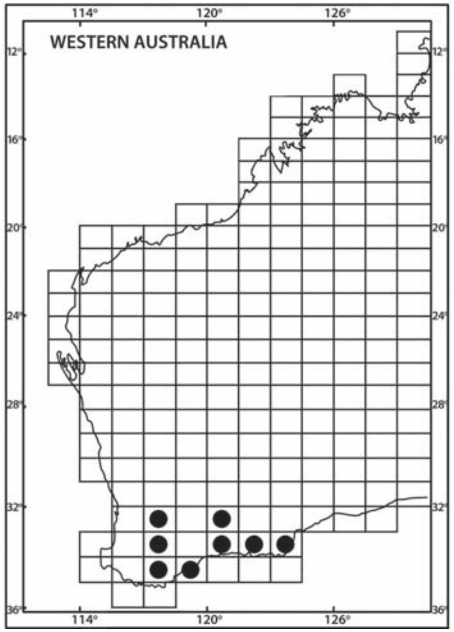


Anthobolus leptomerioides

Choretrum glomeratum



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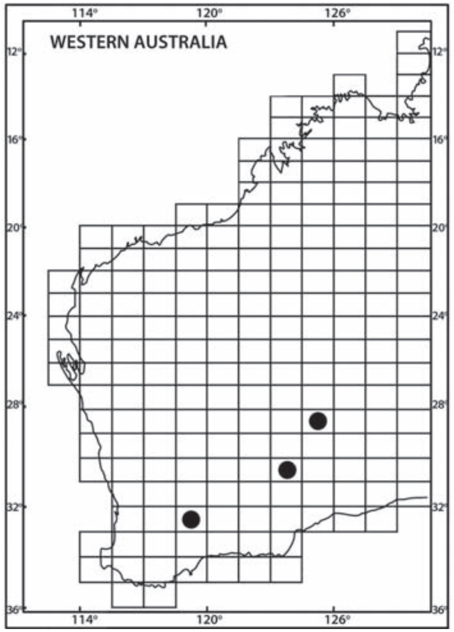
Choretrum chrysanthum



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C. laterifolium R. Br.
An erect shrub, to 3.5 m, with bright green weeping branches. Flowers yellow-green, flowering and fruiting in summer. Occurs on loam or granitic soils (Map 5).

C. pritzelii Diels
An erect broom like shrub, to 2.5 m, branches yellow-green. Flowers white, flowering from February to August, fruiting from April to November. Occurs naturally on sand (Map 6).

Exocarpus (Ballarts)
A genus of 20 species, occurring in Indonesia, Philippines, New Guinea, Australia, New Zealand and the Pacific Islands. All bear small yellow-green flowers. Some species (e.g. E. *sparteus*) are highly decorative. All bear small nuts/or drupes - with a fleshy exocarp resting on a coloured enlarged succulent pedicel. All are edible.

E. aphyllus R. Br. (Leafless Ballart, Stiff cherry, Jointed cherry, Currant bush) An erect spreading tangled rigid shrub, to 2 m, foliage grey green. Flowers inconspicuous yellow-green, flowering peaks July to November but can continue till January. Fruiting occurs from August to January. Occurs naturally on a variety of soils (red, yellow or white sand, sandy clay, limestone, granite or clay) (Map 7).

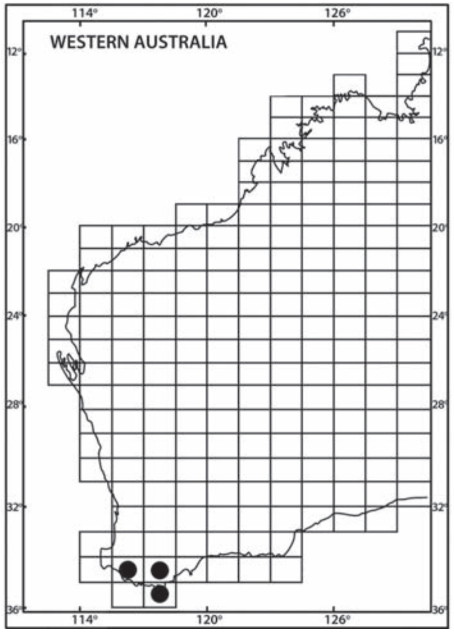
E. laterifolius R. Br.
An erect shrub, to 3 m, foliage green. Flowers reddish- brown, inconspicuous, flowering peaks from May to September commencing in February. Fruiting occurs from April to September. Occurs naturally on sandstone (Map 8).

E. odoratus (Miq.) DC
An erect soft shrub, to 1.5 m, foliage bright green. Flowers yellow-green, inconspicuous, recorded from March to September, but peaking March to May. Fruiting not recorded. Occurs naturally in swampy sands which are wet in winter (Map 9).

E. sparteus R. Br. (Broom Ballart)
An erect broom like shrub, with weeping branches, to 3 m, branches yellow-green. Flowers yellow-green flowering from July to November, but extending rarely to February. Occurs on a variety of soils (sand dunes, granite, limestone, sandy clay, swamps or laterite) (Map 10).

Leptomeria
A genus of 12-14 species, confined to Australia, centred in Western Australia. All bear small bisexual flowers. Most are attractive horticultural subjects. All species bear small nuts, which have a fleshy often coloured exocarp crowned by a persistent calyx. The fruit is acid but can be used to make an excellent jelly. There seems to be limited potential for development of commercial lines in this genus.

5



Choretrum laterifolium

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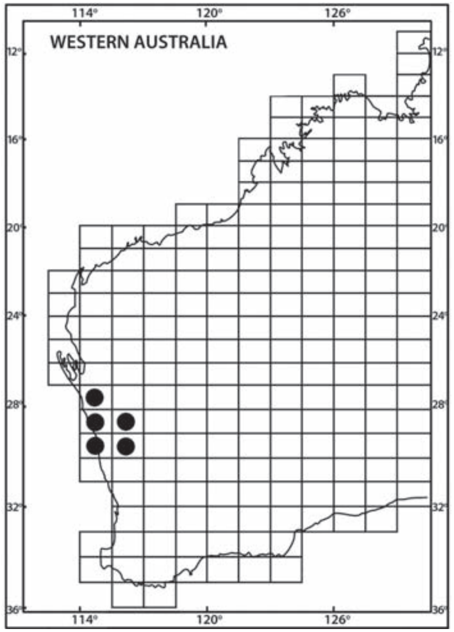
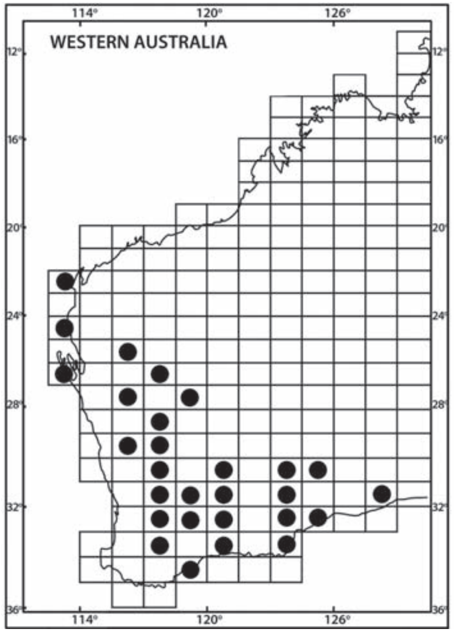


Choretrum pritzelii

Exocarpus aphyllus



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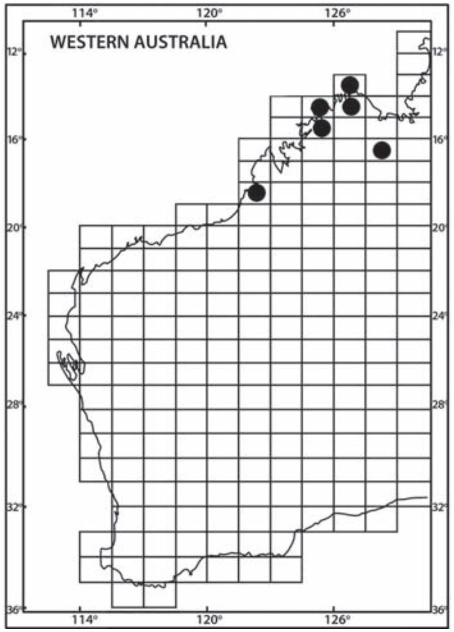
Exocarpus laterifolius



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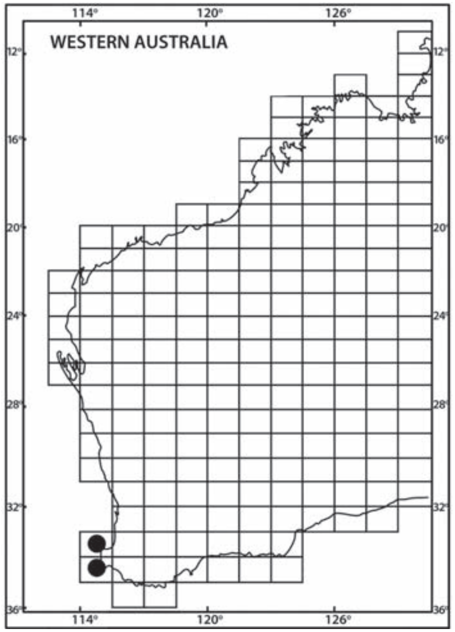

Exocarpus odoratus

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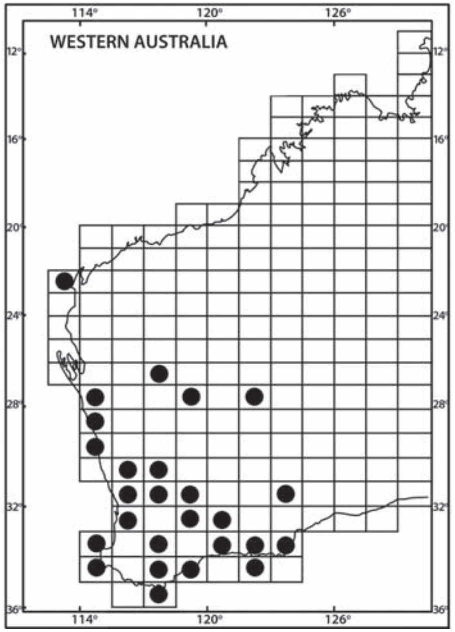
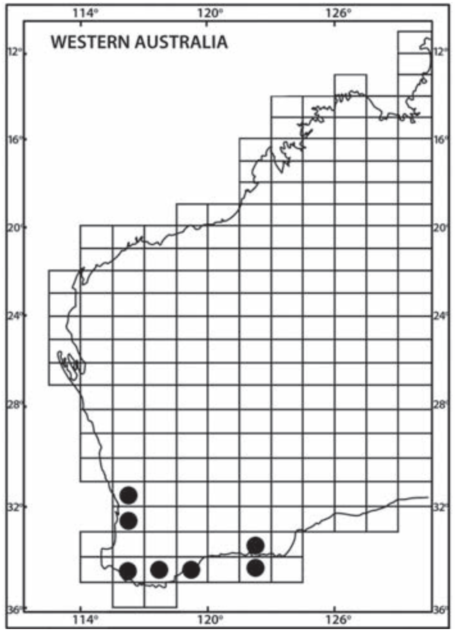


Exocarpus sparteus

Leptomeria axillaris



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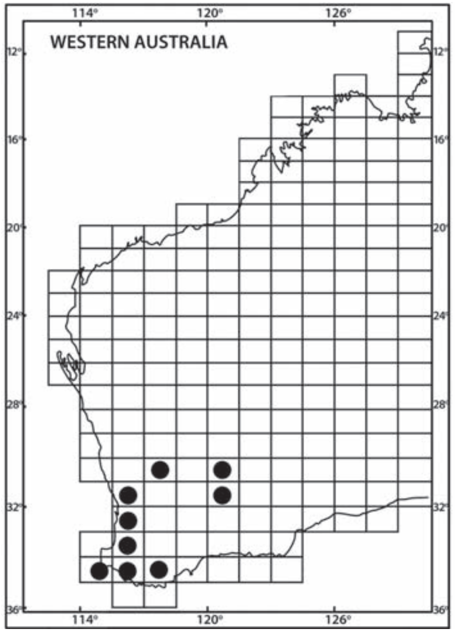
Leptomeria cunninghamii



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L. axillaris R. Br.
A spreading leafy green shrub, to 60 cm, with pendulous branches. Flowers brown, flowering recorded from March to November. Fruiting occurring May to December. Occurs on sand, quartzite and limestone (Map 11).

L. cunninghamii Miq.
An erect much branched, yellow-green shrub, to 1 m tall. Flowers orange-brown, flowering recorded from July to October and extending to February. Fruiting times similar. Occurs naturally on laterite, granite, shale and damp clay (Map 12).

L. empetriformis Miq.
A straggling spreading shrub, yellow-green-grey in colour, to 1 m tall. Flowers orange-brown, flowering from June to September. Fruiting July to October. Occurs on lateritic soils (Map 13).

L. laxa Miq.
An erect slender shrub to 30 cm. Flowers orange. Fruiting period unknown. Rare and poorly known species, no precise localities known (Map 14).

L. obovata Miq.
An erect bright green shrub, with pendant branches, to 50 cm. Flowers orange, flowering recorded in October. Fruiting period unknown. Occurs on sandy stone clay (Map 15).

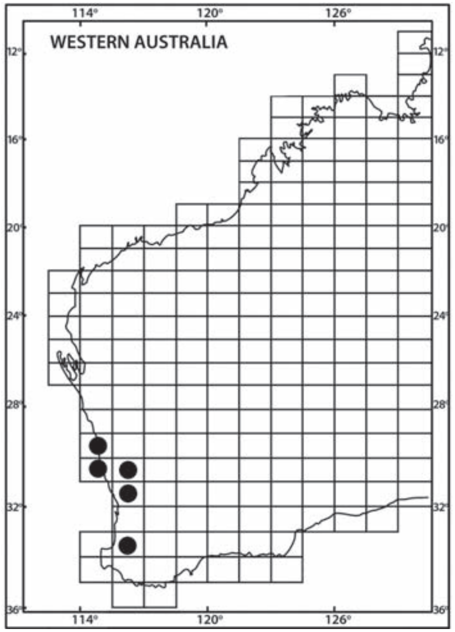
L. pauciflora R. Br.
An erect broom like leafless shrub to 2 m. Flowers yellow-green to orange, flowering from July to November. Fruiting period similar. Occurs on rocky sandy clay, swamps or clay soils (Map 16). This species has the largest fruits of the genus, and perhaps deserves closer attention, for it also has a substantial succulent covering on the nut.

L. preissiana (Miq) DC
An erect rigid broom like leafless shrub to 2 m. Flowers white, flowering from August to December, occasionally extended to January. Fruiting period similar. Occurs on sandy or loamy soils (Map 17).

L. scrobiculata R. Br.
An erect or spreading shrub to I m. Flowers orange-brown, flowering from July to November. Fruiting period similar. Occurs on shale, sand or laterite (Map 18).

L. spinosa (Lehm) DC
An erect, much branched, rigid spiny shrub, to 60 cm. Flowers white, flowering from July to December. Fruiting period August to January. Occurs on sand, laterite and quartzite soils (Map 19).

13



Leptomeria empetriformis

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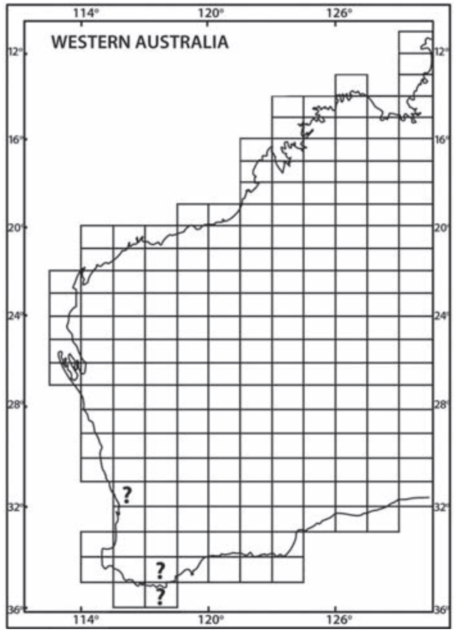
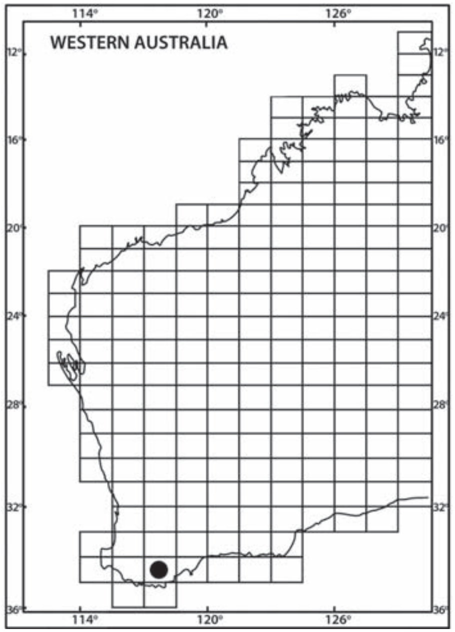


L. laxa

L. obovata



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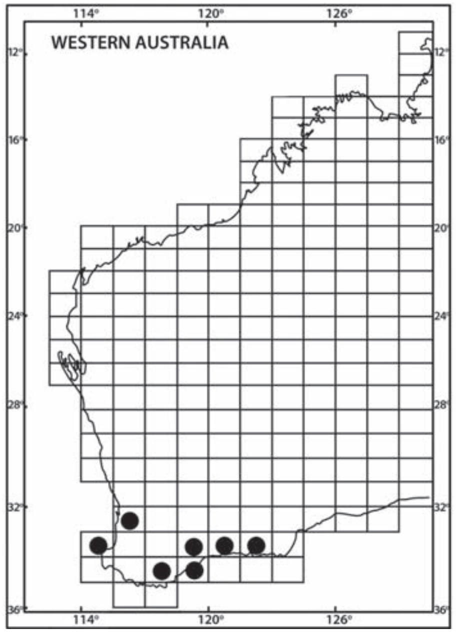
L. pauciflora



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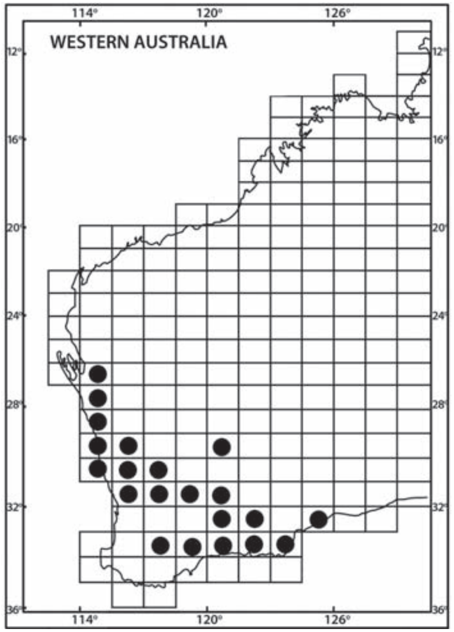
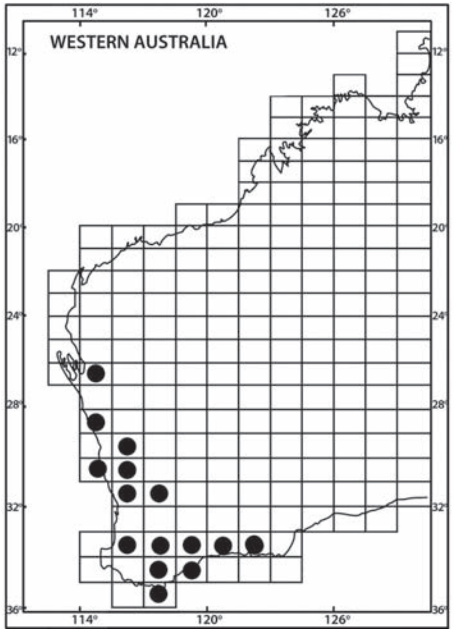


Leptomeria priessiana

L. spinosa



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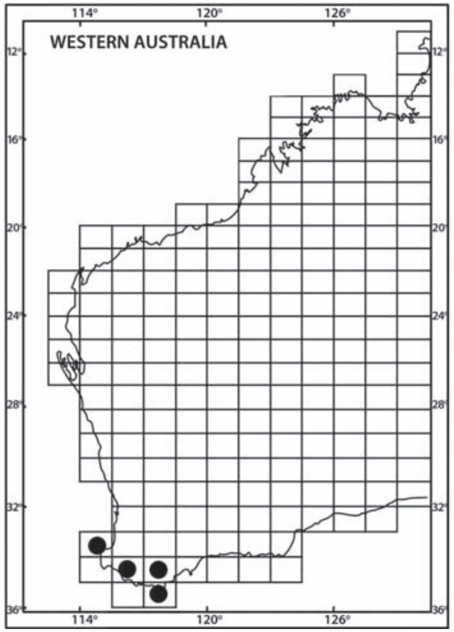
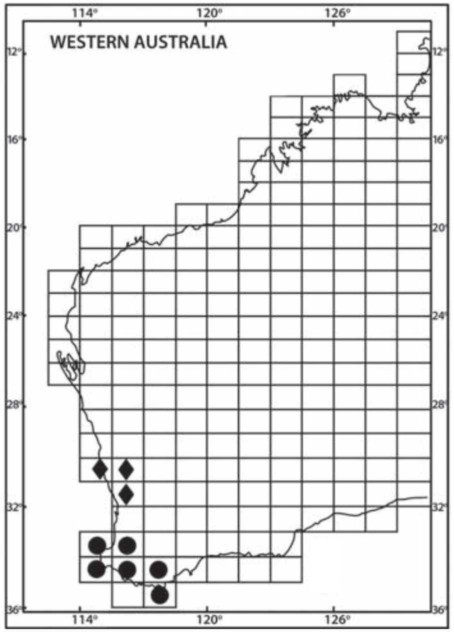


L. scrobiculata (above)

● *L. squarrulosa (below)*

◆ *Spirogardnera rubrescens*



20/21

L. squarrulosa R. Br.
An erect, yellow-green shrub to 2 m. Flowers orange-brown, flowering most of the year with a peak from July to November. Fruiting period similar. Occurs naturally on sandstone, shale, loam and laterite (Map 20).

Spirogardnera
A genus of a single species, confined to Southern Western Australia. The species is highly decorative in flower, but has never been successfully cultivated. The fruits are small, dry and of limited use.

S. rubrescens Stauffer
An erect leafless shrub, to 40 cm. Flowers white, fade red, flowering period August to December. Fruiting period similar. Occurs on lateritic sand (Map 21).

Santalum
The genus *Santalum* consists of approximately 20 species, 4 of which occur naturally in Western Australia. All of the species are root parasites, however, it is not known what the plant extracts from its host, be it extra nutrients/moisture, how dependent the plant is on its host, or if a host is required for the plant's entire life span. Two species of *Santalum* are presently being investigated for commercial purposes, they are, *S. acuminatum*, Sweet Quandong, for its fruit and kernels, and *S. spicatum* for sandalwood production.

Selection and breeding programmes to improve the yield of Sweet Quandong are already in progress. This process will no doubt in the future lead to the commercial production of tissue cultured plants, although it may be many years before we see orchards of Quandong.

Santalum acuminatum (R.B.) D.C. Quandong
A shrub or small tree to 6 m high with cream/green flowers produced from September to January. It can be found growing in red sand, dune sand, clay over gravel, or calcareous sands (distribution map 22).

This is one of the few native Australian plants valued for its fruit and nuts (kernels). The fruit is variable in thickness and sweetness and can be quite acidic and has a characteristic flavour which is said to be similar to 'Black Guava'. Although it can be eaten fresh or dried, the fruit is usually made into jam and used in pies or as a stewed fruit.

The fresh kernel which varies considerably in size is prized by many people and often preferred to other well known nuts. We do not know if the kernel is suitable for roasting. The food value of the Quandong is very high; according to Grant and Buttrose the fruit has a high content of vitamin C approximately double that of oranges for equal fresh weights, while the kernel is a rich food containing approximately 25% protein and 70% oil. Although not widely used, the timber is hard, close grained and excellent for cabinet work.

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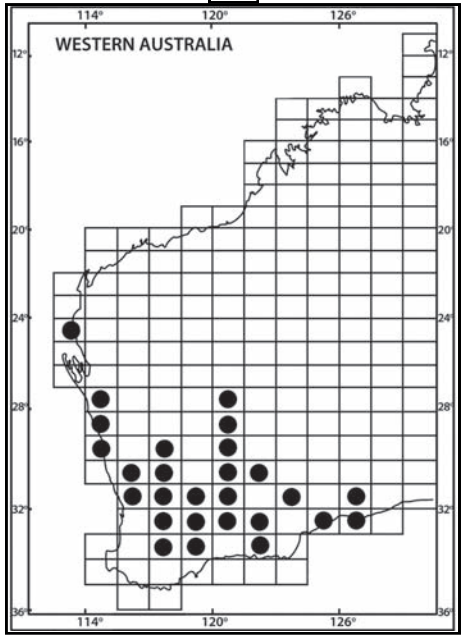

Santalum acuminatum

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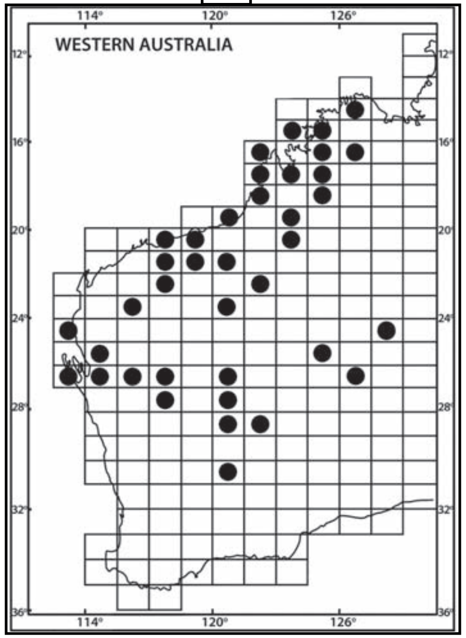
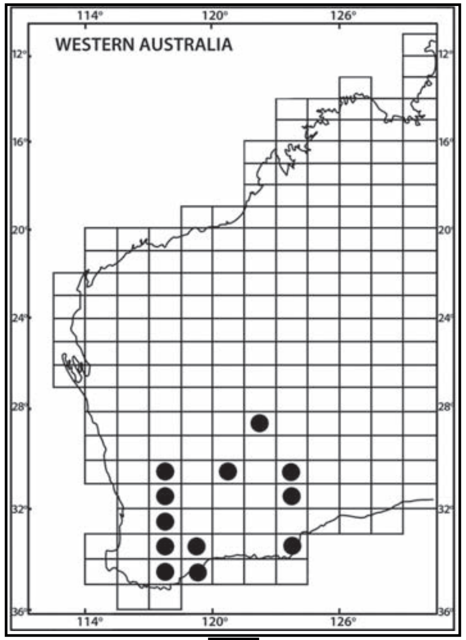


S. lanceolatum

S. murrayanum



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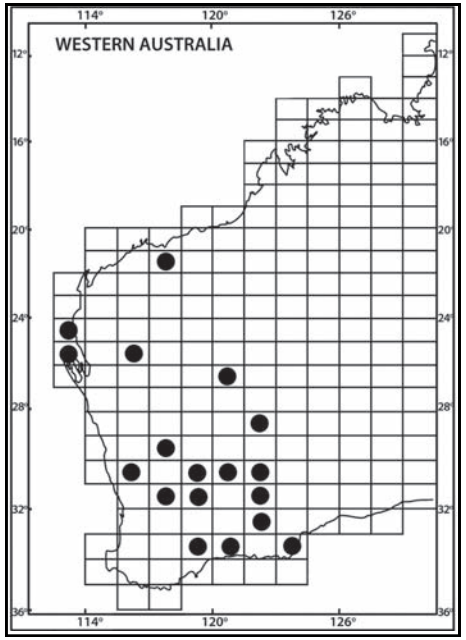
S. spicatum



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In New South Wales the timber was used by Aborigines for making fire and the nuts, shell intact, were used for necklaces, bracelets and other ornaments.

