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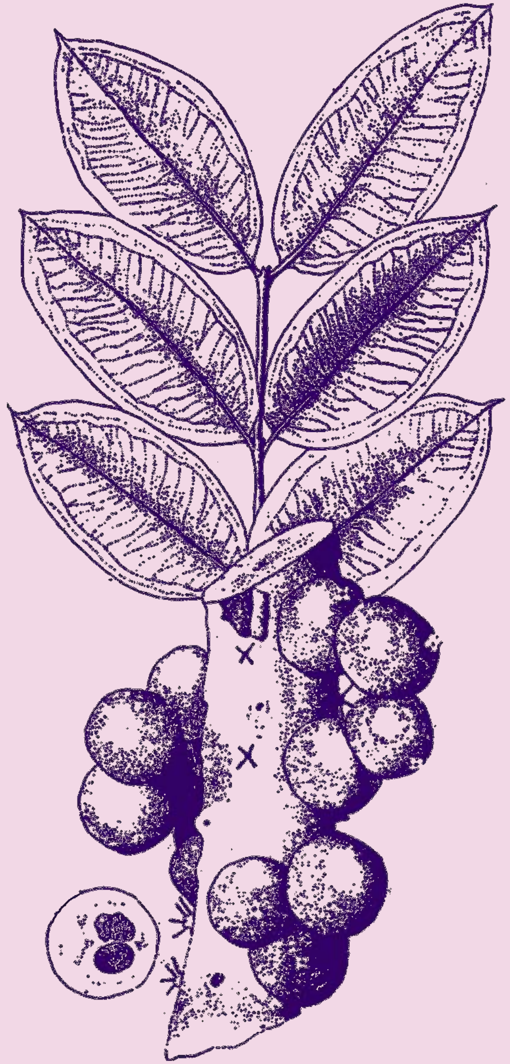

The Jaboticaba, *Myrciaria cauliflora* **(see page 61)**

West Australian Nut and Tree Crop Association (Inc.)

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ZIZIPHUS: A TREE CROP FOR ARID AND SEMI-ARID CONDITIONS

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The genus *Zizyphus* was first mentioned and described by Tournefort in 1735, though many authorities since that time use the generic spelling *Ziziphus* after Miller's use of the epithet in his Gardening Dictionary of 1754; the latter spelling will be used throughout this paper though it should be noted that both spellings are synonymous.

The genus comprises some 100 species (Willis 1973) though more recently Mabberley (1987) mentions only 86 while Tanaka (1976) lists 32 species producing edible fruit or edible products. Commonly called Indian Jujube or Chinese Date, the genus belongs to the family Rhamnaceae and all known species are confined to tropical, or at least warm, climates and are well adapted to growth in arid or semi-arid conditions (Singh and Tomer, 1988).

Various species have a very long historical association with civilized man. For instance, *Z. spina-cristi* L. was probably the plant used to fashion Christ's crown of thorns; the Chinese have cultivated jujube fruit for at least 4000 years and it still plays an important role in their nutrition; the Indian Ber, *Z. mauritiana*, is both an important fruit in India and Assam, and a source of tannin in Burma and Malaya, where its use has been recorded for centuries; *Z. jujuba* was brought from Syria to Rome by the consul Sextus Papinius towards the end of the reign of Augustus Caesar and has thus been cultivated in southern Europe for at least 2000 years (Popenoe, 1974); and finally, *Z. lotus* (L.) Willd. was probably the much written about *lotus* fruit of ancient civilizations.

As with many plants that are used as a source of food human, exploitation and cross breeding programmes to produce high yielding cultivars have resulted in widespread confusion in the nomenclature; some well established species being referred to differently in various localities, while similar common names often refer to more than one species. In this paper only a few of the commonly used species are described, and where possible the most recent epithet is provided along with the authority.

In a survey of the literature it is evident that *Z. mauritiana* and *Z. jujuba* are by far the most commonly cited species, as they both serve as sources of edible fruit as well as a large number of important biochemicals many of which have important pharmacological uses; other species have a more restricted sphere of influence, though some are growing in importance as sources of unusual byproducts.

Even in recent literature, confusion still exists between the correct naming of the two most common species, and perhaps the easiest method of distinguishing them is on their geographical location and tolerance to differing climatic conditions. Basically, the ‘Indian jujube’, or ber, (*Z. mauritiana*) is an evergreen tropical species commonly grown in India, while *Z. jujuba* , the ‘Chinese jujube’, is a mediterranean, deciduous species which can tolerate a temperature range from -6°C to 48°C and a rainfall range from 125 mm to over 2000 mm (Goor and Barney, 1968). Because of its wide tolerance of climatic conditions *Z. jujuba* is now grown commercially in many regions of the USA (Lyrene, 1979). Another difference between the two species has been reported by Salunkhe and Desai (1984) who suggest that though morphological differences are minimal, the sugar content of *Z. jujuba* is higher than that of *Z. mauritiana*. It has been suggested that in Assam both species coexist (Dutta, 1954) which raises the interesting possibility of natural hybridization.

BER

The full botanical description of Ber is: *Ziziphus mauritiana* Lam., 1789, Encycl. Meth. Bot. III, 319. (Syns: *Z. jujuba* Lam., 1789, Encycl. Meth. Bot. III, 318; not Mill.; *Z. orthacantha,* DC.” 1825, Prodr. II, 21; *Z. rotundata*, DC., 1825, Prodr. II, 21)

Watt (1908) refers to the Indian Ber (though he incorrectly names it *Z. jujuba*) as one of the most commonly found fruit trees of the villages of western India and states it to be:

“distinctly wild in the forests of the Siwaliks and Sub-Himalayan tracts of the Panjab and United Provinces, and also in the Deccan and in Upper Burma and Ceylon in dry forests. Elsewhere mostly cultivated or run wild”

The tree has been described by many authors, one of the simplest descriptions being provided by Bourke (1976):

“It is a naturally thorny shrub or tree, of variable habit, ranging in height from about 2.5 to 15 m (8-48 ft). It may ramify from the base and develops a deep tap root. The leaves are alternate, distichous, elliptical, entire or slightly toothed. distinctly-veined, green and glabrous on the upper surface but cottony and pubescent on the under surface. They are shed, at least in part, during the dry season.

The flowers, arising in the leaf axils, are small and greenish. The fruit is an ovoid drupe. Its colour may vary from yellowish to red or brown. It is about the size of a small cherry on wild plants but may be the size of a plum on improved varieties.

The edible pulp is thin and sweetish. The stone is very hard and encloses a single kernel. Improved varieties tend to be taller, to have larger leaves and fruits, but smaller thorns than wild plants. Their fruit shape is also more variable. At least one cultivar has been described as thornless.”

There are many cultivars grown in India and Singh, Bakhshi and Singh (1972) have attempted to distinguish the 40 established cultivars on individual fruit characters. Based on fruit shape and type of apex the cultivars were classified into 8 sections which, it was thought, would help horticulturalists to select the most suitable varieties for specific areas.

Agronomy

Being a tree crop of some considerable importance, it is not surprising that a great deal of effort has been made to investigate various aspects of *Ziziphus* agronomy, much of which has been centred on the Indian subcontinent.

For example, a comprehensive survey of propagation techniques used in this genus has been provided by Bourke (1976) who showed that the tree could be propagated by seed, budding and grafting and by layering and cuttings. He concluded that “the ease with which *Z. mauritiana* can adapt itself to tropical conditions unsuitable for other fruit trees ensures that the cultivation of improved varieties is likely to continue to expand”. The author notes, however, that “to-date no work appears to have been carried out on the selection of seeded or clonal rootstocks”. Air-layering of ber has been shown to be very successful when cut shoots are treated with either IBA or NAA (Chatterjee and Rao, 1978; Ughreja and Chauhan, 1983), while bare-rooted transplanting of ber was considered to be a ‘horticultural breakthrough’ by Sandhu and Dhillon (1982).

The seeds of *Z. mauritiana* have a low level of viability, sometimes as low as 30% (Singh, 1964), and thus considerable effort has gone into studies concerning the possible enhancement of germination levels. Under normal horticultural practice, ripe seeds are floated in 17-18 % brine solution and those that float are discarded as being non-viable. The remaining seeds are cracked to remove the shell and the kernel alone is sown; the removal of the endocarp is said to decrease the time needed for germination from four weeks to one. Some enhanced levels of germination were reported by Shanmugavelu (1964) following the application of giberellic acid to seeds.

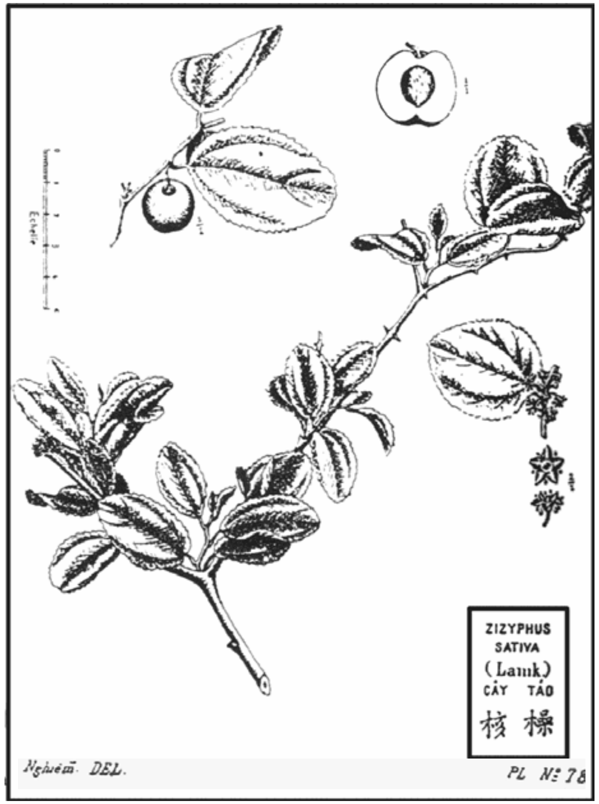
The level of soil salinity plays an important role in natural seed germination, and Dhankhar et al (1980) showed that germination was delayed with an increase in salinity levels. Similar work by Dahiya et al (1981) and Mehta (1982) showed that in combination with high levels of salinity, high Boron concentrations also delayed germination. Increased germination levels were obtained by Bisla et al (1984) when seeds were grown in soil containing high levels of organic manures; the later addition of urea was also shown to enhance seedling growth.

In nursery practice, well established seedlings, preferably grown from seeds taken from wild species, serve only as rootstocks and these are often cut back to ground level if seedling growth has been delayed or retarded, so that budding is performed on the strongest of the next season’s sprouts. It is possible to obtain over 90% success rate in budding if conditions of growth are favourable (Singhrot and Makhija, 1979; Singh et al, 1982; Kajal and Singhrot, 1986).

Pruning is an important factor in obtaining high yields of fruit, and a number of reports refer to the various methods used and the results obtained. In some districts naturally occurring stands (especially the ‘wild’ species Z. *rotundifolia*) are topworked to obtain strongly growing stocks onto which buds from *Z. mauritiana* are grafted (Kashyap et aI1984). Plantations of *Z. mauritiana* are regularly pruned to obtain increases in fruit yield (Singh et al1978; Lal and Prasad, 1979; Yadev and Godara, 1987; Lal and Prasad, 1980a) and, in general, pruning to leave shoots 90 cm long proved most effective in producing abundant flowers, through shoots pruned to 120 cm produced the largest and highest yield of fruit (Lal and Prasad, 1980b, 1980c).