Propagation and Cultivation

Propagation is by seed sown in the autumn or spring. The two methods most easily employed by the amateur are (A) sow the seed, fruit removed but shell intact, in the autumn when the seed is about 7 months old. Sow in 5 cm pots and prick out the seedlings as soon as they emerge, as they have a brittle tap root. The seedlings which take about 4 weeks to germinate are best pricked out into 15 cm pots and grown on for 1 year then planted out. As long as the seedlings are kept moist they will grow for at least 1 year without a host. (B) sow the seed in situ, shell intact, during the autumn within the root zone of a host plant. With this method seedlings should be watered for the first spring, summer and autumn until they are established. The above methods when using fresh seed usually produce a 60% germination rate, when using old seed we find the germination rate is very poor.

The method recommended by the CSIRO is to crack the shell in a vice, remove part of the brown covering around the seed, sterilise the seed in household bleach and sow in a polythene bag with sterilised moist vermiculite or similar medium. The bag is then placed in the dark with an optimum temperature of 16 to 20°C. Seedlings are potted up into 15 cm pots with a host plant e.g. Lucerne (*Medicago sativa*) when their root is about 5 cm long.

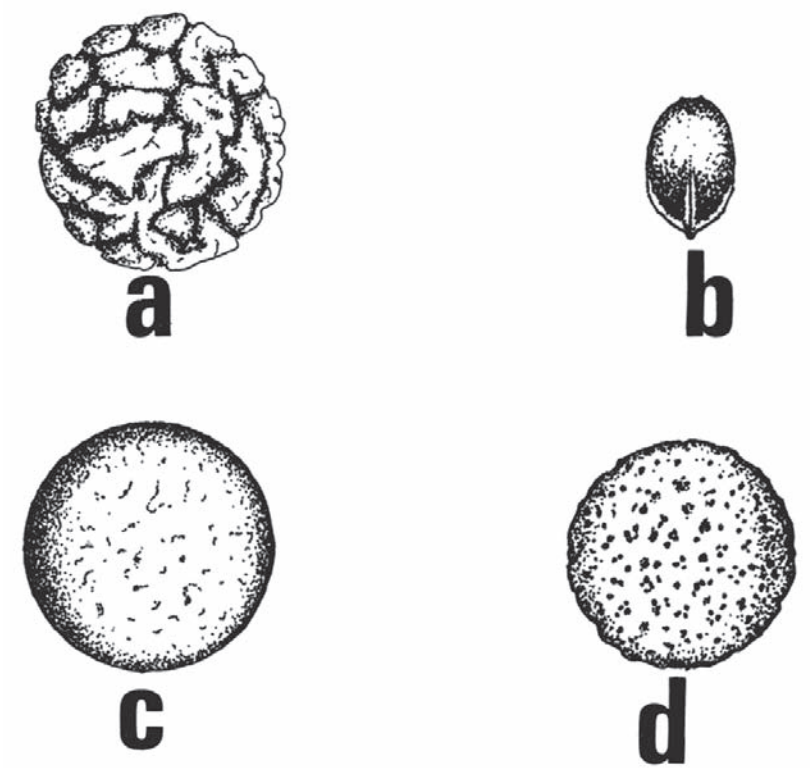

Fig. 3. Seeds of *Santalum acuminatum* (Sweet Quandong) (a); *S. lanceolatum* (Plumbush) (b) ; *S. spicatum* (Sandalwood) (c); and *S. murrayanum* (Bitter Quandong) (d), all to the same scale.

Quandongs are best grown in a free draining preferably sandy soil within the root zone of a host plant, in full sun but not in an exposed position. Although flowering can occur in the third year and fruit in the fourth year, they generally flower when about five years old and produce very few fruit for the first 2 or 3 years of flowering. A reason for this may be poor pollination, a fairly old plant growing by itself can produce a heavy crop of good fruit.

In cultivation the insignificant cream/green flowers are produced over a period of several months often from September to March, fruiting is generally from September to November.

Although plants vary in height a good mature specimen will grow up to about 5 m and is an impressive site when covered with its red fruit. Growth rates vary considerably in cultivation e.g. a 7-year-old plant grown in an area with a high water table was over 3 m high, the flower set was high. A 9-year-old plant grown in Kings Park is about 3 m high and produces regular crops, however it is severely restricted in growth due to intense competition from surrounding vegetation.

Seedlings will germinate under mature trees, however most of the young growth is generally suckers which do not readily transplant.

***Santalum lanceolatum* R. Br. Plum Bush**
A shrub or small tree to 4 m high with insignificant cream/green flowers produced from May to October and occasionally to February. It can be found growing in red sand, alluvium, clay, beach dunes or in sandstone soils (distribution map 23).

This species is rarely grown in cultivation, however the plant is attractive with its bluish grey weeping foliage and small fruit which are often reddish when young, turning to purple or blue black when ripe. The fruit, although smaller than the Quandong, is said to be sweet and of an agreeable taste. The kernel may be edible but we can find no reference to it being eaten. Oil has been extracted from this species and used commercially, however it is considered an inferior species when compared with *S. spicatum*. The wood is close grained and takes a good polish, it is hard, yellowish in colour and useful for cabinet work.

Propagation and Cultivation
Propagation is by seed sown in the spring. Seed sown in Kings Park nursery germinated in 31 days, to our knowledge the seed was not treated. We suggest you sow fresh seed in the same way as recommended for *S. acuminatum* or nick the older seed with a bandsaw as used for *S. spicatum*. We have not been able to establish this species in our Botanic Garden, as this plant grows in predominantly summer rainfall areas; maybe it cannot tolerate cold wet winters. We do not recommend its cultivation in winter rainfall areas eg Perth, WA, however if you wish to try it, obtain seed from its southern population.

***Santalum murrayanum* (L.T. Mitch.) C.A. Gardn. Bitter Quandong**
A shrub or small tree with a weeping habit up to 4 m high, with insignificant yellow/green flowers occasionally produced from May to November, however the main flowering period is from November to August. This species can be found growing in red loam, lateritic, yellow sand or lateritic clay soils (distribution map 24).

As the common name suggests the fruit is bitter and considered inedible. It is not known if the kernel of this species is edible, we can find no reference to it being consumed by Aborigines or early settlers. The bark of the roots was known to be roasted in the ashes of a fire and eaten by Aborigines.

Propagation and Cultivation
Propagation is by seed sown in the autumn or spring. Seed sown in Kings Park nursery germinated in 45 days, to our knowledge the seed was not treated in any way. We suggest you sow fresh seed as recommended for *S. acuminatum* or use older seed and treat by the CSIRO method. According to our nursery records we have only sown and germinated two batches of seed. Unfortunately we have not been able to establish this species in our botanic garden which is surprising as this is a southern species. The reason for this failure is not clear, it may have been due to the nature of our free draining soil and lack of moisture during the critical period between planting and establishing it on a host.

***Santalum spicatum* (R. Br.) D.C. Sandalwood**
An erect shrub or small tree up to 4 m high. The flowers are yellow/green on the outside and red/purple inside, occasionally they are produced from October onwards but more usually from December to May. This species can be found growing in red sand, red loam, beach dunes and granitic soils (distribution map 25).

The fruit of this species, which is brown when mature, to our knowledge is not eaten but may be edible. However the small kernel is edible but quite inferior to that of *S. acuminatum*.

This species has been a valuable export earner for Western Australia; as far back as 1845 this valuable aromatic wood was exported to Asia. Today we believe there is only one licensed sandalwood puller operating in this state. Unfortunately the whole of the tree is pulled out of the ground as the oil also occurs in the roots. We imagine the wood, which is hard, would be ideal for cabinet making, however it may be too valuable for this use. We do not know if all the wood exported was used for oil extraction or if any was used for carving.

This species is very slow growing, requiring 70 to 90 years to attain a commercial size of 127 mm to 200 mm diameter. Compare this with the commercial sandalwood of India, S. album, which can attain a commercial size of 150 mm in 7 years under ideal growing conditions and 10 to 20 years in less vigorous conditions.

Propagation and Cultivation

Propagation is by seed sown in the autumn or spring. Use fresh seed, remove the fruit leaving the hard shell intact and sow the seed in a free draining sandy mix, germination takes about 3 weeks. Prick out the seedlings as soon as they germinate into 15 cm pots and grow on as for *S. acuminatum*. The plants will grow on for at least 1 year without a host as long as they are kept moist, they prefer to be in broken sunlight or under shade cloth rather than in full sun. This species responds well to sowing in situ in the autumn, after the heavy rains have started. The host used for this plant should be a small shrub or a slow growing plant as the host may provide too much competition and choke out the sandalwood.

The following seed treatment and germination technique recommended by Crossland is simple and easy to apply - use only fresh seed 1 to 4 months old, germination rates decrease dramatically if the seed is stored for 12 months or longer. Remove the brown fruit (outer flesh) make a 5-8 mm cut using a bandsaw in the hard shell (endocarp) do not cut too deep as you may damage the seed. When using the bandsaw hold the seed with wooden tongs for safety and ease of handling. Dust the seed with fungicide and place them between hessian sacks that have been soaked in a fungicide solution. Keep the bags moist and at a temperature of 16 to 20°C. The seeds are ready for planting out when the radicle is 4-5 cm long.

Several 7-year-old plants which were sown *in situ* in Kings Park Botanic Garden are growing very well and are at present about 2 m high. They are growing in sandy soil with low water table and were only watered for the first two seasons after sowing, their host plants are *Acacia inophloia*. We would expect this growth rate exceeds by far that of naturally occurring plants.

Seed and Potting on Mix :7 parts clean grey bush sand with 1 part compeat (local peat) by volume. As long as you use fairly clean bush sand it is not necessary to sterilise the above mix.

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Tissue culture propagation of nut tree species

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Introduction

Nut trees have in common with fruit trees a requirement that they be vegetatively propagated in order to maintain the clonal fidelity of orchards. This is usually achieved by budding or. grafting the scion cultivar onto rootstock which is itself propagated from seed, stool beds or cuttings (Westwood 1978, Janick 1979, Baxter 1981, Childers 1983). An alternative method which has been of particular value with many ornamental species is tissue culture in which pieces of plant material are grown under sterile conditions in a controlled environment. While there are many types of tissue culture the one of choice for clonal propagation is micropropagation which has three advantages over conventional methods. Micropropagation allows for the rapid propagation of a species, for plants to be propagated all the year and for production runs to be arranged to fit in with grower requirements. In its simplest form micropropagation is a four-stage process.

Establishment of Sterile Cultures

Plants have on their surface a microflora of fungi, bacteria and yeasts which have to be removed to obtain sterility. A number of approaches are used but the most common is to use a chlorine solution, usually in the form of calcium or sodium hypochlorite. Other sterilants such as mercuric chloride, bromine water or benzalkonium chloride are less commonly used. After surface sterilization explants are usually grown on a simple nutrient medium to screen for contamination. Culture establishment is probably the single most difficult stage to overcome as plant material has to both survive what can often be a drastic treatment and adapt to growth in an artificial environment. Browning of cultures due to oxidation of phenols can be a problem often resulting in culture death. A major problem with woody perennial species is to select material that will be responsive in culture to obtain the final objective. Woody species generally have a juvenile and adult stage. Juvenile material is simpler to work with in culture as it is usually more responsive, but it is of unknown genetic potential. Once a plant becomes adult, flowers, fruits and shows its full agronomic potential it is often difficult to micropropagate. Therefore, to micropropagate adult trees it is best to use juvenile material from adult trees and this can be obtained by wounding the base of the tree to produce suckers, coppicing or repeated grafting of adult material onto seedlings.

Shoot Proliferation

This is the stage during which large numbers of shoots are produced. The explant of choice has terminal or lateral buds and after satisfactory establishment in culture, buds are induced to form multiple shoots by enhanced axillary bud formation.

The key ingredient in the culture medium is the type and concentration of cytokinins used (e.g. BAP, kinetin). In addition, the temperature, photoperiod, quality and intensity of light can influence the response. Once these requirements have been determined by appropriate experimentation it is possible to produce a large number of shoots by frequent sub-culturing of shoots onto fresh medium and it is possible to repeat this virtually indefinitely.

Root Initiation and Growth

Once sufficient shoots have been obtained they are transferred to another medium in which cytokinins are omitted (or their concentration reduced) and auxin added. Response varies with concentration and type. Auxins used in tissue culture include IBA, NAA and IAA. Rooting *in vitro* has been shown to be very difficult with some species as has propagation from cuttings. One advantage of tissue culture is that it is possible to produce large numbers of shoots which are uniform physiologically and therefore study important factors. These can include altering the chemical composition of the medium, the use of rooting cofactors and physical factors such as etiolation and the physical support on which shoots are grown.

Acclimatization

The success of any micropropagation program depends on the ability to transfer plantlets to potting medium and their successful acclimatization to free-living conditions. While this is relatively simple on a small scale, in a commercial situation high survival rates are required and the procedure must be economic. Poor survival on transfer to potting medium is associated with poor water relations due to an absence or reduction of epicuticular wax on the leaf surface, the inability of stomata to close for the first few days, leaves with an altered anatomy with large air spaces and sometimes a poor vascular connection between the base of the stem and the root system. Immediately after transfer, plantlets are kept shaded and under high humidity obtained with intermittent misting, humidity tents or fogging. Humidity and shading are reduced gradually as plantlets acclimatise.

Micropropagation has been reviewed many times and a good overview can be found in George and Sherrington (1984). Information on nut tree species is lacking and the following has been extracted from Hutchinson and Zimmerman (1986).

Castanea sativa (Chestnut)

Chestnuts are difficult to strike from cuttings (Vieitez 1974) and initial research looked at tissue culture as a means of solving this. Callus has been induced from cambial tissue (Jacquiot 1950) and cotyledons (Vieitez *et al* 1978). A basal media supplemented with 1 or 10 mg 1^{-1} (*ca*. 5 or 50 µM) 2,4-D plus 0.5 mg 1^{-1} (*ca*. 2.5 MM) kinetin or BAP was best for callus initiation with root initiation occurring with 10 mg 1^{-1} (*ca*. 50 µM) IBA plus 0.5 mg 1^{-1} (*ca*. 2.5 MM) kinetin or BAP and 10 mg 1^{-1} (*ca*. 50 µM) NAA plus 0.5 mg 1^{-1} (*ca*. 2.5 MM) kinetin.

There have been a number of reports on initiation and maintenance of shoot proliferation, mostly from seedling material.

Using three-month-old seedlings and nodal explants Vieitez and Vieitez (1980a) induced shoot proliferation using Murashige and Skoog (1962) (MS) with 1 mg 1^{-1} (*ca*. 5 µM) BAP in which 50% of explants produced 10 to 20 shoots 3-5 cm tall. Zeatin induced a higher percentage of buds to proliferate and shoots were more vigorous but proliferation was reduced. This was confirmed by Vieitez and Vieitez (l980b) who reported that with 5 mg 1^{-1} (*ca*. 25 µM) BAP shoots were stunted, but were able to elongate by reducing BAP to 0.1 mg 1^{-1} (*ca*. 0.5 µM). Rooting can be achieved by exposing shoots to 1 mg 1^{-1} (*ca*. 5 µM) IBA for eight days followed by transfer to hormone-free medium, in which roots began to emerge in two to three weeks and about 50% rooting occurring after eight weeks. An interesting observation was that rooting was best with initial cultures and poorer with shoots that had been subcultured. These general trends were found by Rodriguez (1982c,d) and Vieitez and Vieitez (1983).

In a more detailed study (Marie Chevre *et al* 1983) using both juvenile and adult material found that a basal medium of MS with Ca and Mg concentration doubled, 1 mg 1^{-1} (*ca*. 5 µM) BAP, 3.5% sucrose and a pH of 4 was suitable for shoot proliferation of both growth phases. Shoot elongation was poor with adult material and it was necessary to add 1 mg 1^{-1} (*ca*. 5 µM) IAA, 1 mg 1^{-1} adenine and 0.5% activated charcoal. Using adult material of various clones of *C. sativa* x *C. crenulata* hybrids with resistance to *Phytophthora cambivora* and *P. cinnamomi* Vieitez *et al* (1983) evaluated a range of treatments affecting culture establishment and shoot proliferation. Experimental trees were pruned to ground level and shoots allowed to grow; establishment was best with shoot-tip explants collected in winter and stored for about three months at 4°C and sprouted in the glasshouse. Storage of shoots for longer periods led to explant necrosis. Cultures were established on MS with NO_3 reduced by half and with BAP ranging from 0.1 to 1 mg 1^{-1} (*ca*. 0.5 to 5 µM). Continued maintenance on MS with half NO_3 resulted in shoots with flaccid tips and elongated dark green leaves and proliferation capacity was rapidly lost. Screening a range of macro and micronutrient basal media it was found that the media of Blaydes (1966), Hellers (1953) + 1 mM NH_4NO_3 and Lepoivre (Quoirin and Lepoivre 1977) with 0.1 to 0.5 mg 1^{-1} (*ca*. 0.5 to 2.5 MM) BAP were suitable.

While limited success has been achieved with adult material there are still a number of problem areas. Explant browning during establishment has been observed (Jacquiot 1950, Vieitez and Vieitez 1980a, Marie Chevre *et al* 1983 and Vieitez *et al* 1983) with the most successful treatment being to soak explants in sterile water after surface sterilization and prior to transfer to media, a method successfully employed by Cresswell and Nitsch (1975) for *Eucalyptus grandis*. Rooting was not achieved in adult material (Marie Chevre *et al* 1983) and only to a limited extent (Vieitez *et al* 1983) by using auxin dips and transfer to hormone-free medium. In addition there is considerable cultivar difference in response to shoot proliferation and rooting (Marie Chevre *et al* 1983, Vieitez and Vieitez *et al* 1983).

In a preliminary report Qiguang *et al* (1985) described a micropropagation procedure for *C. mollissima* (Chinese chestnut) and *C. dentata* (American chestnut) in which Lloyd and McCown (1980) medium supplemented with 0.1 mg 1^{-1} *ca*. 0.5 µM) BAP was used for shoot proliferation. Rooting was achieved by dipping micropropagated shoots in 2 000 or 3 000 mg i IBA for one second and transfer to hormone-free medium or by transfer to sand and keeping cultures under high humidity. The latter procedure has the advantage that rooting and acclimatization were treated as the one process thus eliminating the time-consuming and expensive stage of an additional *in vitro* step.

Juglans spp. (Walnut)
As with *Castanea sativa* early attempts with *Juglans* spp. looked at root initiation from callus as a means of solving problems associated with difficulties in the rooting of cuttings. Using *J. regia* (English walnut) Jacquiot (1951) found no callus on auxin-free medium. Callus was later induced and maintained for a short time (Cammins and Ashby 1969) from stem tissue of *J. nigra* (black walnut) using White (1963) medium with NAA and kinetin but no differentiation occurred. Callus and root initiation has been achieved from cotyledon explants of *J. regia* (Rodriguez 1982a) using 2,4-D and kinetin for callus initiation and NAA and kinetin or BAP for root initiation.

Shoot proliferation has been induced and maintained from sterile seedlings of *J. regia* (Rodriguez 1982b) using BAP and IBA. Research with the hybrid rootstock 'Paradox' (*J. hindsii* x *J. regia*) has been more successful. Testing a range of basal media Driver and Kuniyuki (1984) found performance was better on Lloyd and McCown (1980) or 5 nM IBA. However the continual maintenance of cultures could not be achieved and after 10 sub-cultures shoots were formed that were of reduced size and could no longer be proliferated. Subsequent research, testing individual components at several levels, resulted in a medium in which growth was faster and could be maintained. Rooting could be achieved with Lloyd and McCown (1980) medium with 30 µM IBA or dipping shoots in 5 mM IBA and acclimatizing directly (Driver and Kuniyuki 1984).

Recent research has shown it is possible to induce somatic embryogenesis and subsequent plant formation from cotyledons of open pollinated *J. regia* cultivars, *J. hindsii* and the related genus *Pterocarya* (Tulecke and McGranahan 1985).

Prunus amygdalus (Almond)
Cultures have been established from dormant shoot-tips (Kester *et al* 1977, Tabachnik and Kester 1977) and actively growing shoots (Rugini and Verma 1982, 1983). A basal medium based on Knops macronutrients and MS micronutrients and organics has been used with BAP from 0.7 to 1 mg 1^{-1} (*ca*. 3.5 to 5 µM) for culture establishment. Incorporating low concentrations (0.01 mg 1^{-1} *ca*. 0.05 µM) of auxins tended to produce callus (Tabachnik and Kester 1977) with 'Nonpareil' whereas 0.1 mg 1^{-1} (*ca*. 0.5 µM) NAA was used routinely with 'Ferragnes' (Rugini and Verma 1983).

For shoot proliferation Knops macronutrients with MS micronutrients and organics and 1 mg 1^{-1} (*ca*. 5 µM) BAP have been used, with half MS resulting in chlorosis (Tabachnik and Kester 1977), whereas MS was used for both shoot proliferation and elongation with the latter being achieved by omitting NAA and reducing BAP from 0.7 mg 1^{-1} (*ca*. 3.5 µM) to 0.2 mg 1^{-1} (*ca*. 1 µM).

Rooting remains a problem, and only limited rooting was found (Tabachnik and Kester 1977) using IBA and dark incubation, NAA and light or using sterilised vermiculite in tubes with no auxin. Better rooting was achieved by Rugini and Verma (1982, 1983) using the basal medium of Bourgin and Nitsch (1967) with 1 mg 1^{-1} (*ca*. 5 µM) NAA and dark incubation for 14 days and transfer to hormone-free liquid medium with vermiculite as a physical support or root induction with NAA for four days and transfer to IAA medium for root elongation.

Corylus avellana (Hazelnut, Filbert)
Research on micropropagation has concentrated on developing procedures with seedling material and adapting them to cultivars. Different groups have used varying approaches. Anderson (1983) tested a range of macro and micronutrient formulations with Linsmaier and Skoog (1965) organics plus adenine sulphate and found Anderson (1978) medium superior to MS or Lloyd and McCown (1980). Kai *et al* (1984) used MS macro and micronutrients with Zuccherelli (1979) vitamins, whereas Perez *et al* (1985) used Chengs (1975) basal medium. A combination of BAP and 2iP at 2 mg 1^{-1} (*ca*. 10 µM) and 1 mg 1^{-1} (*ca*. 5 µM) respectively was used by Anderson (1983) whereas 5 mg 1^{-1} (*ca*. 25 µM) BAP, 0.01 mg 1^{-1} (*ca*. 0.05 µM) NAA and 0.1 mg 1^{-1} (*ca*. 0.3 µM) GA_3 was used by Kai *et al* (1984), and 25 µM BAP to induce proliferation and 0.5 or 2.5 µM BAP to elongate shoots for rooting (Perez *et al* 1985). Anderson (1983) and Kai *et al* (1984) described a problem that may be similar but attributed it to different causes. Anderson (1983) found pale yellow leaves with MS medium which he felt was similar to salt toxicity and Kai *et al* (1984) found chlorotic shoots (using MS) but alleviated the problem by changing the iron source from $FeSO_4.7H_20$ and $Na_2EDTA.2H_20$ to sequestrene 138 Fe^2(Ciba-Geigy). Shoot proliferation was better using basal explants compared to shoot tips (Anderson 1983) as found with *Malus* (Hutchinson 1984), *Pyrus* (Xiao-Shan and Mullins 1984) and *Diospyros* (Cooper and Cohen 1984).

Preliminary experiments on rooting (Anderson 1983) have found that half strength Anderson (1978) with 0.5 mg 1^{-1} (*ca*. 2.5 µM) IBA or IAA can be used, whereas Kai *et al* (1984) found 0.1 mg 1^{-1} (*ca*. 0.5 µM) IBA superior to IAA or NAA, with higher concentrations of auxins tending to produce callus. Perez *et al* (1985) used two media, one supplemented with 50 µM IBA for five days to induce roots and then a second hormone-free medium for root elongation.

Techniques developed for seedlings have been adapted to the cultivar 'Daviana' and a number of French cultivars but contamination rates were high for Daviana (Anderson 1983) and improvements are required for commercial use (Kai *et al* 1984).

Difficulties have been found in establishing cultures of 'Negret' where the season had a dramatic effect. Cultures established better in autumn than spring as more buds sprouted, however, shoot proliferation was not obtained (Messeguer and Mele 1983).

Carya illinoensis (Pecan)
Pecans are native to southern United States and Mexico where production is largely from wild and seedling trees with selected cultivars propagated by grafting (Janick 1979).

Initial attempts to culture pecans failed due to internal contamination of buds with *Alternaria*, however cultures established from the spring flush of growth were contaminant-free (Knox and Smith 1980). Growth of internal contaminants could be partially controlled by incorporating 200 mg 1^{-1} streptomycin and 40 mg 1^{-1} filter sterilised pimarcin (Wood 1982).

Cultures have been established from seedlings, the preparation and initial growth of which was found to be important (Hansen and Lazarte 1984). If stock plants were grown under complete darkness no shoot proliferation occurred, but if grown in a glasshouse with light, proliferation was satisfactory. In addition, cultures were established in liquid medium with daily transfer to fresh medium and then keeping cultures on filter paper bridges in darkness for two weeks prior to transfer to light, initially at low levels (1 week at 11 µmol m^{-2} sec, followed by 43 µMol m^{-2} sec^{-1} (Hansen and Lazarte 1984).

Shoot proliferation has been induced from nodal explants using Lloyd and McCown (1980) medium (Wood 1982, Hansen and Lazarte 1984). Hormonal supplements have varied with Wood (1982) using a combination of 4 mg 1^{-1} (*ca.* 20 µM) BAP and 0.001 to 1 mg 1^{-1} (*ca.* 0.005 to 5 µM) IBA best for shoot proliferation and elongation, whereas Hansen and Lazarte (1984) found best shoot proliferation and elongation with 3 mg 1^{-1} (*ca.* 15 µM) BAP.

Rooting has been achieved (Hansen and Lazarte 1984) either *in vitro* using a liquid medium enriched with IBA for six to 10 days and transfer to hormone-free liquid medium or *in vitro* exposure to 10 mg 1^{-1} (*ca.* 30 µM) IBA for eight days then transfer to potting medium for acclimatization.