Similar results were obtained by Zora Singh and Sandhu (1984) who showed that, additionally, the actual timing of pruning had a significant effect on fruit size quality, the optimum period for pruning being mid- May to mid-June. Another parameter, that of planting distance between trees, was investigated by Yadev and Godara (1987) who showed that the pulp:stone ratio and ascorbic acid content of fruit increased with an increase in pruning severity and planting distance. They suggested that for optimum tree performance, medium to hard pruning and planting at either 7.2 x 7.2 or 9.6 x 9.6 m are recommended.

This result is in direct contrast to those published by Bajwa et al (1987) who showed that the severity of pruning had no effect on pulp percentage, and similarly heavy pruning decreased the vitamin C content as well as the fruit's acidity. The differences cannot be explained by differences in fruit variety, as both sets of workers were using the same cultivar, viz. cv 'Umran', but may be explained by differences in climatic zones, the latter group working in the Punjab and the former in Hissar.



Ziziphus jujuba,from an older French book

The genus *Ziziphus* is a plant of arid or semi-arid regions (Kalla et al, 1986) and its commercial exploitation, programmed to yield heavy fruit crops, depends to a great extent on the introduction of efficient irrigation systems and on measures taken by farmers to reduce run-off and conserve water in the soil profile (Pareek et al, 1978).

Another important factor determining successful fruit production under dryland conditions is the degree of slope of the ground which, in turn, determines the extent of run-off.

Sharma et al (1982) have shown that at Jodhpur in Rajasthan, slope-length of the ground reduces the ability of catchment areas to concentrate run-off water, whereas the degree of slope increases water accumulation. They recommend specific catchment/planted area ratios to increase fruit yield under their system of cultivation. Such measures to conserve water becomes critical in arid areas where the annual rainfall varies between 300 and 450 mm and where the soil is composed of 80-90% sand with very low levels of organic matter (Yamdagni et al, 1985).

Microcatchment systems are also of prime importance. For instance, Sharma et al (1986) demonstrated that microcatchments having different combinations of slopes, slope lengths, and contributing areas, aimed at generating run-off supplements of 0 to 400 mm, resulted in a significant increase in run-off and soil moisture storage with increasing slope and decreasing slope length, and these figures were mirrored in the yield and fruit characteristics. Yield, it was argued, was directly correlated to available soil moisture storage. An important corollary to their findings was the fact that, over a seven year period, the formation of a nearly impervious soil crust over the microcatchment area resulted in a 50% reduction in threshold rainfall and a concomitant doubling of the run-off efficiency.

As with many commercial fruit crops, increases in yield have been achieved following the application of growth promoting substances; and the discovery of endogenous cytokinins (Ghosh et aI, 1981) and endogenous gibberellins (Ghosh et al, 1985) in developing fruit stimulated the use of these and other chemicals to enhance fruit production.

For example, Singh and Singh (1976) showed that while NAA, 2,4-D and MENA (a methyl ester of naphthalene acetic acid) failed to reduce fruit fall, 'fenoprop' (2,4,5, TP) significantly reduced fruit fall and resulted in increased fruit size accompanied by increases in their total soluble solids (TSS). Rajput and Singh (1977) showed that trees sprayed with urea just prior to flowering significantly increased the levels of sugars, vitamin C and protein in developing fruits; Patel and Patel, (1979) investigated the effect of GA, 'chlormequat' and 'ephethon' on flowering and fruit set; Singh et al (1982) showed that GA3 increased fruit length, diameter and weight; Rajput and Singh (1982) demonstrated increased yields following treatment with GA3 and NAA; Bal et al (1984) were able to control fruit drop following the application of NAA or 2, 4, 5- T and also that developing fruits were heavier with a high level of TSS.

Fruit and Post Harvest Physiology

Trees bear fruit 3 years after planting, but are harvested only after the 4th season crop. In Northern India the peak season is March/April though some varieties ripen earlier. The fruit reaches markets at a time of the year when other fruits are scarce and are thus an excellent cash crop. The fruits are said to be highly nutritious and are much valued by consumers. Jawanda and Bal (1978) refer to the composition of fruit as follows:

"Depending upon variety, the fruit pulp may contain 13.0 to 20.0% total soluble solids (TSS) and 0.20-0.80% acidity at fully ripe stage. In vitamin-C content, it ranks second to aonia and guava only, containing 70-165 mg ascorbic acid per 100 g of pulp, which is much higher than the vitamin C content of *citrus* fruits, the well-known potent source of this vitamin. Ber fruit is also very rich in vitamin A, containing nearly 80 g of beta-carotene per 100 g of fruit. The fully ripe ber fruit contains 0.9% protein and 12.8% carbohydrates, the highest levels found in fruits. The reducing sugars and total sugars are also quite high and amount to 3.1 % and 10.0% respectively. In mineral contents of calcium, phosphorus and iron, ber fruits excel even apples and oranges."

More specifically Khera and Singh (1976) had previously shown variations in protein, sugar, and ascorbic acid content of seven established cultivars, while Rajput and Tayant Singh (1977) had noted changes in the chemical composition of fruits following foliar spraying with urea, and demonstrated increases in total solids, sugars, vitamin and pectic substrates with a concomitant decrease in fruit acidity.

The ascorbic acid content of ber during growth and maturity has been investigated by Bal and Mann (1978) who demonstrated that ascorbic acid levels rose with advancing maturity;

ripe fruits containing 116.3 mg/l00 g of pulp. This work was confirmed by Bal and Singh (1978a) who also demonstrated a decrease in total phenolics in maturing fruit. These authors also showed a decrease in fruit acidity on maturity (Bal and Singh, 1978b).

Changes in the amino acid content of ripening fruit was recorded by Bal, Jawanda and Singh (1979) who showed that while levels of aspargine, arginine, aspartic acid, *glycine* and serine, and threonine increased, glutamic acid, leucine and isoleucine decreased. Correspondingly, levels of sucrose and fructose increased while glucose decreased during ripening. The protein content of cultivars range from 0.84 to 1.74% while fat varied from 0.13 to 0.26% (Sood et al, 1980).

Apart from the chemical changes taking place in developing ber fruit, physical parameters such as length, diameter, weight, colour and shape have been noted by Bal and Premsingh (1978) who showed that fruit reached the ripe stage 190 days after fruit set, by which time it exhibited a golden colour. Similar work was reported by Gupta et al (1984) who showed that. in addition to establishing stone:pulp ratios for mature fruit, fruit growth and development showed 2 distinct active phases which differed from variety to variety.

The post-harvest physiology of ber fruits has been the subject of considerable interest, particularly in relation to their storage and canning attributes; as early as 1975 Khurdiya had shown that the fruit could be canned in sugar syrup containing citric acid. There is now considerable effort being expended on promoting ber fruit, both as a fresh and easily transportable commodity throughout India. as well as its usefulness as a candy or sweetmeat, either fresh or canned.

Among the first work to be reported is that of Prasad and Shukla (1978), who studied the ripening process and subsequent storage potential of ber and showed that in the presence of carbide, the fruits could be ripened in 2-6 days and could be stored for the longest period in straw at 28°C. Studies on the effects of dehydration on ber fruits were carried out by Khurdiya (1980) following blanching in steam. pricking, or length-wise slitting. Although colour could be retained after drying, the ascorbic acid content of almost all varieties fell to zero.

The effects of different packing regimes on the quality of transported fruit was raised by Jain and Chitkara (1980) who showed that the chemical composition of the fruit was not affected by various packing materials. In any transportable crop, any method to increase shelf life and retain its nutritional status is of paramount importance, and Gupta et al (1987) showed that preharvest sprays of calcium salts reduced the rate of weight and decay loss and decreased ethylene evolution; the fruits retained high TSS and ascorbic acid contents for longer periods than in unsprayed controls.

Ber fruits have been used to prepare wine, and Kainsa and Gupta (1979) fermented the pulp, supplemented with sucrose, with *Saccharomyces cerevisiae* var *ellipsoideus* to produce an acceptable drink; and Khurdiya (1980) prepared an acceptable beverage from the extracted juice of boiled pulp. The fruits have also been used to prepare candy (Gupta et al, 1980) and an evaluation of various cultivars for this purpose has been carried out by Gupta et al (1981) who showed that boiling the fruit in a 40% sugar solution containing 0.5% citric acid resulted in an acceptable sweetmeat lacking harmful microorganisms.

The Chinese Jujube

The full botanical description of this is: *Ziziphus jujuba* MilL, 1768. Gard. Diet., ed. 8. I. (Syns: *Rhamnus zizyphus* L., 1753, Sp.Pl.194.; Z. *sativa* Gaertn .• 1788. Fruct. I. 202.; *z. vulgaris* Lam., 1789. EncycI. Meth. Bot. III, 316.; Z. *sinensis* Lam., 1789, EncycI. Meth Bot. III, 317.)

Commonly known as the Chinese jujube. the fruit has been cultivated in Northern China for centuries. The 4th Century flora, *Nanfang ts' ao-mu chuang*, mentions it, though its etymology is confused with other date-producing plants, while the 17th Century treatise *Pen Tsao Kong Mu* lists 43 varieties of jujube. The geographical range of *Z. jujuba* extends from northern and central China to the mediterranean regions of Spain and France; Khalmatov and Akhmedov (1972) note its cultivation on the dry mountain slopes at Tashkent and Surhkan darin in the Uzbek Soviet Socialist Republic.

Meyer (1915) was the first horticulturist to send back large-fruited varieties to America, though ornamental cultivars were received by the USDA as early as 1837 (Thomas, 1924). Its acceptance as a nutritious fruit has prompted horticulturists to explore its exploitation as a commercial crop (Sweet, 1979, 1985).

A description of the tree appears in many publications, both botanical and horticultural, one of the more succinct being that of Thomas (1924):

"A shrub or tree 20 to 40 feet high .... ; branches zigzag; spines in pairs, straight, or slightly curved; leaves arising from the axils of the spines, 1.5 to 3 inches long and about 1 inch broad, thin, slightly toothed on the margins. borne on short leafstalks; flowers on the lateral branches, 2 to 10 in a cluster, on very short stalks. small. yellowish green; fruit oval. about the size of a plum, of sweetish taste; stone oblong. sharply pointed.

The bark on the trunks of older trees is dark gray with rather narrow, somewhat stratified ridges and deep furrows. The ridges are broken up by horizontal cross fissures at frequent intervals. On the older branches the ridges are broad and flat. while on the younger ones the bark is smooth, reddish brown in colour, with a distinct bloom .....

The leaves vary from ovate to ovate- lanceolate. with oblique, heart-shaped bases, and they are prominently 3-ribbed, smooth and lustrous green above, somewhat paler below, very ornamental.

When the flower opens, the anthers are fitted into the hoods of the petals, from which they are released and their pollen shed the first day. The stigmas remain closely appressed by their inner surfaces until the second day, when the upper portions of the styles recurve, thus placing the stigmas in position to receive pollen. The disk exudes nectar after the stigmas are in position, so that insects are attracted and cross-fertilization is assured.

The mature fruit varies greatly in size and shape. It may be spherical and not more than one-half to 1 inch in diameter, consisting of little more than skin and stone, or it may be ovoid, ellipsoidal, or pear-shaped and 2 inches in diameter. The fruit.... has a curious method of ripening. Brown spots appear here and there on the green fruit and gradually increase in size until they merge and completely cover the surface. The fruit at this time is a beautiful golden brown; within a few days it begins to dry, then wrinkles .... , and becomes darker. If left on the tree until completely dried, it turns to a rich mahogany brown. The stone varies in size and shape, in some varieties closely resembling a cherry pit, in others being ellipsoidal with a sharp spine at one end. In some forms the stone is almost smooth, while in others it is furrowed and ridged."