Pistacia vera (Pistachio)
Cultures have been established from Sterile seedlings (Alderson and Barghchi 1982, Barghchi and Alderson 1983a,b, 1985) and from actively growing shoot-tips of the rootstock *P. terebinthus* 'Tsikoudia' (Pontikis 1984). Explant browning has been a problem (Pontikis 1984) and has been reduced by weekly transfer to fresh medium for six weeks.Barghchi and Alderson (1983a, 1985) used MS medium for shoot proliferation and tested various hormonal supplements and found maximum response with between 2 and 8 mg 1^{-1} (*ca.* 10 and 40 µM) BAP with low levels of NAA (0.25 mg 1^{-1} *ca.* 1.3 µM), but preferred to use 4 mg 1^{-1} (*ca.* 20 µM) BAP only as subsequent rooting was better.

Pontikis (1984) achieved shoot proliferation with Anderson (1978) macro and micronutrients, LS organics and 2.5 mg 1^{-1} (*ca.* 12.5 µM) BAP, 0.1 mg 1^{-1} (*ca.* 0.5 µM) IBA and 0.1 mg 1^{-1} (*ca.* 0.3 µM) GA_3. Both groups reported tip necrosis after four to six weeks on proliferation medium on some cultures, the cause of which is unknown but may necessitate more frequent sub-culturing of shoots.

A range of factors affecting rooting have been tested (Barghchi and Alderson (l983a,b, 1985) in which half strength MS with 2.5 mg 1^{-1} (*ca.* 12.5 µM) IBA with darkness for seven days then transfer to hormone-free medium has proved satisfactory. Pontikis (1984) used LS medium with 1 mg 1^{-1} (*ca.* 5 µM) IBA and 89 mg 1^{-1} (*ca.* 0.5 mM) PG.

Anacardium occidentale (Cashew)
A preliminary report on *A. occidentale* (Philip 1984) found plantlet regeneration from cotyledon explants using Lin and Staba (1961) with IAA and kinetin both at 0.5 mg 1^{-1} (*ca.* 2.5 µM). Techniques developed for *Pistacia vera* may have application as they are both in the family Anacardiaceae.

Other
There are no reports for other important nut species such as *Bertholletia excelcea* (Brazil nut) or *Macadamia ternifolia* (Macadamia). Methods developed for *Telopea speciosissima* (Seelye 1984) may have application to *M. ternifolia* as they are both in the family Proteaceae.

Conclusions
Research work with woody perennial species has lagged behind that on other important groups (e.g. ornamental herbaceous species) but in the last 10 years considerable advances have been made, in particular with fruit (Hutchinson and Zimmerman 1986) and forest tree species (Bonga and Durzan 1982). While there is a substantial amount of information on nut trees, much of it is of limited commercial value as it applies to seedling material (Table 1) and the direct translation of information from seedling to adult material has not been very successful. For example research with *C. sativa* has found that there are many problems with adult material such as explant browning, loss of proliferation capacity with time and difficulty with root initiation. Media used vary considerably with the main common theme that BAP is a suitable cytokinin for shoot proliferation. More research is required to define the optimal conditions for establishment, shoot proliferation and root initiation and growth with all species.

The use of juvenile material from adult trees has only been studied with *C. sativa* and has not been entirely successful. Future research should initially concentrate on a systematic approach concentrating on conditioning of plants prior to establishing cultures and testing a range of basal media and hormonal supplements to learn how to produce shoots.

Once that is known and can be done with confidence, research should concentrate on rooting studies. With a concerted effort and an approach based on scientific logic, micropropagation should have an important role in the production of nut trees.

Additional papers

A recent problem of some plant species in tissue culture has been the occurrence of vitrified or translucent shoots. The symptoms appear similar for most plants in which the stems are thickened and translucent, leaves are thick, brittle, wrinkled and often elongated. Frequently growth is poor with reduced rates of shoot proliferation, poor root initiation and extreme difficulties with acclimatization. Vieitez *et al* (1985) have described and studied the problem both histologically and biochemically for *Castanea sativa*. The problem could be alleviated by changing the mineral portion of the basal medium from MS to Hellers.

Qiguang *et al.* (1986) describes in detail a micropropagation procedure for juvenile material of *C. mollissima* and updates the abstract of Qiguang *et al.* (1985, see main text and reference list).

Protoplasts have been isolated from cell suspension cultures of the almond cultivar Nonpareil, and under appropriate conditions they regenerate a cell wall, divide and form a callus mass (Wu and Kuniyuki 1985). While this report has no application to propagation it is some important preliminary work on the use of some tissue culture techniques for plant breeding.

Table 1 Nut tree species for which micropropagation has been attempted.

	Establishment	Shoot Proliferation	Root Initiation	Acclimatization	Reference
Castanea sativa	(±	+	-	-	Vieitez & Vieitez 1980a
(seedling)	(ss	+	+	±	Rodriguez 1982c,d
	(±	+	+	+	Vieitez & Vieitez 1983
Marigoule[a]	+	+	-	-	Marie Chevre et al. 1983
HV[a]	+	+(1)	-	-	Vieitez et al. 1983
T-13[a]	+	+	+	-	Vieitez et al. 1983
431[a]	+	+	+	-	Vieitez et al. 1983
Cardaccio[b]	+	ns	-	-	Biondi et al. 1981
Mozza[b]	+	+	±	-	Biondi et al. 1981
Politora[b]	-	ns	-	-	Biondi et al. 1981
C. mollissima	+	+	+	+	Qiguang et al. 1985
C. dentata	+	+	+	+	Qiguang et al. 1985

(a) C. sativa x C. crenata hybrids with resistance to Phytophthora cambivora and P. cinnamomi.

(b) C. sativa cultivars selected for wood production.

	Establishment	Shoot Proliferation	Root Initiation	Acclimatization	Reference
Juglans regia	ss	+	+	-	Rodriguez 1982b
Paradox[a]	+	+	+	+	Driver & Kuniyuki 1982

(a) Rootstock, F_1 hybrid between J. regia (male) and J. hindsii (female)

	Establishment	Shoot Proliferation	Root Initiation	Acclimatization	Reference
Prunus amygdalus	ss	+	+	?	Hisajima 1982
Ferravdel	±	±	±	±	Loreti & Morini 1982
Ferragnes	+	+	+	+	Rugini & Verma 1982,1983
Nonpariel	+	+	?	-	Tabachnik & Kester 1977
S. Caterina	±	±	±	±	Loreti & Morini 1982
Tuono	±	±	±	±	Loreti & Morini 1982

	Establishment	Shoot Proliferation	Root Initiation	Acclimatization	Reference
Corylus avellana	(+	+	+	+	Anderson 1983
(seedling)	(+	+	+	-	Perez 1985
Daviana	+(1)	±	±	±	Anderson 1983
Fertile de Coutard	±	+(1)	+(1)	?	Kai et al. 1984
Merveille de Bollwiller	±	+(1)	+(1)	?	Kai et al. 1984
Negret	+	+(1)	-	-	Messeguer & Mele 1983
Segorbe	±	+(1)	+(1)	?	Kai et al. 1984

	Establishment	Shoot Proliferation	Root Initiation	Acclimatization	Reference
Carya illinoensis	(+	+	ns	-	Wood 1982
(seedlings)	(+	+	+	+	Lazarte 1983; Hansen & Lazarte 1984

	Establishment	Shoot Proliferation	Root Initiation	Acclimatization	Reference
Pistacia vera	ss	+	+	+	Alderson & Barghchi 1982
Ohadi	ss	+	+	+	Barghchi & Alderson 1983
Kalleghochi	ss	+	+	+	a,b,1985
P. terebinthus					
'Tsikoudia'[a]	+	+	+	+	Pontikis 1984

(a) Rootstock, tolerant of Phytophthora spp.

+	Successful	?	Difficult to determine from published data
+(1)	Successful but limited response	ns	Not successful
±	Successful but details not reported	ss	Sterile seedling
-	Not reported		

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Footnote: Some authors use mass and others molar units for hormone concentrations. Molar units are preferred and have the advantage that they allow direct comparison of hormone types. If authors have used mass units they have been converted to molar units, rounded-off and placed in parenthesis.

Abbreviations used in text:

BAP benzyl amino purine
IBA indole-3-butyric acid
NAA γ-naphthaline acetic acid
IAA indole-3-acetic acid
GA_3 gibberellic acid

Nut tree distributions and the expansion of the Earth

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This paper contains two assertions, each of which is notably bizarre. The first is that the Earth has, in the geological past, expanded like a blown-up balloon, and that the present continents once covered the whole surface of the Earth, but have split apart under the expansion and are now widely separated. The second assertion is that the first assertion can be proved by a study of nut trees. Bizarre as this may be, it all falls out quite logically, as the following account will show.

The story starts in the Galapagos islands off the coast of South America, in September 1835. In that month, Charles Darwin visited the Galapagos in the ship the 'Beagle', and the observations that he made there (Darwin, 1845) laid the foundations for the Theory of Evolution.

These islands are isolated, some 900 km off the mainland of Ecuador, and consist of a group of about 5 larger islands and many small ones, all of recent volcanic appearance. What Darwin observed there can be summarized in terms of what are now called the Darwin Finches, a group of small birds found only on the Galapagos. He found that this group of birds, clearly related, had taken on differing characteristics from one island to another, and the differences were great enough so that the birds had to be classed under different species, and even different genera.

Now I should emphasize that most of the Galapagos islands are within sight of one another, and that these were normal birds, capable of flight. Even so, the forces which govern evolution are powerful enough so that even a relatively small separation in distance was enough to bring about genetic divergence, great enough to take the birds into different species and genera. And there was nothing special about this particular case of the finches, the same thing had happened with other animals, and with plants.

As the Galapagos appear to be relatively young in geological terms, this brings us to the first point, that when two parts of the range of a species are separated, the two populations will diverge, and do so relatively quickly.

Shortly after leaving the Galapagos, Charles Darwin visited New Zealand. You may be interested in an entry from his journal:
"December 30th, 1835. In the afternoon we. stood out of the Bay of Islands, on our course to Sydney.

I believe we were all glad to leave New Zealand. It is not a pleasant place. Amongst the natives there is absent that charming simplicity which is found at Tahiti; and the greater part of the English are the very refuse of society."

To turn now to quite a different part of the world, a different time, and a very different topic. The topic is what is now called Continental Drift, the place is Paris, and the time is 33 years later, in 1858. In that year Antonio Snider, an American working in Paris, published a book. This book (Snider, 1858) drew attention to the remarkably good match between the west coast of Africa and the east coast of South America. Snider suggested that this good match was because Africa and South America were once a single continent, which had been pulled apart in some way to form the present coasts (Fig.l). He gave a drawing of the combined continent, showing also Europe and North America joined, and even Australia joined to eastern Africa.

This work was lost sight of in later years, but the topic was revived in 1915 when the German scientist Alfred Wegener published another book on the topic of how the continents were formed (Wegener, 1915). Wegener's work, unlike that of Snider, attracted considerable attention, and quite a lot of supporting comment. It really explained a lot, and if you could only accept the possibility that the continents could actually move relative to one another, the logic of the proposal seemed clear. Nevertheless, over the years support again waned. It did not pick up again until 1964, when Sir Edward Bullard published a paper (Bullard, 1964) which included a computer-based fit of the coasts of South and North America against Africa and Europe (Fig. 1). As this work was computer-based, of course it had to be right, and from that point on the concept of Continental Drift did finally begin to achieve general public acceptance; it only took a little more than 100 years!

This work considered only the lands on either side of the Atlantic. Some interesting observations had been made of the occurrence of fossils of a plant genus called *Glossopteris*, in rocks in Africa, Australia, India, South America, Antarctica, and New Zealand. I should here make a second point, which is only a matter of logic. That is, that plants in the same genus must have had common ancestors, and these ancestors must have existed within a single area.

As the rocks containing the *Glossopteris* fossils are now widely separated, then using the principle of Continental Drift it was only natural to assume that these rocks were in continental masses which had drifted apart, and it was not hard to suggest how they had once fitted together (Fig. 2). Further support for the idea came from a study of rocks which had been affected by an ancient glaciation, assumed to be an early south-polar icecap. Notice in Fig. 2 that India is part of this ancient super-continent, which has been called Gondwanaland. The drift of India northwards, and its collision with the rest of Asia, is assumed to be the cause of formation of the Himalaya Mountains.

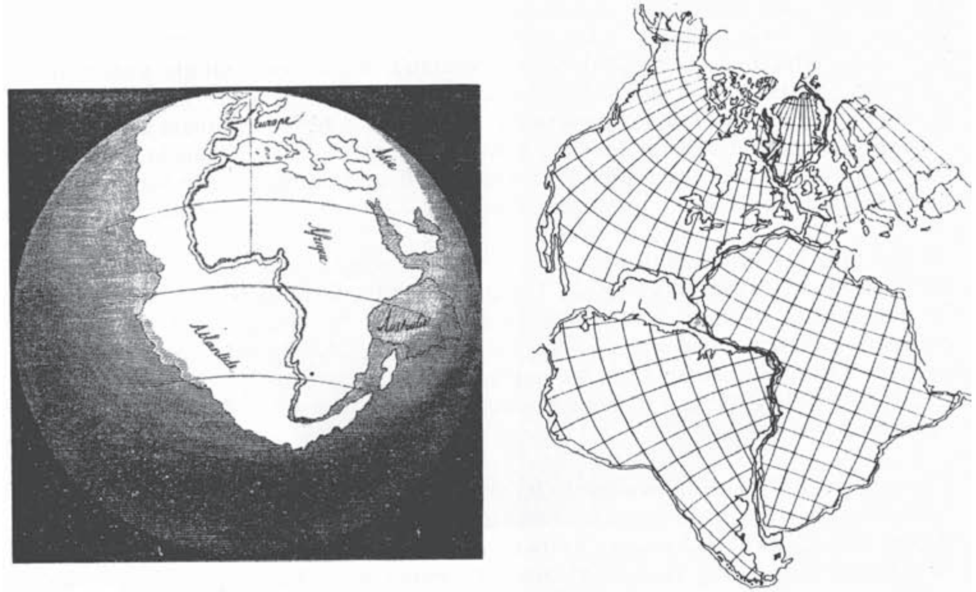

Fig. 1. Pre-Atlantic ocean according to Snider (1958) (left) and Bullard (1964).

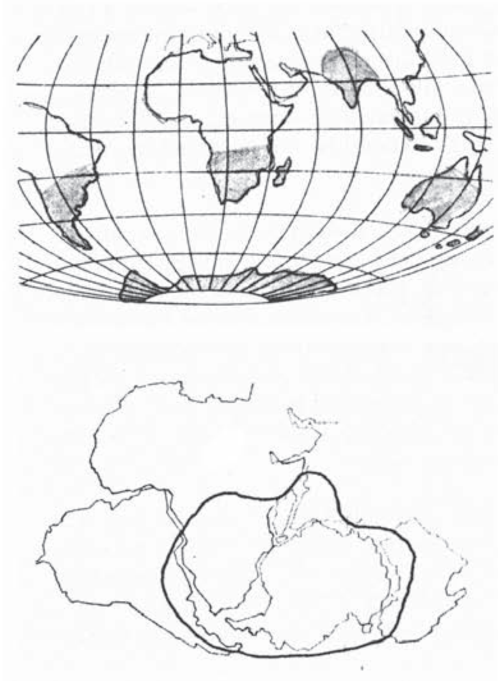

Fig. 2. Sites of *Glossopteris* fossils (top) and suggested former grouping of land around the South pole.

The currently accepted position is that the northern continents of North America, Europe, and Asia without India were once a single super-continent (called Laurasia), which, together with Gondwanaland, made up a single continent containing all the present land areas; this has been named Pangaea (Fig. 3). There is considerable evidence that Pangaea really did exist as a single landmass about 200 million years ago, and that it has since split apart, first to form Laurasia in the north and Gondwanaland in the south, after which each of these again split further into parts which drifted away to form the present disposition of the continents.

In searching for a mechanism for this movement, geophysicists came up with the idea of convection currents (Fig. 4). The interior of the Earth is widely believed to be hot, molten in parts, and it was suggested that the molten rock moved in convection currents, like water boiling in a saucepan, and the movement of these currents forced the parts of the old super-continents apart. If you do not find the situation depicted in Fig. 4 to be particularly convincing, I would have to say that I agree with you.

During the 1960s, scientists came to learn a lot more about the structure of the sea bed, and some very interesting facts came to light. By this time, accurate methods of dating the ages of rocks were known. A series of massive structures, called Mid-Ocean Ridges (Fig 5), were discovered running down the middles of the major world oceans, and these were found to be the sites of volcanic activity, producing new rock (age zero years). As you moved away from a mid-ocean ridge, you encountered progressively older rock, on either side. All the rock was of a type common to sea-beds all over the world, and quite different in nature to the rocks of the continents. The oldest sea-bed rock, that most distant from a ridge, was only 200 million years old; the phenomenon involved, called sea-floor spreading, appears to have created the whole of the present ocean floors during this period of 200 million years. The rate of spread varies from one ridge to another, but is something like 2 cm per year - about as fast as your fingernails grow.

If the sea-floor was expanding at the mid-ocean ridges, where was the new surface material which was created ending up? Well, someone had the bright suggestion that it was disappearing down the deep ocean trenches, and moving under the continents, in so-called subduction zones. Although this is the currently accepted dogma, it seems to me, and others (eg Ciric, 1981), to be a concept which almost completely lacks any supporting evidence. It seems against logic, if one plastic plate is pushed against and under another, for a deep trough to be formed between them. And, in the case of the mid-Atlantic ridge, there are no deep ocean troughs along the Atlantic coasts for the re-cycled rock to disappear into.

If we return now to Bullard's fit of Africa against South America (Fig. 1), you will notice that as you move away from the central point of contact, the match becomes less good. In 1955, Professor S. W. Carey at the University of Tasmania pointed out (Carey, 1955) that the match would be much better if the two continents were curved around an Earth of smaller radius. This was the beginning of the current phase of the Expanding Earth theory.

Fig. 3. Reconstruction of Pangaea

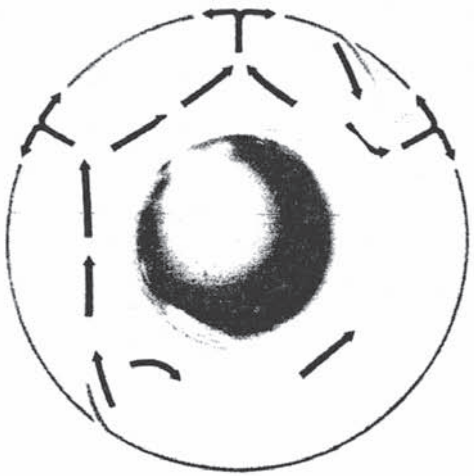

Fig. 4. Operation of convection currents in the earth's mantle.

Fig. 5. Atlantic Ocean floor.

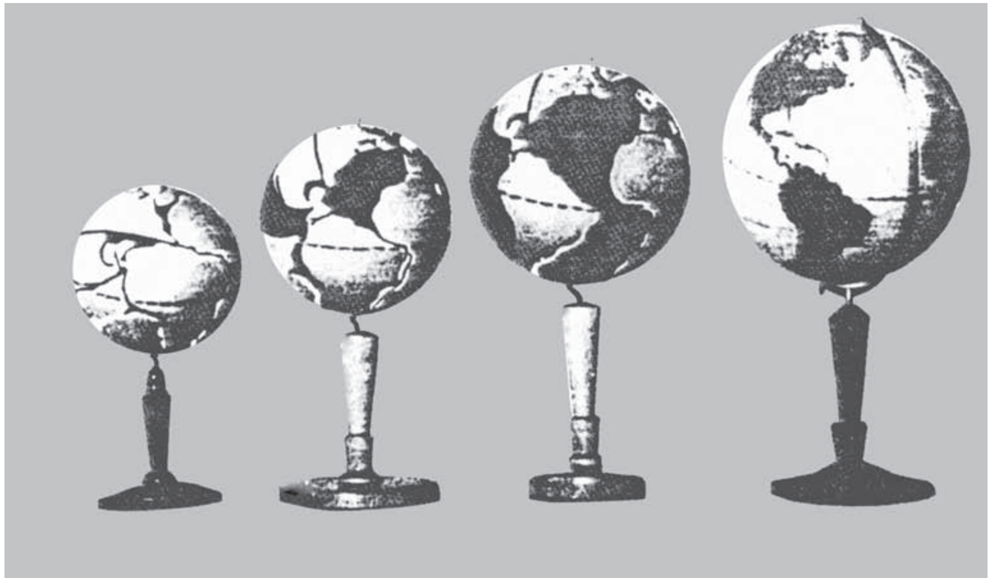

Fig. 6. Models of unexpanded earth according to Hilgenberg (1933) (top) and Barnett (1962).

Like the Continental Drift theory, there were earlier publications which had suggested the same thing. One of these was Hilgenberg's work (1933), which included pictures of models of the Earth with all the present continents fitted together to cover the whole surface of a smaller Earth (Fig. 6). At present, about 70% of the Earth's surface is covered by water. If the present 30% surface which is land had to cover the whole of a smaller sphere, that sphere would be about 55% of the diameter of the present Earth. As the circumference of the present Earth is 40,000 km, an unexpanded' Earth in which Pangaea covered the whole surface would have a circumference of 0.55 x 40,000 or about 22,000 km, that is, 18,000 km less than now.

It is interesting to calculate how long this expansion would have taken, at the present rate observed in sea-floor spreading. Since the rate at each ridge is around 2 cm/yr, and there are usually 3 ridges crossed in going right round the Earth, the total present expansion is very roughly 6 cm/yr. Dividing this into 18 000 km gives an expansion time of 300 million years, which agrees reasonably well with the time from rock age-dating.

It is also interesting that it was suggested as early as 1859 (Drayson, 1859) that the Earth was expanding; this was in a book by Alfred Drayson, entitled 'The Earth We Inhabit: its past, present, and probable future'. The author is described on the title page as 'Captain Alfred W Drayson, Royal Artillery, author of "Sporting Scenes in South Africa", etc. The existence of this work does not seem to have been picked up by anyone else interested in the expanding Earth idea. Further models of the pre-expanded Earth were constructed in the recent phase of interest, such as that made by Barnett (1962). Several views of this model are shown in Fig. 6. Notice that Barnett's model is fairly 'loose', with many large gaps not covered by land, and that some large movements and rotations of the land masses have been suggested, such.as Australia moved against North America, Greenland moved a long way over the top of Canada, and so on.

At this point you may be saying, 'Yes, all very interesting, but what has this got to do with nuts or tree crops?'. Well, the thing is, the geologists have come to a bit of an impasse with this problem -- it's time to call in the nutgrowers! What the geologists have lacked has been a better method of deciding just what piece of one continent was formerly in contact with what piece of what other continent. It is a solution to this problem which I am about to present to you here.

Look at Fig. 7, a world map showing the present distribution of the Proteaceae, the plant family containing the macadamia nut, the avellano, and some other less well-known nuts. The dark parts show heavy concentrations of species, the lighter shading the more lightly populated areas. Now remember the principle that species that are related must have had common ancestors existing in a single range. The only way for the current distribution of the Proteaceae to have come about, is for the species to have spread naturally by their inbuilt dispersal mechanisms (the conventional view), or for the areas of population to have been in contact with each other in the past and since moved apart through continental drift, or a combination of both.

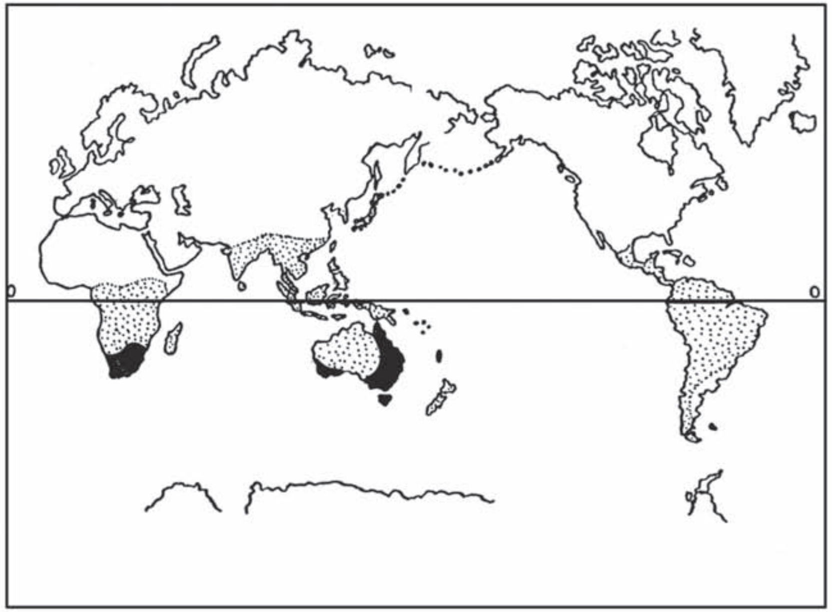

Fig. 7. Distribution of the Proteaceae

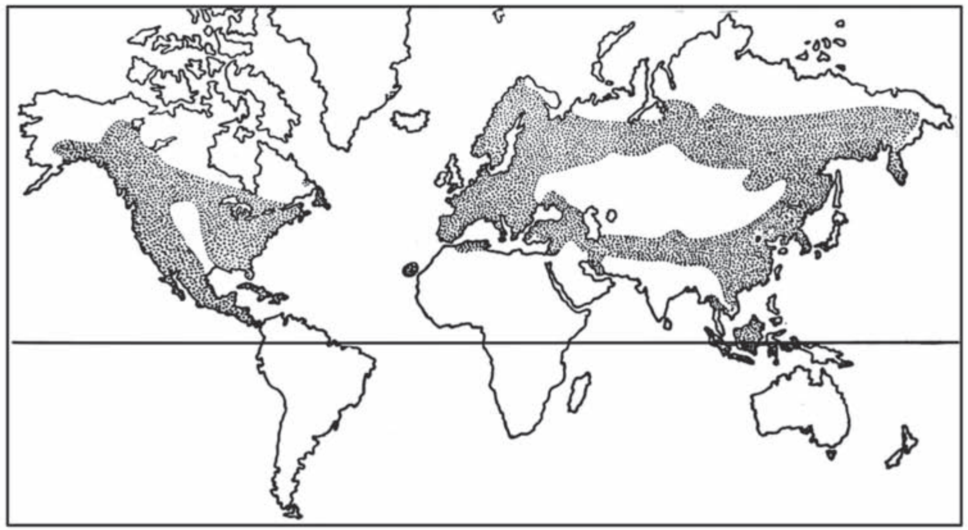

Fig. 8. Distribution of ***Pinus***

Now the Continental Drift approach, which is not disputed at this time, provides a satisfactory broad-scale explanation. The continents involved are the same southern ones as those concerned with the *Glossopteris* fossils (Fig. 2). Notice, however, that the modern Proteaceae extend beyond the range of the *Glossopteris* fossils, and in particular exist all over southeast Asia and up into southern China.

Now look at Fig. 8, the distribution of species of *Pinus*, containing many nut-bearing trees. Notice that this map more or less complements the first one; there are only small areas of overlap, in Central America and the Malesian area, and these are well within the range of what might be expected from natural dispersion.

At this junction I should talk briefly about the rate at which plants spread naturally. This rate is, in fact, very much slower than most people instinctively suppose. Even under favourable conditions, it is usually not much more than a few metres a year, and it is often much less. What effectively constrains the natural spread of plants is not the efficiency of seed dispersion mechanisms, but rather ecological pressures, the need to displace existing plants already occupying the sought-after ecological niche. In practice, you only get very rapid spread of plants when the ecological niches have been cleared, as when the volcanic island of Krakatoa was wiped clean in 1883, or when a new plant with given ecological properties is introduced into an area where there are no competitors for its particular ecological niche.

Purposeful introduction is one of the aims of nutgrowers, and the success of it depends on how closely the eco-characteristics of the introduced plant match those of the introduction site. When the introduction is not on purpose, and the match is very good, then the plant becomes a weed -- a good plant in a bad place.

Back to the Expanding Earth. I have asserted that plants spread naturally at a low rate, under one metre a year, even under superficially favourable conditions. When conditions are less favourable, and a species needs to cross what I have called ‘isophytes’ (Noel, 1985), spread often does not occur at all until a new variety or species with the appropriate characteristics for the new environment happens to arise. A spread of 1 metre a year is equivalent to 1 km in 1,000 years, or 1,000 km in a million years. All the available evidence supports the suggestion that this low spread rate is seldom exceeded and is often much less.

I will move on now to some detailed distributions. First, in Fig. 9, we see the distribution of species of *Elaeis*, the oil-palm, and a major world source of oil from its kernels and fruits. In view of the accepted former juxtaposition of Africa and South America, this distribution is entirely as might be expected.

In Fig. 10 we have the map for the Araucarias, sources of those excellent nuts the Bunya Pine in Australia, the Monkey Puzzle in Chile, and the Parana Pine in southern Brazil. Another species is the Norfolk Island Pine. The inference from this map is that Australia once fitted against the west coast of South America, and if you try it with a model, you will find that this match is a very good one.

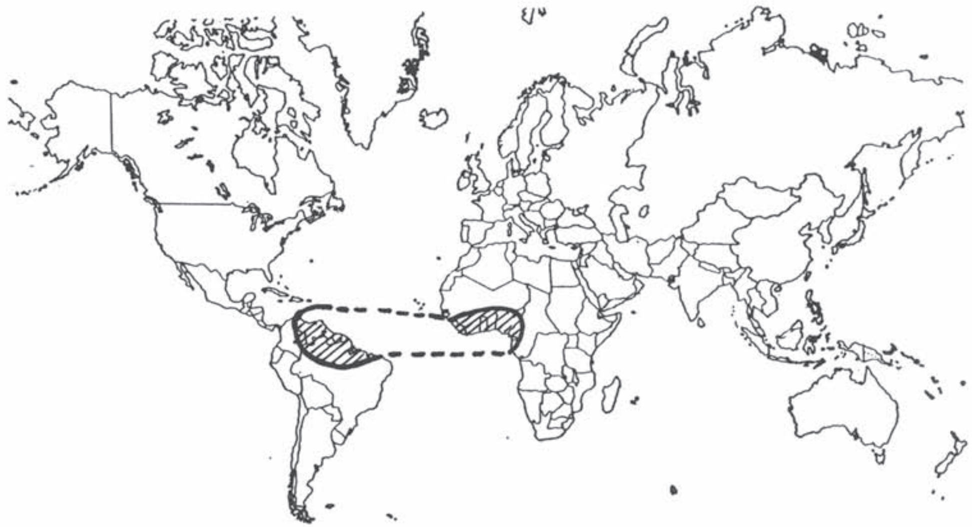

Fig. 9. Distribution of ***Elaeis***.

Fig. 10. Distribution of ***Araucaria.***

The next map (Fig. 11) shows where two of the three species of *Gevuina* exist (the third is in New Guinea). The Chile species produces the Avellano or Chile Hazel nut, and the Queensland species also produces an edible nut (Irvine, 1980). These two species are some 13,000 km apart, about one-third of the distance round the planet. It would be hard to explain this as chance dispersal, say by drifting on ocean currents.

The distribution of *Adansonia*, the boabs or baobabs, is shown in Fig. 12. There is one species in Africa, extending to India (allegedly introduced by Arab traders!), and one in northwest Australia. But the real concentration is in Madagascar, which has around 12 species. The distribution suggests that Western Australia was once in contact with the east coast of southern Africa, or possibly both were linked through Madagascar or India.

The next map (Fig. 13), the distribution of the Canarium family, which contains the pili nut and the java almond, again links Madagascar with Africa (a more central spot) and with the areas of Southeast Asia, the Malesian archipelago, and northern Australia. The range extends well out into the islands of the Pacific.

Similar links, displaced somewhat to the south, are shown by the distribution of *Santalum*, the Sandlewood family (Fig. 14). The focus of the family is in Australia, and it includes the Quandong, the symbol of our local Association. Important former sandalwood sources are in India, Timor, and in Hawaii; there is one species in New Zealand, and there was one on the tiny Juan Fernandez islands right across the Pacific off the coast of Chile. There is also a close relative, once classed in *Santalum* but now given a species of its own (Colpoon), in the Cape area of Africa.

Links between central Africa, Madagascar, the Malesian islands, northern Australia, and Central America are shown by the range of *Omphalea* (Fig. 15), which contains many edible nuts such as the Jamaica Cobnut, and the Candoo nut from Queensland (Irvine, 1980). The range extends some 28,000 km. When you take into account the relatively fast rate at which plants evolve and genetically diverge, you have the implication that the whole of the Pacific has opened up very quickly and in relatively recent geological time.

You may have noticed that all the. last seven species have had southern distributions. It appears that all developed in the southern supercontinent of Gondwanaland, which included South America, Africa, Australia, India, and also Southeast Asia and Southern China. All fall within the current range of the Proteaceae (Fig. 7).

The next map, showing the Pistacia family (Fig. 16), takes us into the northern supercontinent, Laurasia. As well as the pistachio nut and its relatives native to the Mediterranean area and the Middle East, there are other species in Central China and the Atlantic islands over to Mexico, Texas, and Guatemala. The range confirms the former contact of Europe and North America, and is in no way unexpected.

Figure 17 illustrates the range of *Carya* species, the pecan and hickories. Almost all of these are in North America; however, a single species is wild in Central China.

Fig. 11. Distribution of ***Gevuina***

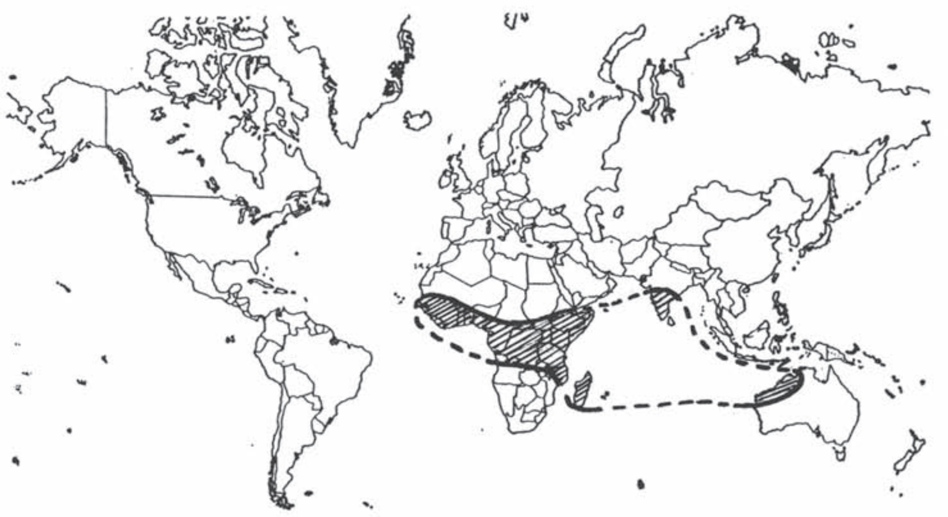

Fig. 12. Distribution of ***Adansonia***

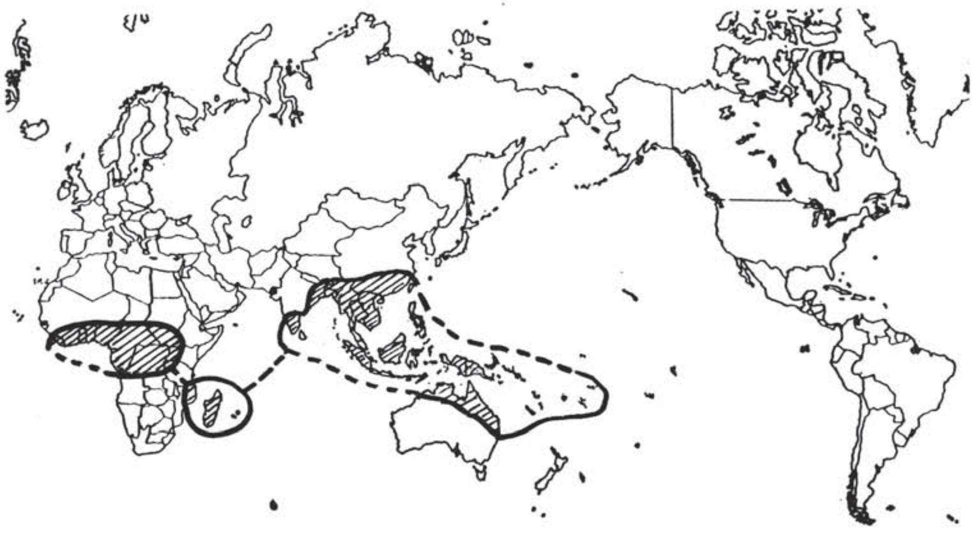

Fig. 13. Distribution of ***Canarium***

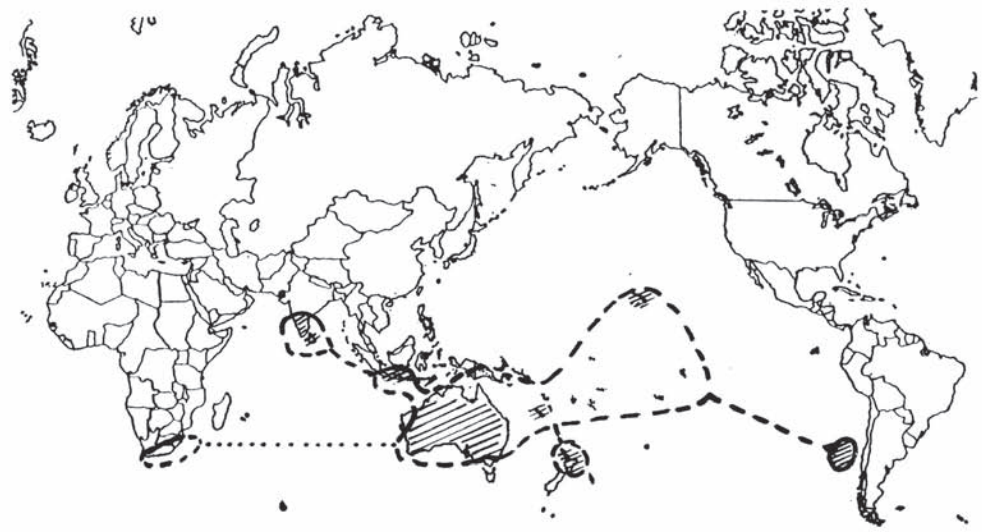

Fig. 14. Distribution of ***Santalum***

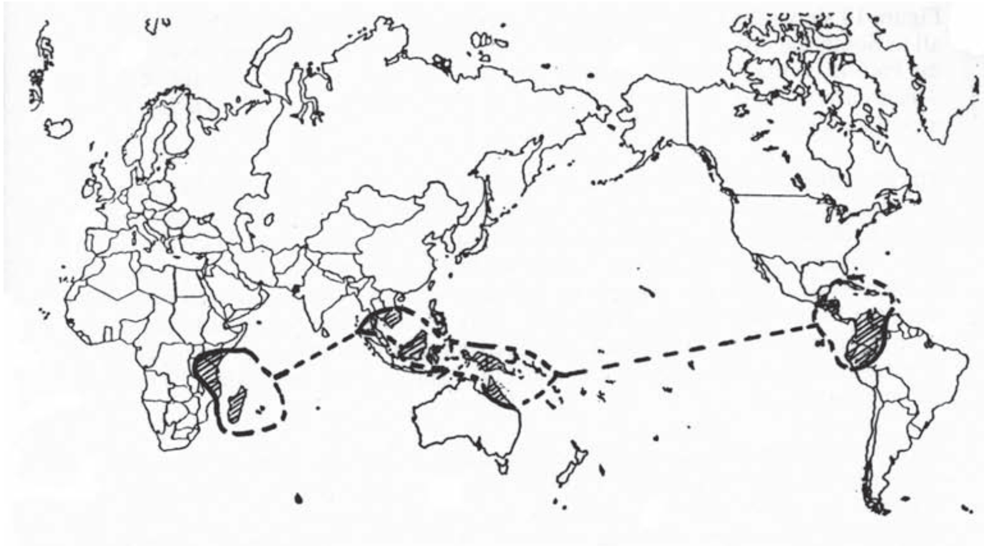

Fig. 15. Distribution of ***Omphalea***

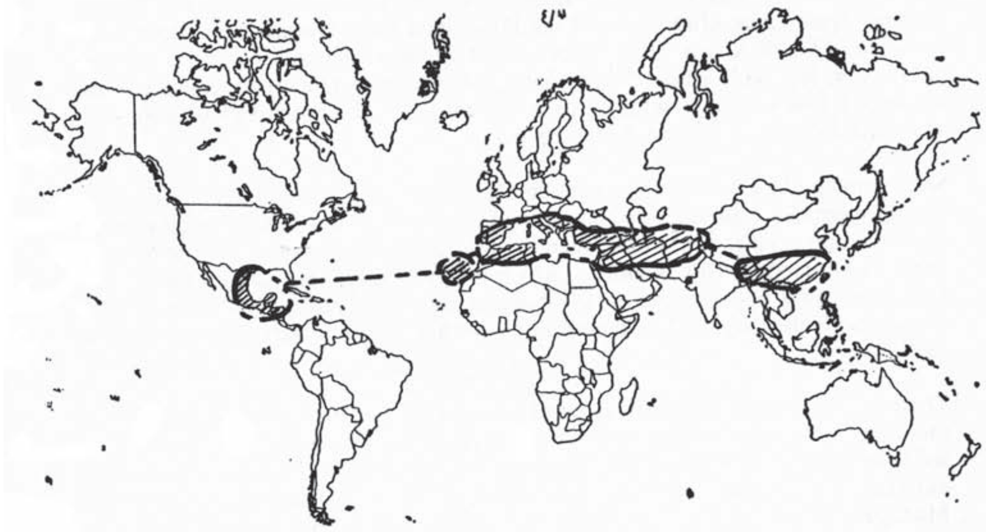

Fig. 16. Distribution of ***Pistacia***

Figure 18 shows the range of the evergreen chestnuts, *Castanopsis*. They are almost all in Southeast Asia, around 100 species, with just two isolated species way across the Pacific on the west coast of the United States. If you think this could be due to ocean currents, consider that in both parts of the range, *Castanopsis* is a hill or mountain species which avoids sea-coasts.

The next map (Fig. 19) shows the distribution of cycads, the zamia palms common to areas which once formed part of Gondwanaland. These have been put in here because the cycads are a very ancient plant family, and their ancestors were known to be of world-wide occurrence from abundant fossil remains. The implication of the map is that the surviving species are not just those which happened to survive from the former world-wide distribution; they are more closely related, all coming from a common ancestor which achieved an evolutionary step, somewhere in Gondwanaland, which enabled it to adapt to changing conditions while its relatives became extinct.

Finally, the fascinating story of the coconut and its relatives. It is often possible to determine the original home of a species which has been widely spread from such things as the number of insects specific to it, or occurrence of close relatives. The coconut has baffled and confused researchers in the past (De Candolle, 1886; Eden, 1963) because there is strong evidence that it is a native of Southeast Asia (Fig. 20). There is also strong evidence that it is native of the West Coast of northern South America. You can see now that both claims are right -- its area of origin was split apart by Earth expansion.

The true coconut has some very interesting non-tropical relatives, the Pygmy Coconut from Chile (*Jubaea*), and the Pondoland Palm (*Jubaeopsis*) from Cape Province in South Africa. Their fruits are just like tiny coconuts, complete with the three eyes, and with a little 'milk' inside. They are very distinctive indeed, and although it is now extinct, what was almost certainly a close relative has been found as a fossil in North Auckland, New Zealand.

So to sum up, the evidence from nut tree distribution ranges is that land masses now widely separated were once in contact, and comparison of different species ranges allows actual contact zones to be identified in fair detail, down to as little as a few hundred kilometres. This is the tool which the geologists have so far lacked -- the realization that because of the slow actual rate of plant spread, current plant distributions are effective in determining former land contacts, just as much as fossil ones.

There is nothing new under the sun, and I am not the first with this concept. Back in the 1800's, the famous naturalist Alfred Wallace made a study of aspects of the wildlife of islands (Wallace, 1902), and pointed out how the evidence required the existence of former land links between Madagascar and Africa, and also Madagascar and the Malesian islands. As the idea of whole continents shifting was not around at that time, this meant postulating former continents and land bridges now sunk beneath the sea, but the idea is there.

Fig. 17. Distribution of ***Carya***

Fig. 18. Distribution of ***Castanopsis***

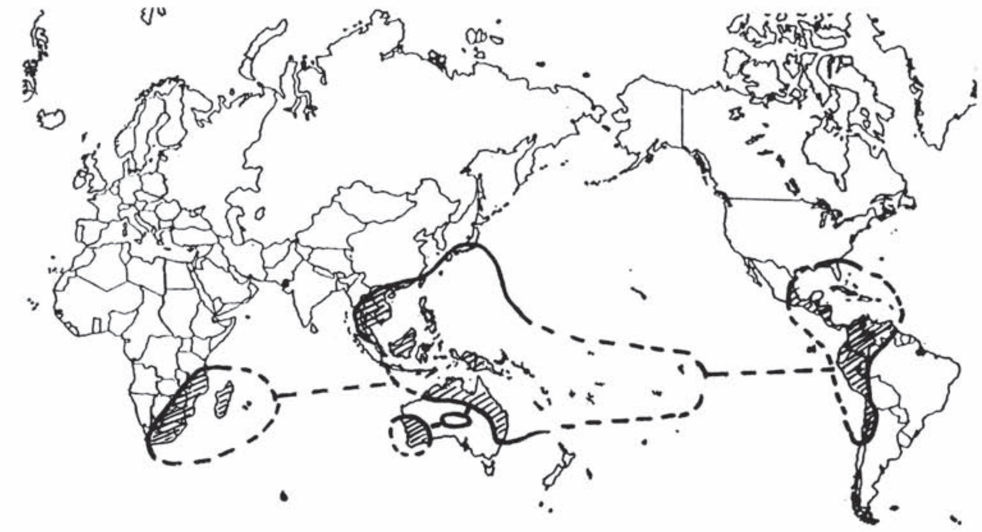

Fig. 19. Distribution of ***Cycads***

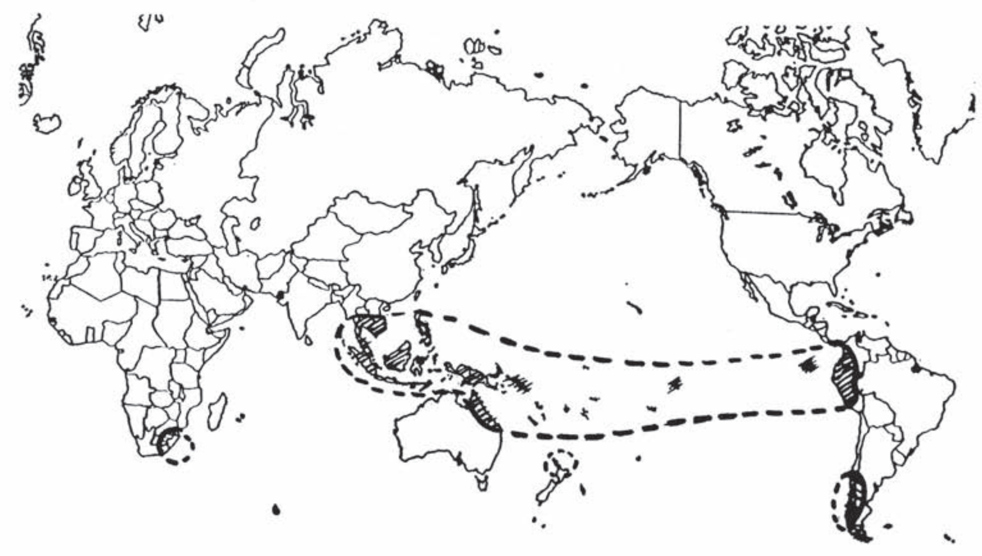

Fig. 20. Distribution of ***Cocos, Jubaea*** and ***Jubaeopsis***

Also, although I have used the example of nut species because it is an area I know something about, you can use other plants, and even animals, to arrive at the same conclusion; consider where you find large flightless birds, all of them are Gondwanaland natives.

I have also examined the distributions of some hundreds of genera of fruit-bearing plants, involving well over ten thousand different species. Nowhere in this great mass of material has there been a single instance of data which would be in flagrant opposition to the assertions made here. What examples do exist of opposing evidence fall into three readily explicable groups. These are, firstly, trees of some ancient broad-leaved families, such as the willows and the beeches, which exist in temperate regions of both northern and southern hemispheres; these can be presumed to have spread before the split of Gondwanaland and Laurasia. Secondly there are a few occurrences of things like a blueberry (*Vaccinium*) species, very isolated in Central Africa, part of shifts from North to South which can be attributed to migrating birds. And lastly there are some natural spreads, like the movement of walnuts (*Juglans*) down the Andes as far as Peru, which although appearing as a 'Laurasian' species in Gondwanaland, is nevertheless an acceptable extension of an existing and contiguous range.

The detail available in the technique described here allows a former link between two land masses to be established. When all the links are considered together, when A is linked to B and B to C and C to D and A and so on, the connectivities so produced allow of only one conclusion -- that all current land masses were once linked to other land masses on every side, and the only way that this could have occurred is for the present land masses to have completely covered the surface of the Earth. For this to have happened, either the main body of the Earth must have expanded, or each continent must have shrunk at the same rate. The evidence overwhelmingly supports the idea that the Earth has expanded.

Once you accept the possibility of Earth Expansion, a large body of other evidence falls into place. There are also a tremendous range of implications from the concept, some of which are capable of experimental test, others of which could have great economic significance. Most of these are not of special relevance to tree croppers, so I will be dealing with these elsewhere, in a forthcoming book (Noel, 1986). A few points which are relevant; knowledge of where plant relatives exist, distant in space but with close genetic links, should be of help in the breeding and introduction of nut and fruit plants. If plant populations have been separated by Earth Expansion rather than natural spread, which inevitably implies genetic divergence, there are many hybridization possibilities which may have been overlooked, many unrealized relationships capable of economic exploitation. Taxonomy, the study of the relationships between species, is on the verge of a major revolution, as we get closer and closer into the genetic make-up of these species. It is even possible to do such things as estimate how long ago two species diverged from a study of their DNA (Sibley, 1986), and this itself will enable us to refine the timing of events in the past expansion of the Earth.

Well, I think at this point I have expanded enough on this topic. I hope that you have found the evidence convincing enough to support the two bizarre assertions I made at the beginning of this paper. Perhaps it is sufficient to support a further, third assertion -- the world really has need of us nutgrowers if it is to press ahead into a world of increasing technological complexity!

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A review of mango crop management

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The title of this paper, Crop Management, is a fairly loose term which requires further definition. Management is seen as the manipulation of all inputs necessary to maximise tree productivity or in other words the control and use of all environmental factors which influence the growth and physiology of the tree to the end that greater yields of quality fruit are produced. In practice, control is seldom achieved and our attempts of modification are often overwhelmed by environmental forces. The main components of management are those classified as climatic or physiological. This paper intends to deal with the climatic factors while the physiological discussion will be restricted to nutrition and tree size control.

Climate

The components of climate are temperature, rainfall, wind and light with the absolute values for these being fixed at any one site. Each component may be modified to varying degrees depending on the level of sophistication applied to orchard management, e.g. wind towers for frost control, irrigation to supplement rainfall and windbreaks to reduce wind velocity. In many instances it is not either economically or physically practical to introduce such modifications.

Temperature - The temperature range and rainfall pattern suited for mango production are paramount in site selection. The optimum temperature for growth has been reported to be between 24° to 27°C (Woodrow 1910, Mukherjee 1953) although trees flourish in areas registering as high as 48°C (Mukherjee 1953). In most instances, damage to or death of trees occurs with sub-zero temperatures with mature trees withstanding marginally lower temperatures than juvenile trees (Singh and Singh 1955).

There are no elaborate frost protection measures as for citrus, reported in the mango literature and the author is not aware of commercial mango production in such marginal environments where frost is a continuing problem restricting normal growth. Low temperatures during flowering affect flower sex expression, giving predominance of males (Pal & Chadha 1982). It also reduces pollen germination and growth resulting in poor fruit set or a high percentage of parthenocarpic fruit which fail to mature (Young 1955, Lakshminarayana & Aguilar 1975, Sauco 1978). The sensitivity of cultivars to temperature at flowering varies greatly (Lakshminarayana & Aguilar 1975, Sauco 1978) with Carabao, Peach, Sabre, Kensington, Haden and Ruby being very sensitive to night temperatures below 10°C. Early flowering cultivars can also have flowering and fruit set affected when caught by unseasonal cold temperatures. Gazit (1975) reports the affect of deblossoming by the removal of the terminal inflorescence which promotes axillary panicles which flower later when temperatures are more conducive to fruit set.

A similar mechanism has been recorded at Nambour (SE Queensland) where July panicles were chilled and auxiliary panicles stimulated which flowered normally in September/October. Singh et al. (1974) report chilling damage to the earlier flowering cultivar Dashehari significantly reducing fruit yield. Deblossoming of terminal panicles delayed flowering and increased the yield by seven to fifty times above control trees.

In early deblossoming studies, panicle removal was achieved mechanically by hand. This is an uneconomical practice. However, successful chemical techniques have been developed. Kadman: and Oppenheimer (1978) achieved deblossoming of Haden mangoes by spraying with 0.5% dinitro secondary butyl phenol while Pal and Chadha (1982) successfully used 250 and 500 ppm of cycloheximide for chemical deblossoming of Dashehari mangoes.

Rainfall/Irrigation - Assuming adequate moisture is available to sustain growth, the seasonality of rainfall becomes the most important criterion. For consistent cropping, the mango requires a dry season for flower initiation and anthesis (Singh 1960, Prasad & Patak 1970). There is an interaction between environmental factors in that low temperatures offset higher rainfall during the flower initiation period but high rainfall and temperatures year round promote vegetative growth at the expense of flowering (Singh 1977).

The manipulation of water supply to crops is one of the most effective management tools we possess. The impact of disease on mango production is such that in most instances, production areas have a pronounced dry season from flower initiation through to fruit harvest (Prasad & Patak 1970). During this period the opportunity exists to vary the water supply to trees. In most instances, irrigation is necessary for the successful establishment of young trees (Mukherjee 1953, van der Meulen et al. 1971, Anon, 1977). In the absence of rainfall, irrigations should be given every one or two weeks on newly planted nursery trees.

As previously mentioned, in warmer climates the mango requires a dry period for flower initiation and development. The associated moisture stress induces cessation of vegetative growth allowing the accumulation of carbohydrate and proteins necessary for initiation (Sen & Mallik 1941, Chacko & Ananthanarayanan 1982). At latitudes of 25° to 28° the onset of low temperatures during the autumn and winter offset excessive rainfall which may occur during the flower initiation period.