Agronomy

Despite its occurrence in the northernmost parts of China, the Chinese jujube grows best "in hot climates and reaches its best development where the weather is dry, the sunshine brilliant, the nights warm and the summer long and hot" (Thomas, 1924). The tree can withstand temperatures as low as -22°C without injury (Fairchild, 1918). Because of its late flowering, the jujube is free from spring frosts, making it a plant that can tolerate a wide range of climatic conditions.

The tree appears to tolerate low levels of soil water, though from studies in Texas and California it responds well to irrigation and produces a heavier fruit crop. The trees, once they are established, appear to tolerate drought conditions better than other fruit trees.

Poor soil conditions do not appear to be limiting and according to Meyer (1915):

"They [i.e. jujube trees] are found equally productive on a piece of strongly alkaline land or in an inner courtyard where the ground has been tramped down until it is as hard as a stone. The soil best suited to this fruit is a porous clay, charged with more or less alkaline matter, like the loess of northern China."

However, Thomas (1924) refers to the views of Prof. J. J. Thornber, Director of the Arizona Agricultural Experiment Station, regarding the soil types suitable for successful jujube growth:

"The soil is a fine, sandy loam, rather deep, and quite alkaline in nature, and they are making a very splendid growth .... One other matter with reference to growing these plants I am sure you will be interested in; namely, originally we grew these plants in our introduction garden on the university campus where the soil is shallow, rather heavy, and intensely calcareous but with no alkali. Here they were irrigated once every two weeks during the growing season, and in the three years' time that they grew in the garden I think they grew altogether not more than 6 inches. In other words, they were almost a total failure, although none of them died and they appeared healthy all the time. At fIrst I thought it was their natural habit of growth, but upon transplanting them to the introduction garden at the university farm, where the soil is alkaline, I found they required alkaline soil for the best growth."

Thomas (1924) also makes mention of the fact that these trees are also capable of good growth in heavy clay soils unsuitable for peaches and other fruit trees.

Trees are planted about 20 to 25 feet apart and pruning should allow them to attain a height of 20-30 ft within 15-20 years (Sweet, 1979). Trees normally require 3-4 years to produce fruit when grafted onto established rootstocks, and almost twice as long when grown from seed. Pruning practice should allow the tree to produce a spreading crown, though in China a type of pruning referred to as 'ringing' is often employed to induce increased fruit yield.

"It is the custom in the Laoling district to ring the trees every year, just when the fruit is setting, by means of sawing through the bark of the trunk, starting the first ring a few inches above the ground and leaving a space of about three-fourths of an inch between the successive rings. They start the ringing when the trees are 6 or 7 years old and continue it for 20 to 30 years, after which time the tree generally dies and is removed. The reason for this ringing process is the fact that a tree which is ringed produces almost twice as much fruit as an unringed one, although the fruits of the latter are much sweeter." Thomas (1924) states that the practice of ringing jujube trees in the U.S.A. has produced no noticeable effects.

As with any fruit crop, successful propagation is essential for commercial exploitation, and for instance, Sweet (1979) states that "propagation is difficult. The seed germinates very slowly and under natural conditions may take up to two years". Attempts to accelerate seed germination following irradiation by gamma rays have been made by Sin 'ko and Chemarin (1979), and by the application of gibberellic acid by Casini and Salvadori (1980), both with only limited success. Seeds have however been used to produce trees which serve as stocks

for future grafting, and Thomas (1924) suggests that fruits should be first retted in water to remove the pulp, and the seeds dried and stratified in sand in a cool place. Before planting they are further stratified in warm sand.

Cuttings taken from the above ground parts of the plant do not root, but cuttings 4-6 inches long of established roots have been successfully used to produce healthy sturdy plants. Some success in propagation from cuttings following the effect of substrate heating has been reported by Shaumarov (1976).

Propagation by budding is also difficult, as the wood is very hard and the bark thin. By far the most successful method of propagation has been grafting, and Popenoe (1974) suggests that in California, at least, whip-grafting is the 'preferred and most successful method presently employed. This author also quote the technique employed at the United States Plant Introduction Field Station at Chico in California:

"The jujube root is one which does not like to be disturbed, and for quick results, and where climatic conditions will permit, I would advocate field-grafting on two-year-old roots. The scions are inserted close to the root, and covered with soil, which should not, however, be over one inch in depth above the top of the scion, so that when the ground settles after a hard rain the young plant will still be able to force its way through it.

The argument in favour of bench-grafting is this: it may be done when the soil is too muddy or cold to permit outside work. The stock-plants are cut off just above the root, or the larger roots themselves are used as stocks. Upon these a scion about four inches long and of the diameter of a lead pencil is whip-grafted, and wrapped with raffia. A wedge-graft may be used if the stock is much larger than the scion. The grafts are then packed in boxes, between layers of moistened cedar or redwood sawdust or 'shingletow'. The box should be kept where temperature remains between 40° and 50°. In about a month calluses should have formed, and the grafts may be planted in the field. Grafting may be done in California any time in February or March, and the plants should go into the field not later than April 1. Scions may be cut between the first of December and the first of February, and stored unti1 wanted for use."

Where large seedlings trees are available, cleft-grafting has been advocated. More recently Chatterjee and Rao (1978) have successfully air-layered *Z. jujuba* in West Bengal, India. One-year old terminal shoots were ringed by removing a 1.5 cm strip of bark and the upper portion of the cut treated with 5-10,000 ppm of IBA or NAA, after which the cut surfaces were wrapped in moist sphagnum moss and protected by alkathene. Up to 95% rooting success was observed 60 days later, whereas no untreated controls had rooted.

Fruit and post-harvest uses

It has been known from the earliest historical records that Chinese jujubes have formed an important part of the diet of the Chinese as well as other Asiatic peoples. Although they can be eaten fresh, they are generally used to produce a preserved sweetmeat which, as well as being highly palatable, has the added advantage of being easily stored and transported. It is obvious from the early texts that the fruit was valued primarily for its sugar content, but later analyses showed it to be, in addition, a valuable source of ascorbic acid (vitamin C). The fruit can be stored in the dried state without an appreciable loss in their nutrient status, and it is suggested that they should be harvested just prior to maturity to retain a slight acid content, which improves their flavour (Sweet, 1979).