The water requirement of mango during anthesis is poorly documented. Mukherjee (1953) stated that during flowering, mature orchards should be irrigated fortnightly, but presents no data base for such an assumption. Van der Meulen (1971) in South Africa, recommended flood irrigation of mature trees from flowering until the rains start - this generally means three irrigations at monthly intervals. Stephenson (1984) suggests that macadamia nut trees increase water usage during anthesis as the flowers and panicles have no stomata to regulate water loss.

If this holds true for mangoes, then one would expect substantial water loss to occur in heavily flowering trees which produce an immense volume of panicles.

There are several reports on the benefits of irrigation for fruit retention, although other physiological factors are involved during the fruit drop period. Purushotham & Narasimham (1981) demonstrated that trees irrigated every ten days from the start of the dry season produced significantly fewer flowers per panicle than the unirrigated control trees but set and retained a significantly higher number of fruit. This was reflected in the increased yield on irrigated trees. Singh and Arora (1965) showed an increase in fruit retention on trees that were irrigated weekly as against those that were irrigated three weekly while Gunjate et al. (1983) suggest that fruit drop in Alphonso mango is partly due to internal water deficit.

It is generally accepted that good water management increases fruit size and productivity in tree fruit crops where moisture is a limiting factor. Azzouz et al. (1977) demonstrated that increased frequency of irrigation from 18 to 37 per year increased fruit yield. Both yield components, fruit number and fruit mass were increased over lower irrigation frequency treatments. Increased irrigation frequency also reduced absolute seed mass as well as increased the percent fruit pulp.

It is generally accepted that the mango has a high moisture requirement for fruit filling and subsequently to support the summer vegetative flush (Singh 1977). This flush usually occurs after fruit harvest and provides the flowering shoots for the next season's crop. In most mango producing areas, the summer flush coincides with the "wet" season.

In summary, no study to date has contributed significantly to the practical development of irrigation and water management strategies of mango. Thus there is a need to initiate further work to define the water requirements of the mango. Ideally, this work should be closely tied in with the water relationship characteristics and the overall physiology of the mango tree.

Wind - The effect of wind on tree and vine crops is well documented (Jawanda et at. 1973, Sale 1983, Anon) although little appears on this topic in the mango literature. Mayers (1984) demonstrated the effect of windbreaking on young mango trees on tree productivity and the control of bacterial black spot (*Xanthamonas campestris* pv. *mangiferaeindicae*) in S.E. Queensland. With the provision of artificial shelter or windbreak trees in most instances the deleterious effects of wind on tree growth and productivity can be minimised. Windbreaking may not be beneficial in all localities. Van der Meulen (1971) in South Africa advises against wind protection. He argues that windbreaks occupy potential cropping space, may create frost pockets and increase humidity favouring flower and fruit disease development. Also wind damage to fruit has been minimal in this area which rarely experiences strong winds. The brief mention given to wind in the Indian literature (Singh 1977, Kadman & Oppenheimer 1978) is in relation to storm and cyclone damage which is extremely difficult to protect against.

Light - The geographical location of any one site fixes the upper and lower levels of incoming light and radiation. In the orchard situation light intensity is modified by planting density and layout and density of canopy. Orchard layout is an important factor in temperate zones but is a lesser consideration in the tropics where there is little change in the angle of the sun.

Majumder *et al*. (1982) reported on high density plantings of the mango variety Amrapoli which is a precocious dwarfing scion type. Planted at 2.5 m x 2.5 m in a triangular system (1600 trees/ha) at four years old they yielded 11.5 t/ha. At seven years of age the yield was 22.3 t/ha and were still increasing. This is in comparison with standard planting densities of 100 trees/ha producing an average of 8.7 t/ha. Most fruit trees show declining production as canopies merge with each other so reducing light intensity. At seven years, this experiment has not reached the crowding stage and efficient use has been made of the area planted.

Density of canopy can be modified by pruning and this practice has been shown to be beneficial with many fruit crops (e.g. peaches, kiwifruit, etc.). Most pruning studies with mangoes have been in association with the biennial bearing problem and it is interesting that few authors have commented on improved light penetration to explain yield responses. Investigations in South Africa (Anon 1979) showed that a 'benefit' pruning technique increased yield by 34% when used on 28 year-old Peach mango trees. With this method, the datum tree was left unpruned while all the other surrounding trees were severely pruned. Statistically significant yield gains were made four years after treatment initiation and maintained for the remaining three years the study continued. It is likely that the response measured in this study was due to improved light intensity reaching the datum trees. Similarly, Rao and Shanmugavelu (1976) in India demonstrated yield responses when 45 year-old trees were pruned. The technique in this case was to thin the canopy by removal of inner branches and to reduce the terminal whorl of shoots from three to five back to the strongest one or two. Better light penetration also improved fruit colour (Rao & Shanmugavelu 1975).

In Queensland, some experience has been gained with pruning of mango trees. Shaping and training of trees at the early stages of growth to give a vase shape with three to four leaders gives an open tree, allowing penetration of light and spray materials for insect and disease control. The inverted triangular shape achieved allows fruit to hang freely outside the canopy of the tree facilitating more rapid drying after rain and improved spray coverage. Some orchards practice mechanical pruning using tractor mounted cutting bars. A side section of the tree is cut back on a face immediately after harvesting. Only part of the tree is done each year. The overall effect is the maintenance of tree size and the accessing of light.

Nutrition

Nutrition in any crop is a powerful management tool which can be used to regulate growth and increase productivity. However, a basic understanding of crop requirements in relation to quantity and timing of application is required for effective use of this parameter.

Aside from normal growth requirements, nutrition has been implicated in various fruit physiological disorders which will be reviewed in this discussion.

The defining of the nutritional status of a plant at any one time has become possible with the development of tissue analysis. This technique rather than soil analysis has become the preferred method in nutritional studies with many tree fruit crops. However, definition of sampling methods and critical nutrition levels that relate to crop performance are necessary before such techniques can be used effectively in crop management.

Sampling Methods - Various researchers have revealed the importance of leaf age, position and fruiting status of the shoot on nutrient levels in other fruit crops. With mango, investigations relating to leaf sampling techniques have been made in Florida (Young & Koo 1971, Koo & Young 1972) and India (Pathak & Pandey 1978, Chadha et al. 1980, Thakur et al. 1981). In both localities similar findings were made. In brief, nitrogen, phosphorus and potassium concentrations decreased with leaf age while calcium and magnesium increased with age. This is in agreement with Smith (1962) who concludes that this pattern is similar for all crops. Also there was a variation in leaf nutrition concentration depending on the leaf position on the shoot. From the basal to the terminal position, nitrogen, calcium and magnesium concentrations increased while phosphorus and potassium levels decreased at any one time of sampling. The terminal leaves of shoots show a high degree of variability showing that they are less stable as sampling units than other leaves of the shoot (Koo and Young 1972). These authors also showed that there were small but consistent differences between leaves from non-fruiting and fruiting shoots. Except for potassium these differences were not significant. More recently Whiley *et al*. (1985) has shown that in avocado, leaf nutrient concentrations are strongly influenced by vegetative and reproductive growth activity which may be occurring at the time of sampling. Sen *et al*. (1963) demonstrated a sharp drop in mango leaf nitrogen concentrations at the time of panicle development. This is further substantiated by Chanhan and Pandey (1984) who showed that reproductive growth from flowering to fruit development is a strong sink for leaf photosynthates in mango.

Smith (1962) proposed that the best correlation of leaf nutrients with plant status occurs when the internal flux of elements is at a minimum. For tree crops, this is usually the three to six month period after leaves are formed.

In summary, the following recommendations have been made in relation to leaf sampling for tissue analysis in mango:

(i) Leaf age - five to seven month old leaves.
(ii) Leaf position - from the middle of the last matured flush and from all sides on the tree. Avoid terminal leaves.
(iii) Fruiting status of shoot - no specific preference but status should be standardized.
(iv) Nutrient supply -the supply of nutrients either by soil or foliar application can dramatically influence leaf concentrations. Avoid sampling in close proximity to fertilizer applications.

Critical Nutrient Levels - Deficiency symptoms have been produced and described by several researchers (Sen et al. 1947, Smith & Scudder 1951, Kumar & Nauriyal 1969). Smith and Scudder (1951) conclude that the mango can survive without symptom expression on a low nutritional plane. In general, the deficiency levels of nitrogen and phosphorus found by leaf analysis were considerably lower than citrus while potassium and magnesium were of about the same order of magnitude. The attempt to define critical leaf nutrient concentrations for mangoes has been made based on the work of Smith and Scudder (1951), Kumer and Nauriyal (1969) and Young and Koo (1969). These results have been drawn together and presented with work by Samra *et al*. (1978). It is concluded that the figures presented in Table 1 can be taken as a guide, but there are discrepancies which need further investigation in the recommended ranges for nitrogen and phosphorus (Samra *et al*. 1978).

Table 1. Critical concentrations of nutrients in mango leaves.

Nutrient	Range (%)	Deficient (%)
Nitrogen (N)	1.0-1.5	<0.67
Phosphorus (P)	0.08-0.175	<0.05
Potassium (K)	0.3-0.8	<0.25
Calcium (Ca)	2.0-3.5	<0.37
Magnesium (Mg)	0.15-0.4	<0.09
Sulphur (S)	0.74-1.5	

Rates and Timing of Fertilizer Applications - The rates of fertilizers used on mango trees reported by various researchers is a difficult subject on which to draw valid conclusions. This is due to the differences that occur in the many aspects of soil type and environmental conditions which exist between the experimental sites.

The sensitivity of different cultivars to nutrients is well documented with other fruit crops and Young et al. (1962) and Tiwari and Rajput (1976) demonstrated that this also occurs with mango. In a series of experiments (Young *et al*. 1962) the Kent cultivar responded to increasing nitrogen levels which had no affect on the Haden cultivar. Likewise, the Langra cultivar responded to higher levels of nitrogen than did the Dasehari and Totapari cultivars (Tiwari & Rajput 1976).

As with most other fruit crops, nitrogen has the greatest impact on fruit yield. Experimental data has generally failed to show a response to the other macro-nutrients when applied at rates greater than the maintenance level chosen for control.

There are numerous papers reporting the effect of foliar applied nitrogen prior to or during flowering (Singh 1974, Tiwari & Rajput 1976, Samra et al. 1977, Singh 1977, Shawky et al. 1978).

In most instances, a range of concentrations between 2 and 6 percent urea were used. Concentrations of urea higher than 6 percent were phytotoxic (Samra et al. 1977). The general concensus reached in most reports was that urea sprays at 2-4 percent had a beneficial affect on the productivity of mango. Shawky et al. (1978) found that 1-2 percent urea spray applied just before flower bud differentiation delayed flowering, decreased the incidence of flowering malformation, increased the number of perfect flowers in the panicle and increased yield by eight-fold when compared to control. Other researchers using two application times 4 months apart report earlier flowering, a shorter anthesis period, improved fruit set and significantly higher yields (Singh 1974, Tiwari & Rajput 1976, Singh 1977).

Minor element deficiencies have been reported from most mango producing countries but these are a reflection of particular soil types with inherent micro-nutrient problems. The most common deficiencies reported are for zinc and copper and full descriptions occur in the literature (Tiwari & Rajput 1976, Nijjar). Rajput et al. (1976) report vegetative responses to 0.8 percent zinc sulphate sprays when applied to apparently healthy trees. However, it is difficult to gauge the authenticity of this response as no leaf concentrations are presented.

Nutrition and Physiological Disorders - The breakdown of flesh of ripening mangoes has long been recognized as a problem in the mango producing areas of the world. The disorder was first described by Verma (1950) but since then it has been further documented in Florida (Young 1957, Malo & Campbell 1982) as well as India and Australia (Srivastava 1963, Whiley & Saranah 1984) and is reported to occur in other major mango producing countries.

The disorder is known by several names the most common being soft nose and jelly seed. Attempts to isolate pathogens have failed and the disorder is considered to be physiological.

Cultivar susceptibility to this disorder varies although Young & Milner (1961) state that it has been observed only in Indian varieties originating in Florida as first and second generation seedlings of Indian varieties. With the Florida varieties the incidence is highest with Tommy Atkins and to a lesser extent Kent, Sensation, Irwin and Keitt (Malo & Campbell 1982). Young (1957) describes Haden as a susceptible variety along with Davis, Haden, Springfels, Zill and Brooks. Both Tommy Atkins and Sensation have shown this disorder under Queensland conditions (Whiley & Sarariah 1984) but to date there are no reports of Kent, Irwin or Keitt developing “jelly seed” in Australia. Malo and Campbell (1982) also report that the disorder is prevalent in some Indian varieties but particularly on the well known cultivar Desheri.

Detailed descriptions of the disorder are reported by Young (1957) and Malo and Campbell (1982). In brief, the disorder generally appears in fruit during the initial stages of maturity and consists of a loss of firmness of the flesh which disintegrates into a soft watery mass. This is generally accompanied by a change in skin colour associated with ripeness. The early stages show a jelly-like translucency adjacent to the stony endocarp which extends throughout the fruit with advancing ripeness. Fermentation and spoilage is the last phase of the disorder. Malo and Campbell (1982) suggest that the disorder begins with the development of a stem-end cavity similar to that commonly found in Kensington Pride.

The physiological disorders of blossom-end rot in tomatoes, blackheart in celery and bitter-pit in apples have all been demonstrated to be nutrient-related. Two major nutritional studies have been documented with mangoes. Young (1960) first noted that increased nitrogen applications significantly improved yield but also caused a great increase in the incidence of soft nose" in Kent mangoes. With further investigations (Young & Milner 1961), he attempted to correlate the incidence of "soft nose" to leaf nitrogen concentration, but found that on calcareous soils, even under high nitrogen regimes, the level of affected fruit was low. He concluded that an element of seasonality exists that influence the degree of expression; and that the soft nose disorder is aggravated by high nitrogen levels in the tree, but that high calcium levels in the tree may alleviate this tendency, or retard development of the disorder. With the increased popularity of the cultivar Tommy Atkins being grown on the calcareous Homestead soils, the soft nose disorder became critically important. Detailed experiments by Malo and Campbell (1982) varying nitrogen and potassium levels failed to establish any correlation between these elements and the incidence of 'soft nose" in the Tommy Atkins cultivar when grown in calcareous soils. As this variety appears predisposed to 'jelly seed' it could be argued that the response lay outside the nutritional limits investigated.

Tree size control

In fruit production tree size control is achieved by:

(i) the use of dwarf scion types
(ii) the use of dwarfing rootstocks
(iii) pruning
(iv) chemical retardants

The ability to control or dwarf tree size adds considerably to the management strategies that can be employed in fruit production. Benefits achieved from dwarfing are increased precocity, ease and economy of spraying and harvesting, and increased production per unit area through high density tree plantings. With mangoes under moist tropical conditions trees tend to get very large. There is a degree of size restriction as environmental conditions for growth become less favourable. A capacity for bearing fruit also tends to restrict size to some degree. However, in most instances without manipulation, trees ultimately grow to unmanageable sizes.

Dwarf Scion Types - The use of dwarf scion types has its limitations in that only scions that feature the dwarfing character can be used. In many instances, these are not acceptable cultivars for production in that they do not meet marketing prerequisites. The variety Amrapoli has already been discussed in relation to high density plantings that can be achieved by dwarfing trees (Majumder et at. 1982). Other varieties of known dwarfness are Julie and Willard.

Dwarfing Rootstocks - Dwarfing rootstocks offer the ultimate in tree size control with considerable benefits to orchardists as seen in the apple industry. Various researchers working with the selection of dwarfing in apple rootstocks developed a selection criteria based on anatomical characteristics. These have been investigated by several researchers in relation to selection of dwarfing mango rootstocks. Majumder *et al*. (1982) concluded that (i) growth of stem; (ii) bark percentage of roots; and.(iii) area of vessels in roots can be used to classify mango rootstocks into various vigour classes. Dwarfing rootstocks had the slowest growth of stem, the highest root bark percentage and the highest number of xylem vessels per unit area of root. Further to this, Arora et at. (1973) studied the inheritance of anatomical characteristics related to vigour in mango seedlings. They concluded that low bark percentage was dominant over high bark percentage and a low number of xylem vessels was dominant over a high number. The segregation pattern of different characters in various crosses in mango did not show any exact Mendelian ratio because of heterozygosity and the complex polyploid nature of the crop.

Mukherjee and Das (1980) present further work where the growth character of several rootstocks are positively correlated to the above anatomical factors. They conclude that anatomical screening is an effective approach for screening seedlings for the dwarfing character.In Israel, Gazit and Kadman (1980) screening for rootstocks tolerance to calcareous soils and saline water found that rootstocks from polyembryonic seed gave smaller trees than those from monoembryonic seed. They also documented the rootstock 13-1 which has some dwarfing effect.

Arora et at. (1973) reported the rootstocks Totapari Red Small, Neelum and Bangalora as dwarfing rootstocks, while in addition, Mukherjee and Das (1980) found Vellai-Kolamhan, Olour, Mylepalium and Ambelavi imparted dwarfness to mango trees.

Pruning - Pruning for tree size control is practised in many temperate fruit crops, but there is little reported on the effect of pruning on mangoes. Iyer and Subramanium (1973) in detailed pruning experiments found that the annual increase in tree size could be minimized by the pruning of previous seasons growth to 5 cm stumps. However, not all varieties responded favourably with flower production and fruit set.

Chemical control - Several chemicals have been released which inhibit growth in plants but to date their commercial application has been limited. However, a new chemical, PP333 (paclobutrazol) (George and Nissen 1984) has effectively dwarfed low chill peaches. There are no reports of this being used on subtropical trees.

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Fruits and nuts of northeastern Mexico

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Introduction

The Huastec Indians of northeastern Mexico enjoy a variety of locally produced fruits and nuts. The region occupied by the Huastec lies just west of Tampico, Mexico, in the foothills of the Sierra Madre Oriental at altitudes from 60 to 500 m. Climatic conditions are warm and humid; the original vegetation of most of the region was moist tropical forest. The average annual temperature is 23.5°C. Freezing temperatures are rare; summertime high temperatures reach 45°C. Rainfall patterns and amounts vary widely from year to year; amounts average around 2 000 mm per year. Soils are alkaline, having been derived from limestone. A more detailed description of climatic and physiographic conditions can be found in Alcorn (1984).

Following are some brief notes about the species producing useful fruits and nuts in this region. Many of the fruits and nuts listed below are only of local importance. I will indicate those which have commercial importance or commercial potential. Old World introductions are indicated by an asterisk. Details on medicinal uses of fruits and nuts can be found in Alcorn (1984). A key indicating sources mentioning uses for some of these trees in other parts of Middle America can be found in Alcorn (1983).

Acacia cornigera (L.) Wild. (Leguminosae): This thorny, wild bush produces a small, red, sweet legume popular as a children's snack.

Acrocomia mexicana Karwinsky (Palmae): The fruit of this thorny "coyal" palm resembles a miniature coconut. It is a popular snack food in this region and in many other parts of Middle America.

Annona globifera Schi. (Annonaceae): This small, wild tree produces a small snack fruit similar to the large custard apples of its cultivated relatives.

Annona reticulata L. (Annonaceae): Two local varieties of this popular cultivated tree produce the well known custard apple. The varieties vary in bark and fruit colour, one being darker than the other. The fruit are sold in local markets.

Annona squamosa L. (Annonaceae): This cultivated tree is not common in the Huastecan area. The fruit, the sweet sop, is eaten as a snack food and occasionally sold in the local markets.

Ardisia compressa HBK. (Myrsinaceae): The small fruit of this wild tree are eaten as a snack.

Ardisia escallonioides Schlecht. & Cham. (Myrsinaceae): The small fruit of this wild tree are eaten as snacks. They are also used in cooking.

Bombax ellipticum HBK. (Bombacaceae): Seed of the ornamental white-flowered variety are eaten as a snack.

Bromelia karatas L. (Bromeliaceae): The sour fruits of this wild, terrestrial bromeliad are eaten as snacks, used to make an alcoholic beverage, and used in cooking.

Bromelia sylvestris Willd. (Bromeliaceae): This wild, terrestrial bromeliad is occasionally planted for its fruit which are eaten as snacks and, more importantly, used to make an alcoholic beverage.

Brosimum alicastrum Swartz. (Moraceae): Locally the nutritious "nuts' (actually seeds) are cooked as a staple or prepared as a dessert. Nuts and leaves are fed to livestock. The sparse, sweet flesh of the small fruits is also consumed as a snack. There are two varieties: a yellow fruited type and a red fruited type. According to myth, this nut was the Huastec staple prior to the introduction of maize. Peters and Pardo-Tejeda (1982) have summarized the trees' uses and Mexican research efforts to develop it as a "new" tree crop which produces high yields even under drought conditions. Widespread commercial exploitation of this multiple-use tree has not yet been realized.

Carica papaya L. (Caricaceae): While improved cultivars of the papaya are occasionally grown, the wild, small fruited type is also exploited for its fruit which are stewed.

Chaetoptelea mexicana Liebm. (Ulmaceae): The small, nut-like fruits of this large tree are occasionally eaten as snacks.

Chlorophora tinctoria (L.) Gaud. (Moraceae): The small, sweet fruits of this large tree (the wood of which is used elsewhere to produce the dye fustic) are popular snacks.

Chrysophyllum mexicanum Brandegee (Sapotaceae): This medium sized tree produces a popular children's snack fruit.

Citrus aurantifolia (Christm.) Swingle*, ***C. aurantium*** L.*, ***C. limetta*** Risso.*, ***C. limonia*** Osbeck.*, ***C. reticulata*** Blanco*, ***C. sinensis*** (L.) Osbeck.* (Rutaceae): These pantropical citrus cultivars are also popular kitchen garden trees in the Huastecan region. Only oranges are grown commercially.

Coffea arabica L.* (Rubiaceae): Coffee is grown commercially here, but it is of low quality. Most bushes are derived from transplanted "volunteer" seedlings.

Cocos nucifera L.* (Palmae): Coconuts are occasionally grown as curiosities.

Diospyros digyna Jacq. (Ebenaceae): This native tree produces the sweet, black persimmon which is occasionally marketed as a snack or for cooking. The immature fruit is used as a fish poison.

Ehretia anacua (Berl.) I.M. Johnst. (Boraginaceae): The sweet, small yellow fruit of this wild tree are eaten as snacks.

Enterolobium cyclocarpum (Jacq.) Griseb. (Leguminosae): The seeds of the large, earpod tree are used for making coffee and cooked in local breads. The tree s also used as a shade tree for coffee plantations.

Eugenia capuli (Schlecht. & Cham.) Berg. (Myrtaceae): The small fruit of this wild tree are eaten as snacks and used in cooking.

Eugenia jambos L.* (Myrtaceae): The rose apple is occasionally cultivated here for its edible fruit.

Eugenia oerstedeana Berg. (Myrtaceae): This small, native tree is occasionally cultivated for its small fruit which are eaten as snacks.

Ficus obtusifolia HBK. (Moraceae): The small figs of this wild tree are occasionally eaten as a snack.

Ficus padifolia HBK. (Moraceae): Small, sweet figs are eaten as a snack.

Garcia nutans Rohr. (Euphorbiaceae): This is another native tree whose commercial potential has never been tapped. Locally the nuts are only used medicinally to cure alcoholism. However, an oil superior to tung oil can be produced from this tree's nuts (Uphof, 1968).

Gonolobus niger (L.Cav.) R.Br. (Asclepiadaceae): The medium-sized fruit of this native, woody vine are eaten fried or stewed.

Gossypium hirsutum L.: Immature cotton bolls of large, dooryard bushes are eaten as snacks by children.

Guazuma ulmifolia Lam. (Sterculiaceae): The small, sweet fruit of this medium-sized, wild tree are popular snacks for children.

Hylocereus undatus (Haw.) Britton & Rose (Cactaceae): The large, sweet 'pitaya' fruits of this cultivated, epiphytic, vine-like cactus are grown for home consumption and for market. The tender stems are also cooked as a vegetable. Two varieties are recognized locally based on fruit colour: red and green.

Inga spuria Humb. & Bonpl. (Leguminosae): The sweet pulp surrounding the seeds of this medium-sized, fast-growing, wild tree is eaten as a snack. The tree is planted for shading coffee.

Lantana camara L. (Verbenaceae): Small fruit of this wild shrub are eaten by children.

Malvaviscus arboreus var. ***mexicanus*** Schlecht (Malvaceae): The small fruit of this wild bush are eaten by children.

Mangifera indica L.* (Anacardiaceae): Several varieties of mangoes are cultivated for home consumption. They are also marketed locally.

Manilkara achras (Mill.) Fosberg (Sapotaceae): The fruit of the chicle tree is a large, popular snack fruit that is marketed locally. The latex is chewed as gum by children, but it is not marketed. Several varieties are recognized based on fruit colour and size.

Mastichodendron capiri (A. DC.) Cronq. var. *tempisque* (Sapotaceae): The medium-sized fruit of this large, wild tree are eaten as a snack and marketed locally.

Musa X paradisiaca L.* (Musaceae): Several varieties of bananas are grown in kitchen gardens.

Nopalea cochenillifera (L.) Saim-Dyck (Cactaceae): The flowers of this cultivated cactus are eaten as a vegetable, as are the thornless stems. Stems are also fed to pigs.

Parathesis serrulata (Sw.) Mez. (Myrsinaceae): The small, sweet fruit of this wild bush are a popular snack fruit.

Parmentiera edulis DC. (Bignoniaceae): The ripe fruit of this small, wild tree are stewed as a dessert. They are also widely used for medicinal purposes.

Persea americana Mill. (Lauraceae): The avocado is a common tree whose fruits are marketed locally. Several varieties are grown.

Persea americana var. ***drymifolia*** (Schlecht. & Cham.) Blake (Lauraceae): This more strongly flavoured avocado is quite popular and marketed locally. The leaf is also used as a condiment.

Pithecellobium calostachys Standley (Leguminosae): The sweet flesh surrounding the seeds of the legumes of this wild tree are eaten by children.

Pithecellobium dulce (Benth.) Coulter (Leguminosae): The tasty pulp surrounding the seeds of this frequently cultivated, large tree are eaten as a snack. The fruits are occasionally marketed.

Pouteria campechiana (Kunth.) Baehni (Sapotaceae): The sweet fruits of this large tree are marketed locally. Both wild and cultivated types with larger fruits exist in the region.

Pouteria mammosa (L.) Cronq. (Sapotaceae): The large, sweet mamey fruits of this tall, cultivated tree are sold in the market. Seeds are used medicinally.

Prunus persica (L.) Batsch.* (Rosaceae): Peaches are occasionally cultivated in dooryards as a curiosity, but they seldom produce fruit.

Psidium guajava L. (Myrtaceae): The sweet fruit of the cultivated guava are marketed locally as snack foods.

Punica granatum L.* (Punicaceae): Pomegranates are occasionally cultivated in dooryards.

Randia laetevirens Standley (Rubiaceae): The small fruit of this thorny, wild bush are eaten as snacks.

Sabal mexicana Mart. (Palmae): The small fruit of this common palm, grown for its leaves which are used as roofing material, are eaten as snacks.

Sapindus saponaria L. (Sapindaceae): The seeds of the wild soapberry tree are eaten as snacks.

Selenicereus cf. spinulosus (DC.) Britt. & Rose (Cactaceae): The small fruit of this small wild cactus are eaten as snacks. The flowers are cooked as a vegetable.