The first complete and critical analysis of the fruit was carried out by Church (see Thomas, 1924) on six varieties of fruit growing in California. The fresh fruit were shown to contain up to 24.1 % sugar, mainly in the form of invertase and sucrose and, surprisingly, they contained in excess of 3% of protein, making the fruit exceptional in this respect. Later analyses confirmed these figures to a large extent and demonstrated, in addition, high levels of other components. For example, Khalmatov and Akhmedov (1972) showed that the vitamin content of fresh wild fruits was very high, the pulp possessing 892 mg of ascorbic acid and 4.2 mg of carotene per 100 g of flesh. Mature fruits also contained a trace of folic acid. In their analysis of cultivated varieties, Kader and Chordas (1982) demonstrated the presence of 559 mg of ascorbic acid per 100 g of fresh weight. In his analysis of cultivars brought from the USSR and now growing in Shimla, India, Rathorne (1986) made the interesting observation that when harvested during the rainy season, fruits had a low sugar content but normal levels of ascorbic acid. The value of this observation lies in the argument that these fruits are best grown in semi-arid areas.

A somewhat esoteric analytical detail of jujubes is provided by Cyong & Takahashi (1982) who demonstrated high levels of cyclic GMP in the fruits - the values, ranging from 30-60 mal/g dry weight, making these the highest levels of cGMP found to date in either plant or animal tissue. The nutritional value of this moiety was not explored, but its chemical identification as adenosine-3,5-monophosphate was determined by Hanabusa et al (1981).

The fruits may be eaten fresh or may be “boiled with millet and rice; they may also be stewed or baked in the oven; they are used, raison-fashion, to make jujube bread; they are turned into glace fruits by boiling them in honey and sugar sirup” (popenoe, 1974). To prepare the candied fruit, sound dried fruit are boiled in sugar solution and then dried in the sun. The skins are slashed and the fruit reboiled in a stronger solution of sugar supplemented with honey. Salhunkhe and Desai (1984) also report various studies on the production of jellies from the fruit in India.

Recently, jujubes have appeared in cans, and Ahmad and Malik (1973) have investigated various physical conditions and chemical supplements on the quality of canned fruit. Similarly, Haq and Ullah (1975) studied changes in fruit weight during the brining and candying process at different maturity levels.

OTHER ECONOMICALLY IMPORTANT SPECIES

Apart from *Z. mauritiana* and *Z. jujuba*, which have been discussed above, three other species of *Ziziphus* appear in the literature with regularity. They are Z. *nummularia*. an increasingly important source of fodder in arid regions; *Z. obtusifolia* , the Lotebush of the North American plains; and *Z. spina-cristi*, a less well-known and somewhat restricted species used as a source of edible fruit and pharmaceutical drugs.

Ziziphus nummularia Wight et Am.

This species is known as ‘Pala’ on the Indian sub-continent, and the relationship between its growth dynamics in the Indian desert and its economic importance as a source of fodder and edible fruit has been outlined by Sharma (1982). Its usefulness as fodder is based on the high proportion of soluble nitrogen in the leaves, and early work on the nutrition of lambs by Malik and Nath (1970) established its future status as animal feed.

Later, Kirpal Singh and Gupta (1977) evaluated the value of pala leaves for the feeding of sheep and goats in Haryana. They showed that dried leaves contained 42.1 % neutral-detergent fibre; 34.2% acid-detergent fibre; and 9.9% hemicellulose, as well as other important constituents making them ideally suitable as fodder. The high level of crude protein and calcium were comparable to those for legume straw.

Continued work on feeding trials with various animals continues in India, particularly in the semi-arid zones. For example, Bhandari et al (1980) examined the nutritive value of pala leaves in Rajasthan as fodder for adult Chokla sheep and showed that, despite the intake of high levels of crude protein and fibre, the sheep lost weight. These authors concluded that dried leaves contain alkaloids and lignin-bound inhibitory factors which decrease the utilization of protein and energy. Similar conclusion were drawn by Bhatia and Rattan (1981) and Sehgal and Bhatia (1983) in their experiments on cross-bred weaners. The effect of tannins in palm leaves on ruminal proteolysis was investigated by Kumar and Singh (1984) and Sehgal (1984) and recent work has suggested a partial replacement of palm leaves by other fodder could be beneficial (Bhatia, 1988).

The overall conclusion that may be drawn from these investigations is that while the high nitrogen content of pala leaves makes them ideal fodder material, the presence of toxic substances may preclude their utilization as the sole source of feed. Instead they should be used in mixtures with other types of fodder, so that the level of toxicity is reduced but their high protein content is maximized.

Z. obtusifolia (T. and G.) A. Gray var. *obtusifolia*.

This species is known as Lotebush in North America and is an important shrub of rangelands throughout southern, central and western Texas. Its main feature is in its ability to resprout from the crown and roots following rangeland brush control measures and, as such, it plays an important role in the ecology of rangeland habitats (Speer and Wright, 1981).

Lotebush is a stiff, spiny, much-branched shrub with greyish-green, grooved twigs (Foster and Jacoby, 1980) and is concentrated directly beneath the shrub canopy where vegetation is sparse and unavailable to large herbivores. The bush also determines the level of basal vegetation in its immediate vicinity (Foster, 1983).

The bush is resistant to herbicides and studies on seed germination indicate that light and cold treatment enhance emergence, and that the optimum soil temperature was between 22 and 27°C.

Z. spina-christi (L). Willd.

This species is confined to regions of W. Asia and N. Africa where it is known as Nabag.