Spondias mombin L. (Anacardiaceae): The hog plum, produced on a spreading, medium-sized tree, is used in a variety of ways. The fruits are eaten as a snack, cooked, used as a flavouring, and made into fruit juice.

Spondias purpurea L. (Anacardiaceae): This is the more popular Middle American hog plum grown in dooryards. The sweet fruit are used as a snack food or in cooking. Several varieties are recognized.

Tamarindus indica L.* (Leguminosae): The spreading tamarind tree is grown in dooryards for the sour pulp surrounding its seeds which is used to flavour a popular beverage.

Vitis mesoamericana Rogers (Vitaceae): The fruits of the wild grape are eaten as snacks.

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Rambai and tampoi in Malaysia

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The Rambai (*Baccaurea motleyana*) belongs to the same family as the famous rubber (Hevea brasiliensis):in the family Euphorbiaceae. The genus *Baccaurea* has over 20 species growing wild in the tropical lowland forests. *Baccaurea* is found mainly in Malaysia and also around India and the Pacific. Most of the *Baccaurea* species are generally too sour but some selected species like *Baccaurea motleyana* are sweet enough to be eaten as fresh fruits and have thus become popular in Malaysia. The fruits of other species have been used in many other ways for various drinks and liquor. The various parts of the *Baccaurea* trees can be used for things such as timber, dye and medicine.

In Malaysia, the Rambai (*Baccaurea motleyana*) or the golden berry is well known locally as a fruit tree, but commercially it is not significant. It is commonly grown as individuals in villages in the north eastern part of the country. The fruits are mainly for home consumption and excess is sold in the market.

There is another species commonly known as Jungle Rambai or Tampoi (*Baccaurea griffithii*). The fruit of Tampoi has a thick wall and the flesh is rather acidic. Sometimes they are sold in the market by natives who collect them from the jungle as they are seldom planted.

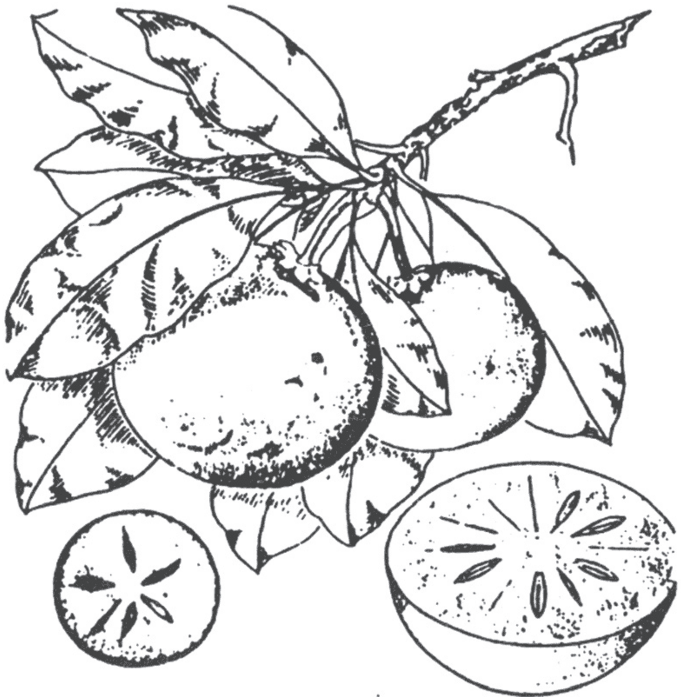
The characteristics of the *Baccaurea*s are that they are evergreen trees of average height from 10 to 18 m in the wild state (see Fig 1). Those grown around the urban areas and in villages are not as tall, normally about 10 m. The *Baccaurea* trees are easily recognizable by their shape, dense foliage and the spirally arranged leaves. The flowers are yellowish green arranged in string like structures with a scent. The fruits or berries are arranged in strings and hang down beautifully from the older woody branches of the tree. Flowering starts with the onset of dry weather. This is followed by the fruiting season which comes once or twice a year.

Although they are fairly well known, the Rambai fruits are not very popular as fresh fruits because the flesh is soft and sticks to the seed which is usually swallowed. They are seasonal fruits and are produced plentifully by each tree. At present there is no breeding work conducted on this species. Only through selection some trees with sweeter fruits are propagated for planting. As a fruit, its potential is not commercially exploited. More research should be conducted with regard to their culture, breeding and postharvest physiology. In the meantime, Rambai trees can also be grown for landscaping as they are beautifully shaped evergreen trees with dense foliage. Only the two better known *Baccaurea* species are described below in this short article to stimulate some interest in them as they have lacked attention in the past.

Rambai *(Baccaurea motleyana)*
An evergreen tree growing to about 18 m in height, the Rambai has a low, round, bushy crown and large leaves, 15-30 cm long and 7-15 cm wide. Its leaf blade has a heart shaped base with an uneven and wavy edge. Its flowers are borne on the larger branches of the tree, the male flowers being light yellow, fragrant and on strings 7-25 cm long while the female flowers hang on longer strings, 25-90 cm long. The fruits are buff in colour, oblong in shape with 1-3 seeds in them and the fruit skin is thin and velvety. The translucent white pulp is edible and its taste varies from sweet to acidic. The nutritional value based on 100 g edible portion of the fruit is 5 mg vitamin C, 2 mg calcium and 20 mg phosphorus. Its vitamin content is very low compared to other fruits and vitamin B1 and B2 are totally absent. The fruits may also be fermented and made into a liquor, the timber can be used for making posts and the bark for fixing other dyes.

Tampoi (*Baccaurea griffithii)*
Locally found in the lowland forests, from Perak southwards, the Tampoi resembles the Rambai except for its glabrous leaves, twigs and fruits. It has leaf blades which are narrowed to the base and are not heart shaped like Rambai. Its inflorescences are normally 8-20 cm long and are clustered on the branches and occasionally on the trunks. The fruits are 2-6 cm wide, flatly rounded in shape. The fruit skin is dull brown with little brown spots. The pulp is creamish white, opaque when matured and translucent on ripening and is sour sweet. The fruits are borne singly or in bunches of 2-4 at the ends of stout strings, 5-20 cm long. It produces strong timber.

In conclusion, of more than twenty species of *Baccaurea* found in Malaysia, all are edible but most of them are too acidic to be eaten as fresh fruits. Only a few species have tiny fruits. A few sweeter ones have been selected, and among them, the Rambai and Tampoi. In spite of these, they have not been planted on a commercial scale while others in the wild are not worth cultivating. These wild species however must be conserved as genetic resources. They can be used for future breeding of new varieties of Rambai and Tampoi. The other parts of the *Baccaurea* have yet to be exploited for their use as timber, dyes and medicine. As they are beautiful trees, they can be used more for landscaping in urban areas, parks, public gardens and even in home gardens.



Leucaena Species

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Over the past few years, especially since the great drought of 1982, when we lost 85% of all our seedlings, the realization of a different approach in nut and tree crop planting has been undertaken by us. The principles are simple, the seedlings must be compatible with our environment and they must show it to us themselves by surviving without watering, fertilizer, weed control and still provide the possibility of dual purpose trees. The second purpose is generating an income.

What does not fit these environmental and economic conditions will die, and so be it. What we are doing now is raising some 10-25 seedlings, planting them out in different locations on our little farm and seeing whether they live or die. If they do not survive, they contribute to an economic assessment: they do not suit our environment. If they do, then we try to look for the links connecting them in their natural environment, even though they may be dispersed widely in different continents. We have to try and obtain seeds, germinate them, raise seedlings and see how they react in our environment. What works is likely to be a long term economic proposition. This is a Darwinian method but the main purpose is to find dual purpose trees which grow by themselves irrespective of their origin and which can be presumed to be able to earn a living, if planted in numbers.

On that basis, we look at species which are successful in Australia, but not in our environment. This is what happened with *Leucaena leucocephala*, a fast growing fodder crop in Queensland which had some toxic effect on some grazing stock. However the CSIRO has overcome that problem.

Research has shown that *Leucaena* is a small genus of about 14 different trees and shrubs. Most of these are subtropical or tropical. Most of them are in North Central America but a few of these species are found in other areas, including one in South America. At least one grows at 35°N lat. near the snowline.

We were looking for two different characteristics: one is drought resistance, and the second is frost resistance. All told, it seems, that of the 14 sp. of *Leucaena* three are capable of withstanding some cold, and one of these is used as everyday food by the peasants (campesinos) of Mexico. The three species are:

L. retuse is a small and valuable shrub, which has been released as a browse shrub by the USDA, which can stand frost and possible drought. A few of mine have survived three Canberra winters, but they have defoliated on each occasion. It has a frost resistant gene, and is therefore a breeding species. *Leucaena*s cross and hybridize. This one requires a special bacteria for nitrogen fixing, I have had some and passed them on to the CSIRO for separation and breeding.

L. pulverulentula is a big tree and can withstand some cold. I was able to keep the few I raised alive.

L. esculenta is a tree with edible pods in the high mountains in South Mexico, (about 17°N lat. and around 2 000 m elevation). I have one growing but I did not dare to expose it to frost last winter, but will do so this year. The pods are an item of commerce in Mexico and if the trees can reach the stage of seed production with frost exposure, that may be important.

The other species, and there are about 10 or so left, are dealt with in the following pages. I feel some of these are suitable to much of WA in tropical and subtropical latitudes. *Leucaena* seeds are a prohibited import and if you get seed, it must be grown in quarantine, for the first generation at least.

Botanically, *Leucaena*s are close to wattles, and they are a central American group of Acacias, from the subfamily of the Mimosoideae. As a group they are sometimes referred to as part of the INGA group of woody legumes. Whether there is any chance of crossing them with any of the wattles is a matter which I cannot comment on, a vague possibility may exist. Most of the *Leucaena*s are desert or mountain desert trees without spines in hot to warm climates. The three species which may stand some cold and drought are of interest to people like us who live in such climates as Canberra. I would seek out in WA places where the desert Kurrajong grows, and would try to plant the frost sensitive ones in that environment. (Desert Kurrajong: *Brachychiton gregorii*)

Seeds from Mexico are almost impossible to get, but someone may have contacts there. *Leucaena* seeds were collected by the CSIRO sometime in the late 1960's and the early 1970's, but the researcher who collected them is no longer with the CSIRO.

I feel, that it is worthwhile persevering with this genus as most members are large and often fast growing trees with local economic significance. Note that the one species used in Australia is not referred to in these notes, but it is worthy of note that there are two subspecies of *L. leucocephala*, one is a shrub (grown in Australia) the other is a large tree in El Salvador, which to my knowledge, is not found here yet. Some of these tropical *Leucaena*s may be of use in tropical WA for trial purposes, hybridization or outcrossing.

Although agronomists in Indonesia observed in the early 1900's that *Leucaena pulverulenta* would grow well at high elevations either by itself or grafted on *leucaena* (*L. leucocephala)*, little effort has been made to exploit this species and others of the genus. Yet most *Leucaena* species are used for browse or farm fuelwood in their native habitats and often for shade, fence trees, posts, and fuelwood.

Nine *Leucaena* species are recognized in addition to *L. leucocephala*. They grow from the highlands of Texas to the coastline of Ecuador and extend greatly the range of adaptability of leucaena itself. Recent tests show that these can be crossbred with leucaena, thereby forming a major gene reservoir for its further improvement.

Hybrids can be used to contribute new genetic variation to leucaena but can also be used directly. It is predicted that future leucaena cultivars will represent combinations of these species, much like the modem sugarcanes that are also high in chromosome number and highly variable in the tropics.

Species of primary interest are:

Leucaena diversifolia (Schlecht.) Benth. A pink-flowered tree with tiny leaflets, it displays great diversity of form, has wide natural distribution, and occurs to 2 000 m elevation in Central America. Advantages are quick growing, low mimosine content, grows at high elevations, produces more wood than *L. leucocephala* at high elevations, good seed yields, and some lines are tolerant of acid soils. It is less useful for low altitudes and hot, humid climates, and seems rather susceptible to drought.

Leucaena esculenta (Moe. and Sesse) Benth. A large tree of highland Mexico, it grows to 10-18 m high, with long leaves, fine leaflets, reddish stems, and corky bark. It is cold tolerant (occurs naturally at 1000-2 200 m elevation in Mexico), has low mimosine content, and high wood yields. However, the thick corky bark in some lines can be a nuisance, growth is slow and seed yields are low.

Leucaena macrophylla Benth. A shrub or tree of dry lowland Mexico, it has very large leaflets and rapid growth. It grows in droughty to wet situations, can be fast growing and some lines are acid-soil tolerant. It has large leaves with low forage yield and a high mimosine content.

Leucaena pulverulenta (Schlecht.) Benth. A tall tree of northeast Mexico and south Texas, it has small leaves and tiny leaflets. It is cold tolerant (found growing native to 35°N latitude), drought tolerant, has very dense wood, is an excellent fuel and makes promising hybrids with *L. leucocephala* (shows aggressive growth with good form). However, it has slow growth and natural outcrossing within the species.

Leucaena shannoni Donn. Smith. A shrub or small, umbrella-shaped tree found in southern Mexico and Central America. It is a good pollen source for bee pasture, an excellent soil cover (umbrella shape; tree spreads over large area and almost weeps) and erosion control. Forage yields are low and seed production is poor.

Four other *Leucaena* species offer additional possibilities for use in the tropics or as parents for important leucaena hybrids.

Leucaena retusa . A bright-yellow flowered shrub of the southern United States and northern Mexico, enduring snowy winters at up to 2 000 m elevation. It hybridizes with other leucaenas, but has atypically slow growth, brittle wood, and an unusual nitrogen-fixing bacterium.

Leucaena lanceolata. A shrub of western Mexico that is widely used as animal browse. It is heat and drought tolerant and has broad leaves like *L. macrophylla*. It also is highly variable because of cross-pollination.

Leucaena collinsii. An elm-shaped small tree of southern Mexico, adapted to middle altitudes (500-1 500 m) and acid soils. It is fairly rapid in growth and may be a useful parent species for improving tree form.

Leucaena trichodes. A large-leaf species that ranges from small drought-hardy shrub to a tall tree (22 m) in southern Panama. This South American *Leucaena* appears to be slower in growth and of interest primarily in hybridization.

Aleurites: the wood-oil trees

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Introduction

The genus *Aleurites* comprises a small number of tree species in the family Euphorbiaceae and all are found in tropical and subtropical eastern Asia and on the islands of the Pacific.

The genus was established by Forster in 1776 though it had been previously described among the common plants of Japan as early as 1712 by Kaempfer. The tree first described by Kaempfer was given the name *Aleurites cordata* by Braun in 1821 and this name has remained with us. Unfortunately, as often happens with descriptions of little known plants, new species were often referred to as *A. cordata* while specimens of *A. cordata* found in different localities were often given new names! Most people today accept that there are five established species of *Aleurites* - though in 1978 a sixth species, *A. erratica*, was described from Hawaii. Doubtless other closely related forms will be found in the future and will be given specific epithets to further confuse an already confused public!

The importance of the genus *Aleurites* lies in the fact that all of the species produce large quantities of nuts which themselves yield, on crushing, a high quality oil which dries quickly to form an opaque, waterproof nonelastic film on wood or other fabrics; wood-oil is now also used extensively in the paint and varnish industry. By far the largest producer of wood-oil is China which exported in excess of 130 000 tonnes in 1983 though recent years other countries, realising the economic importance of wood-oil, have set up large plantations of *Aleurites* species in competition with China.

In this article we examine the status of the various species known to be economically important and investigate their growth characteristics and cultivation under differing conditions. We will also look at the economic feasibility of *Aleurites* as a potential tree crop for Australian conditions and suggest avenues of approach for its cultivation. Firstly, however, we will discuss the properties of wood-oil per se and its economic importance on a world scale.

Wood-Oil (Tung Oil)

From our earliest historical records we see that man has sought to protect his personal possessions from the effect of biodeteriorating microorganisms and probably one of his earliest methods of achieving this was to cover the surface of fabrics, wood, leather, etc. with vegetable oils. For example, artefacts from Egyptian and Chinese tombs still reveal the presence of transparent glossy surfaces on many objects which were thus, to some extent, protected from the ravages of nature.

However, not all vegetable oils are suitable as protectants - only those that dry completely to form a thin transparent layer when exposed to air; oils such as linseed oil, olive oil, etc. do not have this property and are referred to as nondrying oils.

The most important of the drying oils known to man is that obtained from a species of *Aleurites* grown in China. This oil is referred to either as 'Chinese wood-oil or 'Tung oil'. The two terms are interchangeable though confusion existed in the early literature because oil from *A. montana* was translated from the Chinese term 'Mou Yu' meaning wood-oil while a similar oil, obtained from *A. fordii* - known in Chinese as 'Tung Shu' - became conveniently termed Tung oil'. With the development of the wood-oil industry in China during the last two centuries oil from *A. fordii* became more plentiful because of the tree's greater climatic hardiness and the Tung oil' trade became paramount.

Wood-oil extracted from *Aleurites* is a viscous, pale straw to yellow brown liquid though its purest form is almost colourless. It has a characteristic odour said to be due to the presence of damaged and/or diseased nuts in the extraction procedure. The oil dries quickly to form an opaque, nonelastic, wrinkled film. The oil is soluble in ether, petroleum ether, chloroform, benzene and carbon sulphide. On heating to 250-290°C wood-oil solidifies within minutes into an elastic jelly which remains insoluble in the usual organic solvents. Chinese wood-oil is composed primarily of the triglyceride of elaeostearic acid the formula of which is $C_{18}H_{30}0_2$ or more fully

$$CH_3.(CH_2)_3.CH:CH.CH:CH.CH:CH.(CH_2)_7.CHO_2H$$

As with any commercially important product that is produced from divers sources and by a variety of extracting procedures certain constants relating to the product must be maintained. In general, wood-oil is characterised by its density, refractive index, acidity values, saponification index, dispersion capacity and viscosity. All drying oils, of vegetable origin also utilise another value to determine their comparative acceptability to the trade - the iodine number in which the drying power of the oil is directly proportional to the magnitude of its iodine value. Oils having an iodine index above 130 are classified as drying oils while those below 100 are nondrying oils. The iodine index of Chinese wood-oil varies between 220-235.

Tung oil has a variety of uses in addition to being used in paints and varnishes. For example, it is used in waterproofing products made of paper, leather, and fabrics; it is used to produce oil cloth and linoleum and various roof coverings; it is important in the printing industry in inks; it is used in the manufacture of soaps and putty; it is utilised as a preservative for wood and in a very specialised capacity as an additive to brake linings, synthetic resins and insulating varnishes for electrical cables.

The Species

Early in this century only three species of *Aleurites* had been described and Wilson (1913) easily distinguished them one from another on the shape of their fruits; *A. fordii* Hemsl. having fruits that, were smooth, spheroid and slightly flattened; *A. montana* Wilson having sublobular fruits and *A. cordata* R. Br. with three cornered, flattened fruits which were wrinkled. Conveniently, the two remaining species also bear distinctive fruit which help to distinguish them; *A. moluccana* Wilid. bearing oblong, thick walled nuts and *A. trisperma* Blanco with nuts having a very thin shell. In addition to these well established species other names sometimes crop up in the literature; *A. javanica* Grand. is a synonym for *A. moluccana* while *A. triloba* is a doubtful species found in North Bihar, India, and described by Sinha and Misra in 1975. These local varietal species are not referred to again in this paper nor is *A. erratica*, a variety of *A. moluccana* found in 1978 on Canton Atoll in the Hawaiian islands by Degener, Degener & Hummel and given specific rank based on "notable macroscopic and microscopic characters".

A. cordata R.Br.

This tree has many synonyms, the most common being; *Dryandra cordata* Thunb.; *Elaeacocca verrucosa* A. Juss.; *Aleurites japonica* B l. and P*aulownia imperialis* Chapm. It grows to a height not exceeding 10 m and the deciduous leaves appear before the flowers. It is found primarily in the hot regions of Japan and some specimens have also been found in China. According to Burkill attempts to grow this species in Malaya failed as did similar trials in South America. An accurate description of this tree is given in the International Institute of Agriculture bulletin of 1938:

"Although chiefly monoecious, the tree shows a decided tendency to dioecism which affects not only the flowers but also the aspect and size of the tree, so that the staminate tree is higher and less ramified than the pistillate one ... The leaves are alternate, with the blade measuring 2.8-10 cm in length and breadth; the petiole is from 4-10 cm long. The leaves are glabrous on the upper surface and slightly pubescent at the level of the ribs on the lower surface, particularly in young leaves. The leaves are fundamentally cordiform; the lamina, however, may be divided into lobes corresponding to the main ribs, resulting in 3 or 5 lobed leaves. At the base of the lamina are 2 nectariferous glands. The flowers are unisexual, reddish white or pale violet in colour, and are grouped in compound clusters, conical in shape ... In regard to external appearance, the pistillate flower is identical with the staminate flower. The ovary is well developed, generally comprising 3 carpels, though the number of these is not fixed. Each carpel encloses only one ovule.

The fruit is a globular drupe, measuring 2-2.5 cm in length and 2-3 cm in breadth. It is normally trigonal, trilobate and trispermous. When ripe, the fruit is dark brown in colour. The air dried fruit weighs approximately 5 g, hence, it is by far the smallest of *Aleurites* fruits ... The tegument is coriaceous, closely attached to the enclosed seeds. The seed weighs approximately 1 g, the seed tegument is greyish brown and smooth. The kernel represents approximately 64 per cent of the weight of the seed. The greater part of the kernel is formed of a yellowish white albumen, in the centre of which lies the embryo...."

A. cordata produces “abrasin oil” which in its most pure form is colourless and tasteless and which thickens quickly an exposure to air; it is used for varnishing paper and for coating wood. The oil can also be used locally and is burned in oil lamps. The oil is extracted from dried seeds by pressure or by steam extraction following the grinding of seeds in a mortar and pestle. The residual cake left after oil extraction is usually used as a fertilizer.

A. cordata oil is produced chiefly in Japan where it is known as Japanese Tung oil or Japanese abrasin oil. It is a viscous pale yellow fluid, soluble in ether, petroleum ether, chloroform and carbon tetrachloride but insoluble in ethanol. Fatty acids constitute a major portion of its weight among which elaeostearic acid is predominant; this latter constituent gives the oil its drying qualities. At 22°C its density is 0.924 making it amongst the densest oils known. It has a refractive index at 24°C of 1.5065, a dispersion capacity of 0.034 and an iodine index of 181.

***A. trisperma* Blanco**

This tree is also referred to as *A. saponario* Blanco and grows wild in the Philippines where it is known as Banucalag nut. The flowers are monoecious and arranged in large panicles. The fruit is subglobular and smooth and bears three seeds. Drying of the thin fruit coat causes the seeds to separate from the shell making collection easy. Seeds contain from 32-35% oil which on extraction yields a dark coloured oil of poor quality and is said to cause skin irritation; the oil is said to be an effective insecticide.

A. trisperma oil has a refractive index of 1.492; a density of 0.938 and an iodine index of 164. Glycerides of oleic and elaeostearic acids make up 97.3% of its composition.

A. moluccana Wilid.

The tree is also known as *A. triloba* Forst. and more commonly as the ‘Candle Nut Tree’ or the ‘Indian Walnut’. The fruits are referred to in the literature as Indian nuts, bancoulnuts, Molucca nuts and San Domingo fruits. The species is native to Malaya and may attain a height of 25 m. Leaves are deciduous, oval and 3-5 lobed and bear a reddish brown pubescence on the abaxial surface. Flowers are monoecious and when opening emit a pleasant scent reminiscent of lime tree flowers. The fruit is a large fleshy drupe, almost globular, and contains either one or two seeds each covered by a very hard integument. The kernel contains a drying oil that is said to be inferior to linseed oil. The candle nut tree is thought to be indigenous to Malaya (Burkhill 1966) but it is also found throughout Indo-China in Burma, Thailand, Cambodia and also in the Hawaiian Islands. In these areas it is not thought to be indigenous and was probably introduced by man. Wild stands of the tree have also been found in Australia, New Zealand, New Guinea, Java and various other Pacific islands suggesting its widespread introduction in remote times. Its widespread distribution probably stems from the fact that as well as producing edible nuts, which also yield a drying oil, the tree itself is very fast growing and can be successfully grown as a shade tree; it is frequently found around villages in Burma and Cambodia where it functions exclusively as an amenity tree.

Apart from producing a drying oil the nuts of *A. moluccana* can also be eaten. Burkhill (1966) describes their culinary use in Java thus: “The seeds are used a little in food, chiefly among the Javanese: they enter into a sauce which is an almost invariable associate of the green vegetables eaten with rice. Thus used in sauce, no great amount is demanded, for only a very little is eaten at a time; but the use is so wide that the local produce does not suffice, and there is an import of nuts into Java from the east of Malaysia. In the preparation the kernels are crushed and oil is extracted which is used as an illuminant. The cake is then dried and pulverized; next it is steeped for forty-eight hours in running water, then steamed and set aside in a basket in a dark place to ferment with a banana leaf over it and a stone to press it down. The fermentation goes on for four days.

The kernels are also eaten, but sparingly, roasted. The nuts are put in the fire until half the shell has been burned; then they are cracked open and the kernel removed. This roasted kernel - it would be dangerous to eat it raw - is pounded with such other flavourings as salt, chillies, and shrimp paste, and eaten as a relish. The Malays may add the cooked kernels to curries.”

The nuts can also be used as candles - hence the name - and generally in Java the kernels are pounded with cotton and copra into a stiff wax which can then be shaped into a candle around a wick and burned - producing a nauseating smell.

The importance of *A. moluccana* as a source of drying oil was established more than a century ago and the oil was known as either ‘bancoulier oil’ or ‘candle nut oil’. It is said to be inferior to linseed oil taking 2-3 days to dry to a firm finish. In the Philippines the oil is known as ‘lumbang oil’ where it is much used in the soap industry and for coating the surface of boats. The methods of extracting the oil from *A. moluccana* nuts vary from region to region and in all cases it is the removal of the very hard outer tegument that offers the greatest problem. For example, in China the nuts are spread on the ground, covered with straw which is then ignited and the hot nuts thrown into cold water causing the shells to burst. In the Philippines the nuts are generally heated in a stove at 95°C for 3-4 hours and then plunged into cold water. Both of these methods are based on primitive technology and modern methods rely on crushing mills after which shells and kernels are separated by placing the crushed residue in salt water with a specific density of 1,100.

The extracted oil varies from locality to locality and figures indicate that sound kernels have a very low acid content (e.g. 0.075% oleic acid) while spoiled kernels may yield oils with an acid content of up to 4% oleic acid. Extraction of the oil is achieved by pressing and good quality oil has the following characteristics:

Density at 20°C	0.9246
Refractive Index	0.9246 (?)
Iodine Index	154
Solidification point	21°C-22°C
Clarification point	32°C

Oils from the Philippines show slight variations in these conditions e.g. a refractive index of 1.474 and an Iodine Index of 152.

A. moluccana produces a poor timber which is light and not very durable. However, experiments carried out in Queensland, Australia, as early as 1928 indicated that the wood might be useful for making paper pulp and results indicated a yield of 62% cellulose.

***A. montana* Wilson**

This tree is also described under the following synonyms: *Dryandra oleifera* Lamk., *Vernicia montana* Lour., *Eleacocca vernicia* A. Juss., *Aleurites vernicia Hassk.,* and *Aleurites cordata* Mull Arg.

The trees grow to 10-15 m in height with glabrous, 3-5 lobed leaves making up the spreading canopy. The species is indigenous to Southern China and is said to be endemic throughout the Indo-China region. It is sometimes the dominant species in secondary forests and although it is extensively planted as an economically important tree crop it is definitely a wild species in the forest of southern China, Tonkin as well as in North Annam.

The flowers are arranged in paniculate cymes and flowers appear after the leaves. In the wild, staminate flowers predominate and thus fruit production in the wild state is insignificant. The fruits are globular, slightly trigonal with 3 longitudinal grooves. Each section of the fruit bears one seed which are enclosed in blackish brown verrucose teguments enclosing a yellowish white kernel constituting up to 63% of the weight of the seed.

The tree comes into fruit after three years and yields a drying oil of reddish colour which dries fairly rapidly and is used in China for strengthening fabrics and painting wood; it is also used in the lacquer industry in many countries and in the soap industry. Burkhill (1966) also mentions its use in making linoleum.

In Southern China fruits ripen in September and October and are either knocked off the branches with poles or allowed to fall to the ground at maturity (Chang 1983). Prior to the extraction of the oil nuts are covered with damp straw and allowed to ferment thus successfully removing the husks; another method is to place the nuts in boiling water causing the husks to burst open. Seeds are normally dried in the sun after which they are ground in a mortar. The resulting meal is steamed and the meal is pressed to extract the oil which is filtered through cloth or silk. Analysis of the oil from Southern China gave the following constants:

Density at 25°C	0.9314
Refractive Index at 25°C	1.5140
Iodine Index	162.2

***A. fordii* Hemsl.**

This species is also described in the literature under the following synonyms: *Elaeacocca verrucosa* A. Juss., *Dryandra oleifera* Wall., *Aleurites cordata* Hook. The tree attains a

height of 10-20 m with glabrous leaves. It grows primarily in central and western China in regions bordering the Yang Tse Valley; it is also found growing up to the Tibetan border. Although indigenous to the region the tree is extensively cultivated on account of its superior quality wood-oil which is in great demand world wide and which has resulted in this species being widely cultivated in countries other than China.

The leaves are deciduous and the reddish white flowers are borne in paniculate cymes which occur before the appearance of the leaves. Both staminate and pistillate flowers occur on the same branch and fruits are subglobular, dark, olive green drupes which become dark brown or black on maturity. Each fruit contains 3-7 brown seeds and contain a poisonous purgative chemical which renders them inedible.

The quality of the oil produced by *A. fordii* is considered to be the best available and the Chinese still use traditional methods of extracting the oil.

> "The fruit is collected in a green state, made up into heaps and covered with straw or grass. Fermentation takes place, the fleshy part of the fruit is rotted away until the nuts are easily removed. They are then placed in a large circular stone trough and crushed under a heavy stone roller, which, drawn by an ox or other animal, revolves in the trough. After being roasted for a short time in shallow iron pans, the crushed mass is thrown into wooden vats with open work bottoms, over cauldrons of boiling water, and thoroughly steamed. Meanwhile, iron rings, about 18 inches in diameter, are placed on the floor and covered with layers of straw whereupon the steaming meal is arranged to a depth of several inches, then ends of the straw being drawn over to cover the tops of the cakes which, thereby formed, are withdrawn from the rings and placed on end on sloping wooden presses. When a press is nearly full of cakes, wooden wedges are inserted in the upper end of the slope, and as these are driven home, one after another, by a hammer, a brown fluid exudes from the cakes and drops into a tank underneath. This fluid is the commercial wood-oil, and amounts to 40% of the weight of the seed. It is widely used throughout China, and, for transport, is packed in wooden tubs with tightly stoppered lids or in carefully stoppered bamboo or wicker baskets, lined inside and outside with tough waterproofed paper. The refuse cake is used as a fertilizer." (Burkhill 1966)

The published constants for Tung oil from *A. fordii* vary depending upon the country in which the trees were growing and the extractions made. However, the figures represented below indicate average values for the best quality oils.

Refractive Index at 25°C	1.517
Specific weight at 25°C	0.9352
Iodine value	165
Colour	colourless - very pale yellow

Because of the excellent quality of the oil and because of the inability of China to meet world demands attempts to cultivate *A. fordii* have been made in many countries possessing climatic conditions similar to those of Central and Western China. However, early attempts to grow the tree under tropical conditions e.g. in Malaya were unsuccessful (Burkhill 1966).

Countries with climates conducive to the cultivation of *A. fordii* trees include the United States of America where many of the southern states facing the Gulf of Mexico have extensive plantations. Tung oil production in the USA reached its peak in the 1960's involving some 15 000-17 000 tonnes per annum and making the USA self sufficient. Regrettably, oil production ceased after 1975 when the plantations were severely damaged by frost and hurricanes. After 1976 most farmers felt it imprudent to embark on a new planting programme though some farmers in the Mississippi delta have replanted but still lack the facilities for crushing the nuts. South America, Argentina, Paraguay and Brazil produce, collectively, some 30 000 tonnes annually. Other countries growing significant quantities of Tung trees include Australia, New Zealand, and some African countries including Kenya and Malawi.

A. fordii is a fast growing tree and fruits can be obtained after 3 years though this is rare; 5-7 years being the optimal time for fruiting. Subsequently the tree reaches peak production after 10 years and continues to bear fruit until the thirtieth year. Yields however depend very largely on successful plantation management, accurate manurial applications and adequate husbandry.

Cultivation

It is fair to say that the traditional methods employed in China to grow *Aleurites* as a commercial crop are not very efficient. One reason for this is the fact that *Aleurites* is a very hardy plant capable of withstanding drought, frost, rocky conditions and can survive and grow under rudimentary or nonexistent plantation management. Consequently, Tung trees have been grown only on land unsuitable for the production of food crops and other crops with more exacting agricultural requirements. Chang (1940) in his survey of traditional methods of Tung tree cultivation has noted that the trees are less adapted to growing on the lower hill slopes and the plains and thus plantations are normally found on hilly areas where no attempts have been made to equate tree to tree distribution resulting in unprofitable plantation revenues. Fertilizer regimes in these plantations also appear to be haphazard with the main source of nutrition arising from a mixture of ash from wood or grass and animal manure. Harvesting is most primitive and nuts are collected either by knocking the branches with poles or allowing them to fall to the ground.

Where *Aleurites* has been introduced as a commercially viable crop into countries other than China, attempts have been made to place the system of cultivation on a more scientific basis with emphasis being placed on seed selection, forestry management and fertilizer application . In this respect even China since the 1949 Revolution has gradually replanted all of its old, underproductive trees with new selected stock resulting in a 60% increase in output within three decades (Wong 1983).

The seeds of *Aleurites* have very hard, thick seedcoats resulting in extremely long germination periods sometimes running into months. Furthermore, germination is invariably uncoordinated in any given batch of seeds resulting in seedlings of uneven size and age.

In the Philippines attempts have been made to reduce the period of dormancy by either burning grass over the partially planted seeds or by heating the seeds, prior to planting, in a moist heat oven (Esmade 1969). Neither method is very successful and both systems result in a very large mortality rate amongst the seeds; figures as low as 30% viability in batches of seeds have been noted (Brown 1921). More recent work by Eakle and Garcia (1977) have shown that a pre-sowing treatment of seeds using sulphuric, hydrochloric and nitric acids did nothing to hasten the germination rates in seeds of *A. moluccana*. These workers also postulated the presence of a germination inhibitor within the seed coat which needs to be leached out even after the seed coat has been ruptured.

Once seedlings have been established growth is rapid and they may attain a height of 1 m in the first year. Such seedlings are susceptible to frost damage which, in most unmanaged Chinese plantations, is discounted but where seedlings are raised in a nursery prior to field planting they need to be protected. A novel approach to this problem was carried out in America by Wu and Overcash (1969) where attempts were made to delay foliage development in seedlings of *A. fordii* in the second year by spraying with maleic hydrazide (MH), a known inhibitor of leaf development. Regrettably, these preliminary experiments failed to establish the concentration of MH necessary to inhibit vegetative growth without killing terminal buds and producing malformed leaves.

Chinese growers have known for some time that trees growing in close association with one another produce a higher yield of fruits when compared with trees that are growing as individuals. This phenomenon was noted by Hill (1966) in plantations of *A. montana* where the highest yields were obtained from trees planted at the closest spacings. This was later confirmed by Spurling and Spurling (1973) with the same species grown in Malawi who showed that a "great yield and marginal quality improvement" was obtained resulting from close planting. These authors also suggested that a closed canopy also suppressed weed growth thus saving on manual labour costs and on the use of herbicides; enhanced yields were also observed 15 years after planting. In order to explore the phenomenon of increased yields following close planting investigations were made by Phiri (1985) who conducted a large scale planting programme on *A.fordii* and *A. montana* also in Malawi. Trees were planted either in single rows where the inter tree spacing was 2.29 m and the inter row spacing was 4.57 m; double row hedges where the trees were spaced at 2.29 m but the hedgerows spaced 9.14 m apart or a three row hedge system where intertree spacing remained at 2.29 m but where the 3 row hedge was spaced 9.14 m apart. Each trial gave a tree population of 956, 785 and 964 trees ha respectively. The subsequent yield indices clearly showed a statistically significant increase in the single row hedge system with a concomitant ease of management factor over the other two systems.

Improvements in growth responses and oil production in *Aleurites* following the application of soil amendments has been noted by a number of workers in several countries. Trace elements such as boron and magnesium have had some beneficial effects (Merrill *et al* 1956) as have zinc (Webster 1950, Barrows and Gammon 1960, Forster 1962) manganese, iron and copper (Lagasse and Drosdoff 1948).

However, it is the application of the elements N, P and K that have had the most obvious effects on the growth characteristics of *Aleurites* trees. For instance potash has been shown to increase oil content and percentage kernel of trees in the USA (O'Rourke and Neff 1953, Sitton *et al* 1954, Merrill *et al* 1955) and it would appear that as trees mature and come into the fruit bearing stage the demand for potash increases (Neff *et al* 1953) though curiously the application of potash to young trees has had the effect of depressing growth. Potash has also been shown to hasten maturity of the fruit (Brown and Potter 1945, Neff *et al* 1953). More recent trials on potash application to *A. montana* in Malawi (Spurling and Spurling 1974) demonstrated little or no effect on yield, tree health or oil content.

Phosphate fertilizers had no effect on yield or tree health in Malawi in recent trials (Spurling and Spurling 1974) though previously Forster (1962) had shown a beneficial effect on yield when superphosphate was added in the presence of nitrogen. Other workers have also found little response to phosphate application except with young trees on deficient soils (Lagasse and Drosdoff 1948, Lagasse *et al* 1956) or on podzolic soils in Russia (Bagaturija 1963, 1968).

By far the greatest response of *Aleurites* trees to soil amendments is that seen following the application of nitrogen and Spurling and Spurling (1974) commenting on their own and other people's manurial trials concluded that nitrogen is the most important nutrient for *Aleurites* regardless of soil type and climate. In their experiments Spurling and Spurling (1974) grew trees at low populations of 125 to 175 trees per hectare and conventionally spaced and were provided with either a top dressing of ammonium sulphate or a mixture of farmyard manure, cotton seed cake and tung (*Aleurites*) nut cake. In all of many trials nitrogen at 0.25-0.30 kg nitrogen per tree gave a consistent response; tung cake was also shown to be a useful nitrogenous fertilizer and could replace ammonium sulphate at an application rate of 11 kg per tree; based on the projected slow release of nitrogen over a longer period of time. Another feature of nitrogen application observed by Spurling and Spurling (1974) was the significant reduction in dieback disease following regular dressings. Confirmatory work on the efficacy of nitrogenous fertilizers on the growth and yield of *A. fordii* and *A. montana* in Malawi was demonstrated by Phiri (1985) who showed that increased tree response levelled off after the addition of 105 kg of nitrogen per hectare.

Aleurites in the Antipodes

In the early decades of this century attempts were made to test the feasibility of growing *Aleurites* in New Zealand and Australia as commercially viable crops.

In New Zealand trials to grow *Aleurites fordii* on a systematic basis began in 1929 though seeds from China had been planted by individual growers on a haphazard basis for some years previously. The first trial from which recorded results were obtained was in 1929 when approximately 1000 seeds were grown at Northcote while at the same time 60 000 seeds, obtained from Florida, were sown in Helensville. Both trials gave impressive results indicating that *A. fordii* could be successfully grown in the North Island despite the strong prevailing winds.

Commercially established plantations were set up in 1932 and one such company, The New Zealand Tung Oil Corporation, was able to send seeds to other newly established plantations. By 1936 in excess of 5000 acres had been planted with *A. fordii* and an abundant harvest of fruit was obtained. Regrettably, despite a promising start to wood-oil planting in New Zealand the industry fell into decline for economic reasons and a recent communication from the New Zealand Ministry of Agriculture and Fisheries confirms, in 1986, that Tung oil trees are no longer grown commercially anywhere in New Zealand.

In Australia planting of *Aleurites* was also begun in the 1920's and Penfold and Morrison (1934), who first reported the successful acclimatisation of *A. fordii*, indicated that the most suitable sites for cultivation were on the east coast region north of Sydney including New South Wales and Queensland as far north as Cairns. They also commented that because of its ease of management, low demand for fertilizers and its resistance to serious diseases it should offer farmers a suitable crop for cultivation particularly as leguminous plants could be intercropped with the trees.

In Queensland a small plantation was established in 1927 and later larger plantations of 18 hectares were set up near Innisfail. The first analyses of wood-oil from the Queensland sites showed that the oil content compared favourably with oil from other countries.

The first trials with *A. fordii* in New South Wales were also set up in 1927 and figures obtained in 1938 from the International Institute of Agriculture suggested that all plantations were "in production and in good condition". Average yields were 18 kg of dried fruit per tree.

However, despite these promising early trials recent communications from the Department of Primary Industry in Queensland indicate that Tung oil trees are no longer grown commercially and only a small plantation of approximately 2 ha is known to exist and this does not produce oil. The story from New South Wales is similar and the Department of Agriculture there states that no Tung oil has been produced commercially since World War 2.

The reasons for the demise of the Tung oil industry in both New Zealand and Australia is difficult to explain particularly after early trials showed that an economically viable industry was possible. It may be that world demand can be met from other sources or substitute materials may have become commercially advantageous. In this respect it is of interest to note the statement of Franke and Richter (1971) who state that while there is no equivalent universal synthetic product to replace wood-oil it is being replaced by synthetics in some industries and thus they see no increased demand for wood-oil in the near future. They further caution that in order to maintain its position in world trade the wood-oil industry will need to concentrate on the breeding of more efficient varieties with increased oil yields and lower cost level per area of plantation. With these criteria in view it may be possible to increase the usable volume of tung oil on a world scale and in the future re-establish the industry as a viable concern.

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The case for multipurpose development of the versatile palms

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The mention of palm tree crops brings to mind row upon row of African oil palms on Malaysian plantations, oases of date palms in the deserts of the Near East, or extensive stands of coconut palms in the Philippines. In each case, one is apt to think only of a single commodity: palm oil, dates, coconut oil. Such impressions do an injustice to the importance of palms because there are more than 50 species yielding useful products and because all palms have multiple uses. Beyond the confines of the modern plantation, coconut and date palms are renowned for the hundreds of ways in which they can be used.

Natural stands of palms are of remarkable utility to local peoples, especially for the poor. Palms provide edible fruits, oilseeds, sap for beverages or sweeteners, palm hearts, stem starch, leaves for thatching and basketry, leaf midribs for fencing, wax for candles, trunk wood for construction, fuelwood, feed for livestock, and traditional medicines. About 20 wild palm species are exploited for commercial quantities of rattan canes, starch, seed oil, fibre, fruits, and wax. The value of these products is high. For example, annual commerce in products from native palms in Brazil amounts to over US$100 million, and trade in raw rattans in Southeast Asia is said to be worth more than $50 million per year. Gathering and processing wild palm products provide opportunities for local subsistence farmers to earn a cash income.

The tropical zone is the homeland of most of the world's approximately 2 700 species of palms. Through a combination of products from cultivated palms and wild trees, palms rank as the third most important plant family in the world. Only the grass and legume families surpass it.

Humans have been using palms of one kind or another since prehistoric times, but because palms do not occur throughout the tropical zones in the same numbers or diversity of species, use varies from continent to continent. Asia possesses the greatest number of palm species and also what appears to be the longest and most complicated pattern of utilization. The New World tropics rank second in species diversity, and though its native palms are used in many ways, the traditions are not nearly as long as in Asia. Africa, with comparatively few native species, ranks third, but the large populations of native oil and palmyra palms compensate for the lesser diversity.

Subsistence-level gathering of palm products has almost no adverse effects on native palms, unless rural human population densities are very high. Where these same products are commercialized, the effects vary according to the particular product. Overexploitation for palm hearts in southeastern Brazil and for rattans in Southeast Asia has reduced local populations of these palms. Tapping of palms for sap does not harm the tree providing it is not excessive. Likewise, the harvest of leaves for thatching, basketry, or cuticle wax is not detrimental if done with moderation. Collecting fruits for subsistence or commercial purposes presents no threat.

Special Status

Palms represent some of the oldest known domesticated tree crops. Both the coconut and date palms have been a part of cultivated fields and gardens since the dawn of agriculture, and over millennia have undergone genetic modification to such an extent that neither palm has ever been found in a truly wild state. Examination of palms within tropical production systems can provide a broad picture of their traditional roles, roles which must be understood and appreciated in designing more productive systems which are culturally and ecologically sensitive.

Where shifting cultivation is practised in the tropics, palms (and a few other useful tree species) are afforded special status. Forest clearing to plant annual crops often spares palms - partly because of their economic value and partly because palms are difficult to fell with an axe and cannot be girdled since their trunks have no bark. Palms also are tolerant of the burning of brush and trees necessary to clear a field for planting. There is evidence that as a result of being protected, palms enjoy an advantage over invading woody plants and increase their density and area. The babaçu palm forests of Brazil appear to have been spread by the action of shifting cultivators.

A few species of perennials are occasionally planted along with annual crops on shifting cultivation plots to provide a farmer with future supplies of fruit and other products. In the Amazon Basin the peach palm is one such tree. After having abandoned a field for annual crops because of competition from weeds and declining soil fertility, the farmer returns from time to time to harvest the trees. The planting of palms under these circumstances represents an important step toward ultimate plant domestication. In fact, this appears to have been what happened in the case of the peach palm.

Palms in the wild or informally cultivated by small farmers are more fully utilized for their products than those grown on modem plantations. For example, if a palm is felled for its trunk wood, the leaves will be used for some purpose and the palm heart extracted and eaten or fed to livestock.

Palms have several botanical characteristics not shared by other tree crops. The palm family is classified as belonging to the monocots, plants which produce a single seed leaf. Therefore, solitary palms have only a single growing point. A few species, such as the doum palm, produce aerial branches; some palms, such as the date, produce basal suckers; others, such as the açai, grow in clumps composed of independent plants. Solitary palms, like the coconut and African oil palms, are particularly vulnerable to damage to the growing point because it may result in the death of the entire tree. This growing tip, embedded deeply within the top of the trunk, is the tender edible bud which is processed into hearts of palm.

Because of their growth habit, palms cannot be pruned to maintain a low stature. As a result, spraying for disease or insect control, and fruit or leaf harvest, become more difficult as the tree reaches its full stature. A mature coconut palm reaches over 20 metres. At one time in Malaysia, there was an attempt to train pigtailed monkeys to pick ripe nuts from tall coconut palms. A more workable alternative has been to cultivate dwarf coconut varieties which begin to fruit when under one metre in height.

Ancient Practice

Under cultivation, palms can be grown at a closer spacing than most other tree crops because they have a compact crown and do not branch and spread. The fact that more light is able to penetrate the tree canopy permits intercropping of annual and other perennial crops, or pasturing livestock on natural or planted grasses beneath the trees. Palms are particularly well-suited to the multiple cropping systems so common among small farmers; they provide a measure of environmental stability and at the same time are a ready source of numerous useful products the farmer needs.

Although most palms bear male and female flowers on the same tree, several species are dioecious, bearing male and female flowers on different trees. The date and palmyra palms exhibit this characteristic, which is both a disadvantage and an advantage. To assure maximum fruit yield when cultivating dioecious palms, it is necessary to provide an adequate number of male palms in a field. Alternatively, one can plant only female trees and pollinate them artificially with pollen collected from superior male trees. This is an ancient practice of date growers and one which is standard procedure on modem date plantations.

Terminal flowering, a rare growth habit among woody perennials wherein a tree flowers but once in its life and then dies, is another notable characteristic of certain palms. The sugar palm of Southeast Asia is an example. It is tapped for its sugary sap and often felled before the onset of flowering to extract the starch which has accumulated in the trunk for that purpose. The need to replant this solitary palm about every 10 years is a disadvantage. The sago palm too is terminal flowering and contains appreciable amounts of starch in the trunk, but since it produces basal suckers the dead trunk is replaced naturally within a few years.

The impressive increases in grain crop yields that resulted in the green revolution and the outstanding success of the African oil palm, which has become a major plantation crop within recent decades, were two key factors which prompted agricultural and rural development planners to assess the economic potential of palms in the tropics. Palms, along with certain other tree crops, were recognized as ideally suited to the intensive cropping systems of small farmers and as contributing to environmental stability. The latter is of particular concern, since so many small farmers occupy marginal lands prone to erosion. Contributing also to the interest in palms was the fact that a number of species were already being grown by small farmers and showed good potential for yield improvement.

Rather than a single programme to study underdeveloped palms, the modern trend has been to create small programmes for individual species. This has the advantage of being more feasible at the national level and permits a research design which takes into account local social, economic, and ecological conditions. However, it does result in costly duplication of basic research in such areas as propagation, insect pests, and disease control. Influencing palm research focussed on individual species were the precedents of separate coconut development programmes in the Philippines and Sri Lanka, a date research centre in the western United States (now closed), and the more recent African oil palm research programme in Malaysia.

Data Incomplete

To gain an idea of the scope of modern palm development, examples can be cited from the Americas, Africa, South Asia, and Southeast Asia. In each of these examples, one or more products have been commercialized to some degree. Although development programmes have focussed on improving the quantity and quality of the major commodities, they have not overlooked the secondary products of the respective palms. As will be evident in the following discussion, the data on production and the area occupied by these underdeveloped species are incomplete.

The babaçu palm covers nearly 200 000 km2 in the northern half of Brazil and occurs in almost pure stands. Its fruits have long been a source of edible oil, starch, and fuel; the leaves make excellent thatch and the trunk furnishes wood and palm heart. In the 1910s, the babaçu industry began with extraction of oil at local factories and the export of kernels. Over the years there have been sporadic attempts to modernize the industry to include mechanical shelling of the extremely hard nut and to extract oil and starch from the fruit and produce charcoal from the hard shell by an integrated process. Since 1980, new factories have been built and the Brazilian Government has created a special programme for the babaçu. In addition to industrial processing, research is under way to design management techniques applicable to the natural stands; these include annual cropping and integrated livestock grazing. Studies are also being done to identify superior planting material for the plantation cultivation of this palm. It is estimated that more than two million people derive part of their income from collecting and cracking babaçu nuts and making charcoal from the shells. Since the natural supply of the nuts is not fully utilized, the modernization of the industry will provide additional opportunities for small farmers. Brazilian production of babaçu kernels exceeds 250 000 tons each year.

Occurring in great numbers in the lower Amazon is the açai palm. A clumping palm sometimes planted as an ornamental, it furnishes excellent palm hearts and fruit for a popular local beverage and has some potential as a cellulose source. A sizable work force is needed to cut the palms in the forest, extract the hearts, and transport them to local factories for processing and canning. This palm heart industry - the largest in the world - is centred in the lower Amazon. Brazilian production is about 115 000 tons per year, going to domestic and export markets. Fruit production is 55 000 tons per year. Since as many as 25 palms may constitute a single clump, each one at a different stage of development, cutting the largest stems for palm hearts is not detrimental.

The açai is an ideal species for permanent exploitation. Government agencies in Belem are doing studies to determine optimal utilization practices for this palm and to assure a continuing supply of its products. There is good potential for small farmers to begin to cultivate this palm.

Dual Programme

A third promising species of tropical America is the peach palm. Unknown in the wild, this palm has been cultivated for hundreds of years in the humid lowlands of Central and South America. The cooked pulp of the fruit is eaten and is a good source of carbohydrate, protein, and vitamin A. Flour can be made from the dried pulp and oil extracted from the pulp and seed. The palm is being successfully cultivated in Costa Rica for palm hearts. A dual programme is underway in Costa Rica and the Brazilian Amazon to develop the peach palm into a source of high-quality protein. Since small farmers have traditionally cultivated the palm, they are in a position to benefit directly from having available improved planting material.

In Africa, despite the limited diversity, there is some interest in the potential of native species of *Hyphaene*. The doum palm of North Africa is an ancient tree crop cultivated for its edible fruit and a host of other products. It is said to be planted along river banks in northern Kenya. In South Africa, resource planners are trying to determine how the ivory nut palm can be managed to sustain the palm wine industry of Maputaland. Currently almost a million litres of palm wine are produced there each year, most of it from the ivory nut palm. This palm takes its common name from the fact that the hard seed can be carved into buttons, trinkets, and other objects.

The palmyra of South Asia is an example of a palm with a very long history of multiple use. The chief product is the sap, which is made into sugar or fermented into the popular palm toddy. Toddy is also distilled to produce spirits. This palm is abundant in India, where it is often planted. The fruit, palm heart, and fleshy first juvenile leaf are all eaten. A stiff fibre extracted from the leaf stalk is a commercial product entering world trade. Outdated statistics place annual fibre exports at 4 000 tonnes. FAQ sponsored a workshop on the palmyra palm in 1983 and published a summary of its potential for improvement (Kovoor 1983). The palmyra is another tree crop typically grown by small farmers.

The climbing rattans of Southeast Asia, species of *Calamus* and *Daemonorops,* have wide utility for construction and basket making, apart from their commercial use in furniture manufacture. These palms also bear edible fruit and palm hearts and play a role in traditional medicine. Most rattans are still cut in the wild. However, they are already being cultivated on a small scale throughout the region. In the mid-1970's, rattan trade amounted to about 46 000 tonnes, with Indonesia providing some 90 per cent of the total. In the past few years, there has been a rattan workshop, publication of a book on the subject (Dransfield 1979) and a Rattan Information Centre acting as a stimulus to the rattan industry and holds promise for small farmers to grown rattans commercially.

A final underdeveloped species is the sago palm, a swamp tree of Southeast Asia and a traditional and commercial source of sago starch. In addition to an edible and industrial starch, this palm also furnishes leaves for thatching and making baskets, leaf stalks, and the outer layer of the trunk for construction and palm hearts. Natural sago stands have been estimated to cover two million hectares, and an additional 200 000 hectares are under cultivation. The high level of interest in this palm is evidenced by three international symposia and an FAQ workshop on the sago since 1976 (Flach 1983). Development of sago swamps without significant modification of the environment is in line with contemporary approaches to resource management. Like the other palms discussed here, sago development can directly benefit small farmers.