It is indigenous to W. Sudan and other countries of the Sahara, and the fruit is eaten as a food source. The fruit flesh is rich in sugars, notably glucose and sucrose, and also in iron. The~, which is normally eaten with the flesh, contains 28.5% lipid and 18.6% protein; oleic and linoleic oil are the predominant fatty acids. The protein is rich in sulphur-containing amino acids. Critical analysis of the fruit was carried out by Nour, Ali and Ahmed (1987), who showed that the fruits contained between 5.3 and 7.4% crude fibre and the pulp 86.1 % total carbohydrate.

The physiological characteristics of fruits at different stages of maturity were determined by Abbas et al (1988), who demonstrated an increase in levels of carotenoids and vitamin C and a decrease in total chlorophyll and pectic substances as the fruit ripened.

Parameters determining the storage propensities of the fruit were examined by Al-Niami and Abbas (1988), particularly with reference to the effect of temperature on chemical changes in the fruit. This species is also a rich source of biochemicals and these will be discussed in the next section.

Extractable components

From earliest times species of the genus *Ziziphus* have been noted for their medicinal and therapeutic qualities and, for instance, Burkill (1966) refers to the export of mucilaginous products from certain species to Europe as medically effective syrups. This author also mentions the effective use of various extracts in Malaysia in childbirth, as a soporific, and as a source of tannin.

More recently Han and Park (1986) have listed and described the various alkaloid components of *Ziziphus* plants and their relationship to folk medicine, while Devi et al (1987) have listed various peptide alkaloids known to occur in various *Ziziphus* species. In this section we examine, very superficially, some extractable components of the better known species and their possible medicinal importance. It must, however, be stated that much of the work reported is of purely academic interest to the small group of scientists involved in biochemical synthesis and analysis.

Z. mauritiana. Despite its importance as an important food source little work has been reported on its chemical components. Tschesche, Wilhelm and Fehlhaber (1972) characterised the two peptide alkaloids, 'mauritin A' and 'mauritin B' and later, Tschesche et al (1974) isolated 'mauritine', a newly discovered peptide alkaloid, while Srivastava and Srivastava (1979) elucidated the structure of 'zizogenin' - a newly discovered sapogenin. In the same year Tschesche et al (1979) isolated two new cyclopeptide alkaloids from the bark. Work by Sharma and Kumar (1982) isolated 'jujubogenin', n-octacosonal and aphitolic acid from alcoholic extract of the leaves.

Z. jujuba. Much of the reference material relating to the extraction of alkaloids and other components in this species frequently misuse the correct specific epithet and frequently refer to older, and now superseded, names.

The earliest reference to the exploitation of the Chinese jujube is that of Nakano (1969) who took out a patent on his method of extracting the hypnotic chemical, 'betulic acid' , from the seeds. In the same year Akhmedov and Khalmatov (1969) begun a wide-ranging study of the pharmacognostic properties of this species growing in Uzbekistan. The plant is a known source of sapogenins, and these were extracted from *Z. jujuba* var *inosa* by Shibata et al (1970). Further work on the pharmacognosy of this plant was carried out by Chirkina and Kriventsov (1973), who demonstrated antimicrobial and antiviral properties of fruit extracts.

A new sapogenin was isolated by Kawai et al (1974), and new alkaloids were separated by Tschesche et al (1975) and Abd-el-Hamid and Arner (1976); and terephthalic acid by Thakur et al (1975). Jubosides were characterised by Tschesche et al (1976), Ziyaev et al (1977), and Otsuke et al (1978); and isoquinoline alkaloids by Khokhar (1978). Cyclopeptide alkaloids were examined by Chughtai and Khokhar (1978), and 'spinosin' by Woo et al (1979). Woo and his associates also isolated acylated flavone-C-glycosides from seeds (Woo et al, 1980) but probably the most interesting group of biochemicals to be studied are sweetness-modifying components, which have been the subject of extensive investigation.

Sweet-taste sensation is normally induced by the adsorption of sweet substances on the receptor protein in taste receptor membranes. In order to investigate further the mechanism of taste reception specific inhibitors serve as useful experimental tools. Such chemicals, 'ziziphins' (triterpene saponin glycosides) were isolated and characterised by Kennedy and Halpern (1980) and the substance, which proved somewhat recalcitrant, was finally characterised by Kurihara et al (1988) as a complex rhamnopyranosyl jujubogin.

Continued work on the isolation of newer, and presumably more interesting, biochemical components has resulted in the accumulation of a mass of published work, most of which bears little relevance to the economic value of the plant per se, and is therefore not discussed further.

Z. nummularia. The earliest extensive exploration of cellular metabolites in this species was carried out by Tschesche and his co-workers at the University of Bonn. Tschesche and Eckhardt (1974) isolated the alkaloids 'nummularine-A' -'B' and -'C', which were newly discovered 13-numbered ring structures containing peptide alkaloids. 'Tschesche et al (1975) isolated and characterised three more and Tschesche et al (1977) isolated yet three more new alkaloids. In the same year Srivastava and Chauhan (1977) carried out extensive chemical analysis of the whole plant and isolated 'manogenin', 'taxifolin' and a new compound 'taxifolin-3-glycoside' .

Work has continued in this general biochemical field, though some stress has been placed on the role of tannins in the plant, particularly with regard to their role in digestibility of fodder [Kumar and Singh (1984); Sehgal (1984); Sehgal et al (1985)]. New metabolites are being continually found in this plant, such as 'nummularogenin' (Srivastava, 1984); '*sativa*nine' (Shah et al, 1986), and most recently 'nummularine-S' (Shah et al, 1989). However the relationship between these new substances and any practical application is tenuous in the extreme and need not be considered further.