Revolutionary process

The multiple product approach being pursued for underdeveloped palms has had a feedback effect in terms of the major commercial palm tree crops. At the FAQ Palm and Dates Research Centre in Baghdad, research is being carried out on a number of secondary products from the date fruit as well as on utilization of other parts of the palm. The Philippine Coconut Research and Development Foundation and the Coconut Research Institute in Sri Lanka are both actively investigating broader use of coconuts and the other trees, when replacement becomes necessary.

On the industrial side, the integrated processing of coconuts, rather than making copra for oil extraction, will revolutionize the coconut industry and directly benefit producers, most of whom are small farmers. A major effort is under way in Southeast Asia and the Pacific Islands to produce coconut wood from palms which must be replaced. Aiding in all aspects of coconut development is the Coconut Information Centre in Sri Lanka.

Thus far, there has been almost no interest on the part of African oil palm plantation operators to utilize the other products of the palm. Fruit branches, pruned leaves and oilseed processing residues are used as green manure in the fields, but the practice of burning palms that have been removed has precluded other uses. Burning is done to control diseases and insect pests. Some recent research findings indicate that the practice may not be necessary, which could broaden possibilities. In West Africa, where these oil palms occur naturally, they are tapped for palm wine and the leaves and trunks utilized.

Currently, there is insufficient recognition of the multipurpose potential of either cultivated or wild palms. Development of palms can increase the commercial output and industrial uses of the major commodities and at the same time assure sustainable subsistence use of palm products by small farmers. Because palms are highly adaptable multipurpose trees, their rational valorization can fulfil a combination of commercial and subsistence needs.

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Further information on palms may be found in:
Jones, D. (1984). Palms in Australia. Reed Books Pty. Ltd.,Frenchs Forest, NSW and by contacting:

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Wind shelter is essential for horticultural production

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Introduction

Unfortunately the need for effective wind shelter is not recognized by many horticulturists in Western Australia (WA). It is however essential, for as the value of a crop increases, so too does the need to have unblemished fruit and unstressed plants. Reasonable wind shelter is provided without question for sensitive crops such as pipfruit, stone fruit and berry fruit, in other countries. The productivity of many other crops however, will also benefit from effective shelter.

One of the first operations of any prospective horticulturist should be the planting of wind shelter. Any new horticultural business really needs to establish wind shelter at least 2 years before the planting of the main crop. To be of value, an effective shelter belt must more than compensate for both the production lost from the space occupied by the shelter, and the cost of establishing and maintaining that shelter.

The Need for Shelter

Direct damage:

Mechanical damage done to the stems, leaves, flowers or fruit is the most significant in terms of growth and yield reduction, and of lowering produce quality. In addition to the up-rooting of plants and limb breakage, continual abrasion decreases fruit size and increases the incidence of russeting (fruit scarring) and disease. The life of polythene structures (eg. tunnel houses) is also prolonged by reducing wind, and overcoming the abrasion which occurs where the film is in contact with the supports.

Indirect damage:

Wind not only increases the loss of water from the soil necessitating more frequent irrigation, but because the plant is placed under moisture stress, the stomata (leaf breathing holes) close and the rate of photosynthesis is lowered, reducing plant growth and subsequent yields.

In areas like south-west WA, low temperatures during blossoming retard bud growth and restrict the growth of the pollen tube, preventing fertilization. Also, cool winds reduce bee activity, as they prefer to work in warm conditions, and will travel further in light winds. The warmer conditions created by adequate shelter prolong the growing season, and crops are often earlier. There are potential fuel savings for heated glasshouses if they are suitably sheltered, however in summer the lack of cooling wind may make the glasshouse too hot.

Suitable shelter can greatly reduce both wind and water erosion. Sprinkler irrigation is more effective, and the efficiency and time available for spraying is increased. Aesthetically, a well sheltered block provides a more pleasant working environment. A mixed shelter belt may also provide food for honey bees during periods when the crop is not flowering, and provide sanctuary for predacious birds and insects.

*Disadvantages***.**
Too thick a shelter in this climate may cause heat stress to crop plants in mid-summer. Also insect pests can harbour in the trees, and in a few instances, the shelter could become an alternate host for crop diseases. A living shelter (trees) will compete with the crop for water and nutrients, although this can be controlled to a certain extent. However, as Fig. 1 shows, the benefits usually outweigh this root competition. The cost of establishment and maintenance must also be considered. The benefits of wind shelter however, more than compensate for any of these disadvantages.

Shelter Dimensions
A good shelter belt requires adequate height, permeability and length. Wind reduction is directly proportional to the height of the shelter belt. A shelter belt deflects the wind upwards, causing a reduction of windspeed on the leeward side. The original windspeed develops again at a distance of about 30-40 times the height of the belt (Figs. 2 and 3).

Good wind shelter is provided up to 10-15 times the height. This is the best figure to use in estimating the protected area. For example, a shelter belt 10 m high will give wind protection for between 100 and 150 m from the belt, depending upon the susceptibility of the crop.The length of the shelter belt is important in maintaining a reasonable degree of shelter when the wind veers from its normal direction. Wind speed actually increases around the ends of the shelter belt (Fig. 4).

A shelter belt needs to act as a wind filter, not as a barrier, if the belt is too dense, a low pressure area is created in the lee of the belt, which drags the wind-flow down as it is passing over the belt (Fig. 5). In WA a relatively high permeability is needed to offset the effects of high summer temperatures. I would suggest that a permeability of 50-70% should give efficient wind shelter and sufficient summer cooling. That is, when you stand near the belt and look through it, you should be able to see 50-70% sky.

Shelter Planting
The desired shelter belt density can be obtained by tree spacing. This varies with the species of tree used. A low density species (eg. *Casuarina equisetifolia*) might require 1-1.5 m within the row, whereas a denser species (*C. obesa*) might be better at 2-2.5 m within the row. These spacings will also vary depending upon how many rows of trees are planted in each belt. The more rows, the larger the in-row spacings should be.

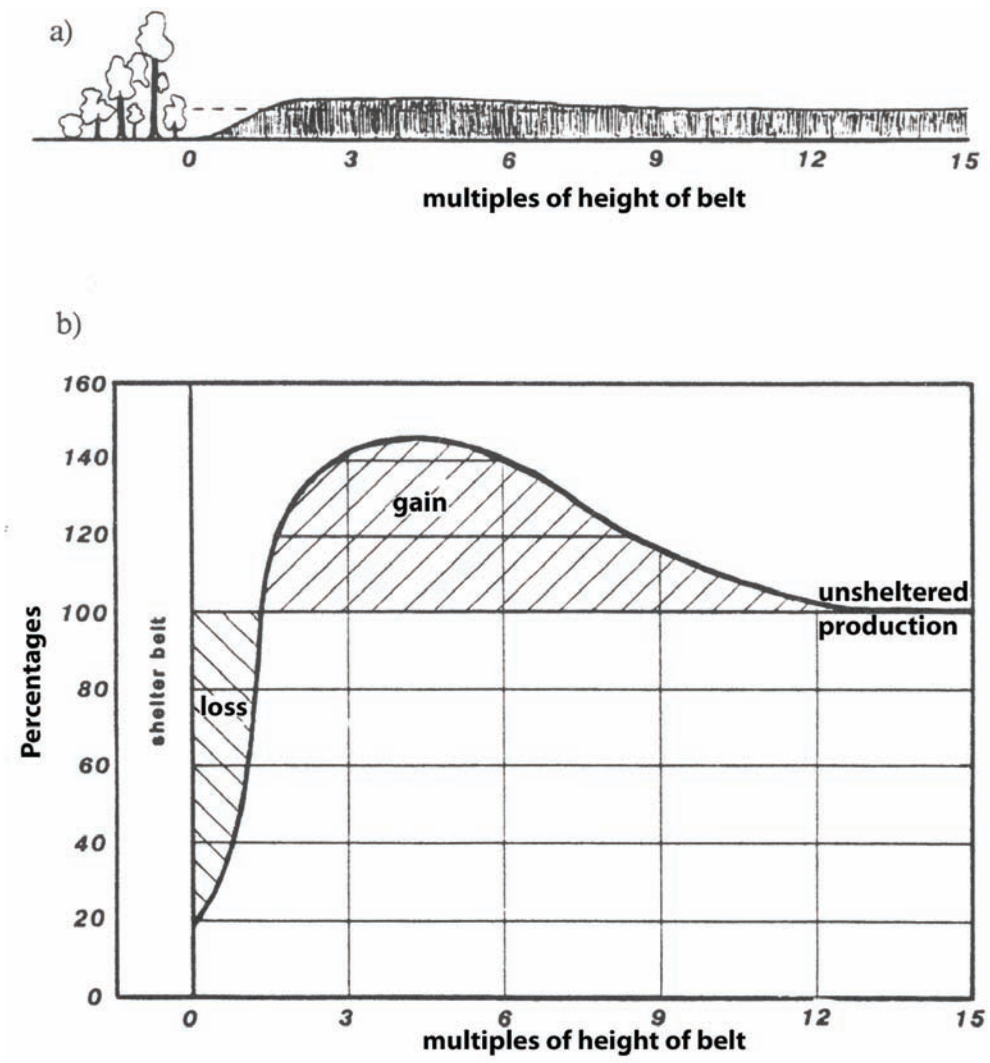


Fig. 1 a) Cross section through shelter belt and crop.

b) Percentage loss and gain in production for wheat.

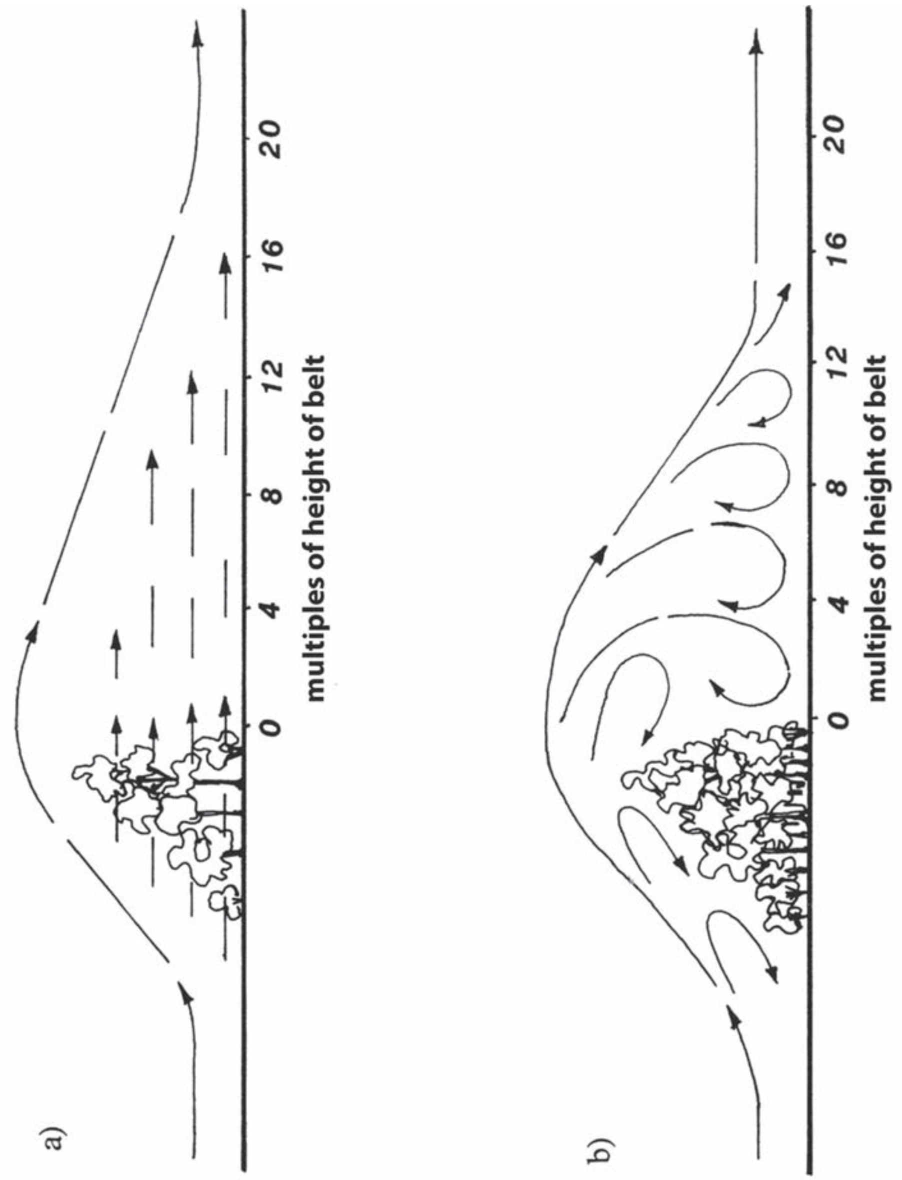


Fig. 2. Wind flow over a) a moderately penetrable shelter belt and b) a dense shelter belt.

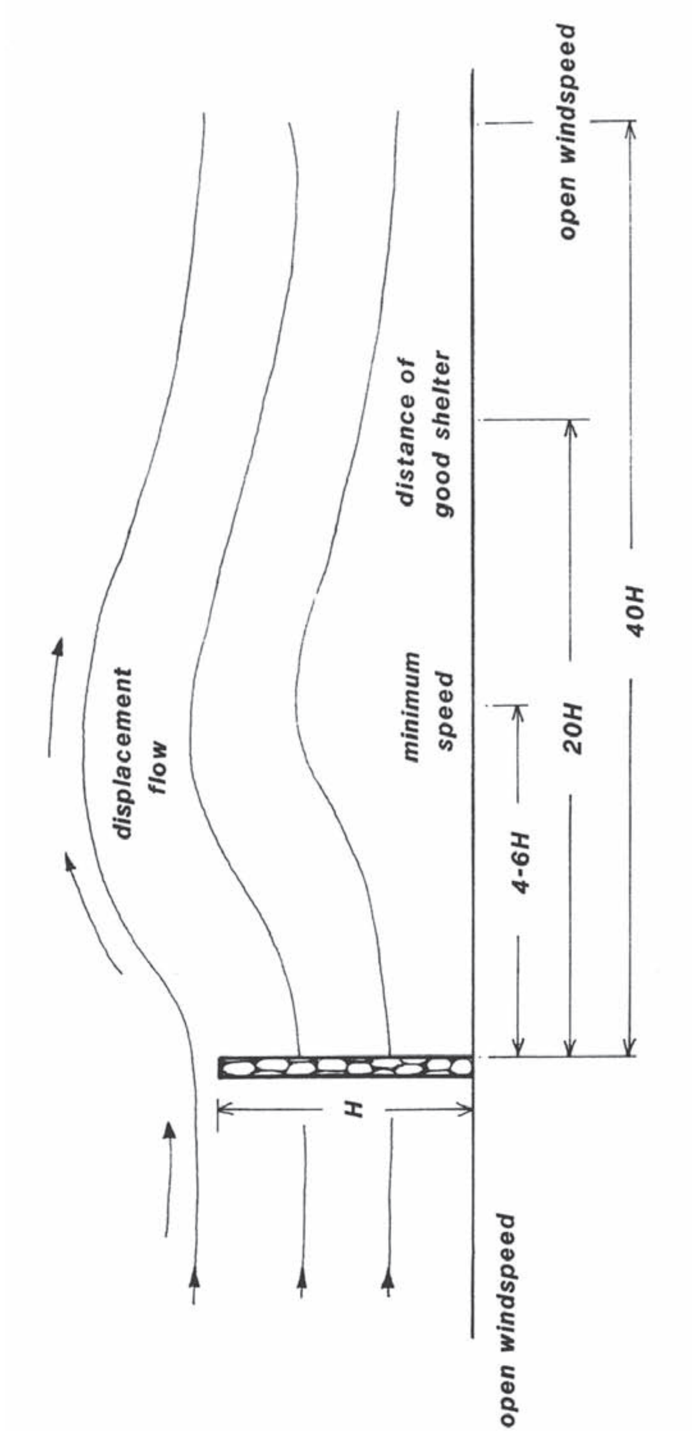


Fig. 3 Wind flow over a permeable barrier.

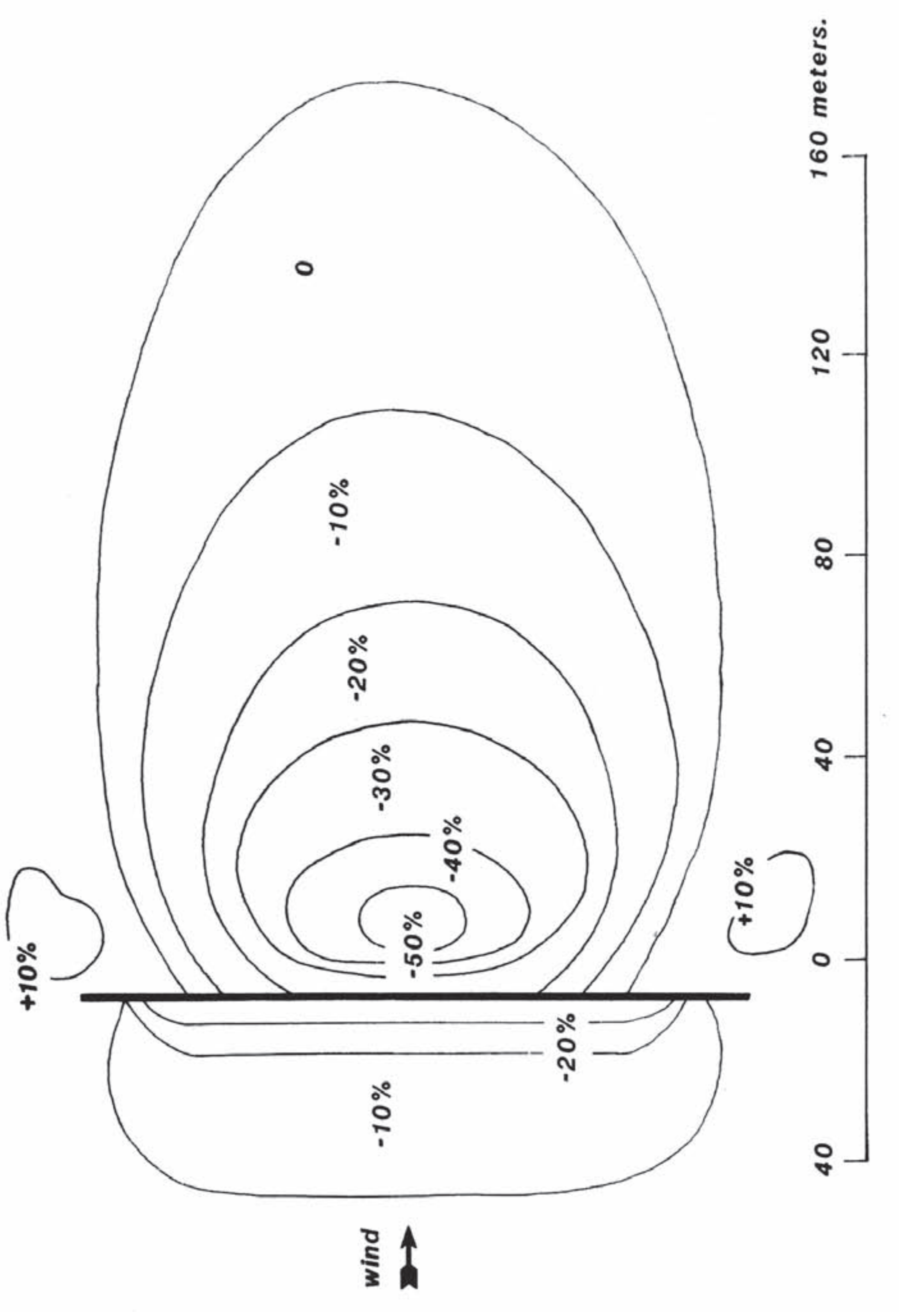


Fig. 4 Reduction of wind by a shelter belt 4.6 m high. Readings were taken 3.7 m above the ground.

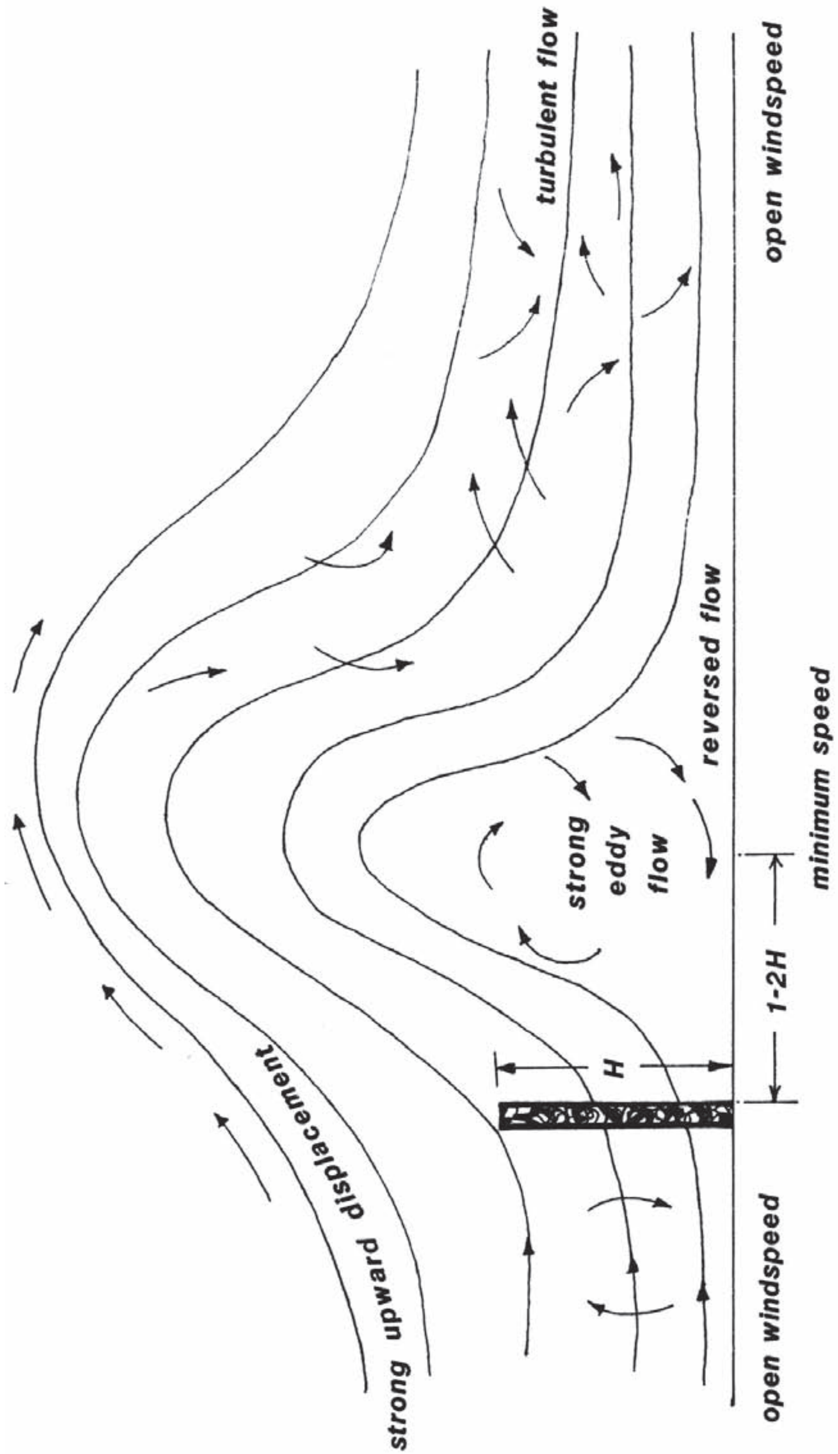


Fig. 5 Wind flow over a dense barrier.

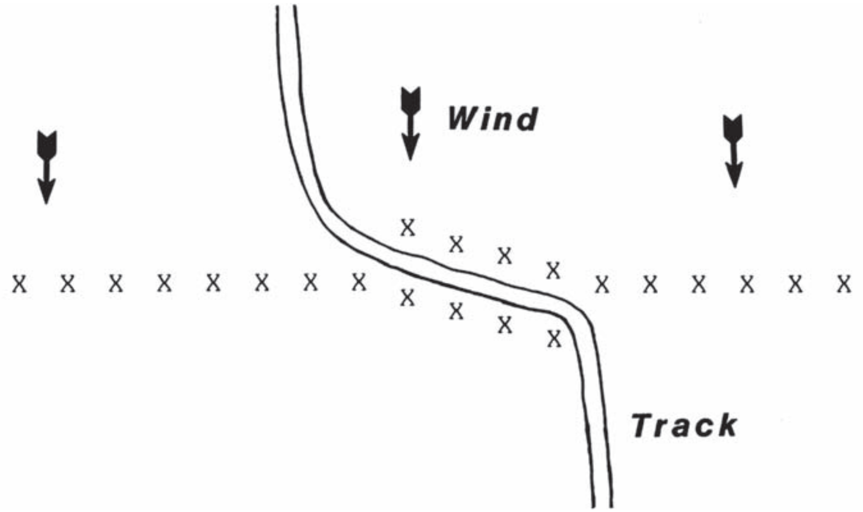
Multiple row plantings should also use an alternate planting pattern:

X X X X
 X X X

X X X X
 X X X
X X X X

The spacing between rows again varies with the tree species, however, commonly 2 m is left between the rows.

The shelter must be continuous, that is, do not leave large gaps in the belt, as these will become wind funnels, creating a venturi effect (speeding up the wind). If a gap must be left in a belt for say, vehicles, one design that might help is:



Tree species is another factor which varies from one region to another. For southwest WA however, the best all-round wind shelter tree seems to be the *Casuarina*. It is hardy, resistant to almost all pests and diseases (including weevils), is evergreen, and is a native to this region. Several species of this tree are suitable: *Casuarina cunninghamiana* (Sheoak), a dense tree; *C. obesa* (Swamp Oak), a medium density tree; and *C. equisetifolia* (Horse-tail tree), a low density species. Also, *Alnus glutinosa* or *A. cordata* (Alder) are worth considering, particularly for damp sites. *Cryptomeria*, some *Eucalyptus*, and possibly *Populus* and *Salix* are types worth looking at also.

Fencing around shelter trees is essential where there is stock nearby. At no stage should stock have access to shelter belts. To prevent stock from eating out the growing points of young trees, the minimum distance from a fence to a row of trees should be 2 - 2.5 m.

In heavy soils, deep ripping along the tree lines before planting is necessary for good establishment, and subsequent growth. Also controlling weeds in a 0.5 m circle around each tree for a least the first two years should ensure survival. Irrigation and even fertilizer applications will give uniform and rapid establishment of your shelter, which in turn will give quicker and more effective shelter for your crop establishment. Finally, when planting, check the location of any above or below ground power, water or telephone lines.

Artificial Shelter

Sometimes shelter belts are constructed out of artificial materials similar to shade cloth. Where root competition, shading or lack of space are a problem, such materials are often used. Artificial shelter has been used in horticulture for many years, but some doubt about its efficiency, as compared with trees, has recently been raised in New Zealand. This material is ideal for restrictive situations, but is much more expensive than living shelter. One type 'Paraweb', is a particularly tough and long-lasting material, but even some shade cloths can be used. Artificial shelter must still have a 50-70% permeability. Remember however, when using shade cloth, that the rating given to these materials refers to their sunshading, not wind-sheltering ability. So the only grade suitable for wind protection is a 32% cloth grade.

Whichever type of shelter is chosen for horticultural crops, the extra costs and effort involved are far outweighed by the advantages obtained.

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