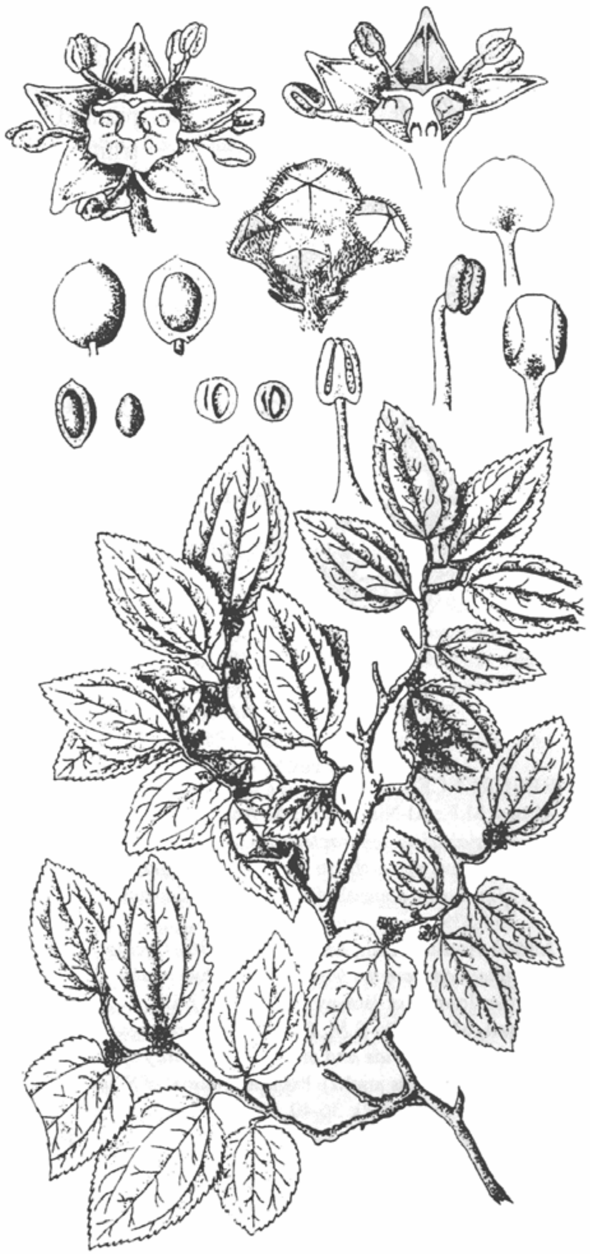
Z. spina-cristi. This plant has been used by 'native' medicinal practitioners for centuries, particularly in the Middle East, and a recent survey by Tanira et al (1988) has shown that ethanolic extracts of leaves had a distinct and measurable anti-inflammatory and a moderate antipyretic effect in animals. The extract also inhibited the growth of *Bacillus subtilis*. However, no analgesic or diuretic activity was recorded.

In a search for the constituent chemical responsible for these physiological reactions, considerable effort has been expended on their extraction from plant tissue. For example, Tschesche et al (1974) obtained peptide alkaloids, and Ikram and Tomlinson (1976) success fully isolated the triterpenes betulic acid and ceanothic acid from dried plant material. Nawar et al (1984) extracted leaf-flavonoids which were characterized as 'quercetin', 'rutin', 'hyperin' and 'quercitrin' and further peptide alkaloids were extracted by Devi et al (1987).

Other species. Many other species of *Ziziphus* have been analysed in a search for pharmaceutically active constituents, but caution is necessary in identifying the exact species employed in the analysis in that, in most cases, herbarium specimens of the samples are not deposited with recognized herbaria making positive identification impossible.

Among the earliest work reported in this field is that of Rao and his colleagues in India, who successfully isolated various phenols from *Z. xyloporus* Willd. (Rao et al, 1968b), and various anthocyanins from the wood of the same tree (Rao et aI, 1968a). Tschesche and his school isolated alkaloids from *Z. mucronata* Willd. - a South African species (Fehlhaber et al, 1972) - and from *Z. amphibia*, a doubtful species (Tschesche et aI, 1972) and similar alkaloids from *Z. oenophila* Mill (Tschesche et aI, 1974). Cyclopeptides were also isolated from this species by Cassels et al (1974). Rao et al (1983) also demonstrated anti-inflammatory and anti-cholinergic activities in extracts of *Z. oenophila*.

Another species, *Z. rugosa* Lam, has been the subject of much interest and Kulshreshtha and Rastogi (1972) isolated a glycoside from alcoholic extracts, while the use of this plant in India for the treatment of diarrhoea and menorrhagia (Tripathi et al 1988) has stimulated renewed interest in its chemical constituents (Pandey et al, 1988; Tripathi et aI, 1989). An-



Zizyphus joazeiro from Brazil

other Indian medicinal species, *Z. trinerva* (an unlisted species) has also been analysed for active constituents (Pandey et aI, 1982) as has *Z. xylopyra* Willd. (pandey et al, 1986).

In South America *Z. joazeiro* Mart. is an important medicinal plant with powerful antipyretic activity and, as such, has been the subject of much investigation. For example, Higuchi et al (1984) were successful in isolating triterpenoid saponins from the bark, and Barbosa Filho et al (1985) isolated betulinic acid, oleanolic acid and saponin also from the bark. The antipyretic activity of aqueous extracts of this plant were demonstrated by Nunes et al (1987).

Conclusions

The genus *Ziziphus* contains a number of species which exhibit growth characteristics that could make them economically viable as tree crops in Australasia. They tolerate a very wide range of climatic conditions and, in particular, are suitable for growth in arid, or at least semi-arid, regions, but they also respond positively to irrigation. They are fairly easy to propagate though workers have noted a low seed viability in some species. One of the more useful and successful methods of propagating trees that have been selected for specific attributes is by tissue culture, and Goyal and Arya (1985) have now established a system for the clonal multiplication of *Ziziphus* trees in vitro.

Of the various species described here, the fruit-producing varieties probably have the greatest potential as commercial crops, though Z. *nummularia* could well be tried as a source of protein-rich fodder on marginal lands. Similarly, *Z. obtusifolia* could be planted as a rapidly growing, fire resistant, soil stabilising species in open country abutting grazing land.

However, without doubt, it is the fruit producing species *Z. jujuba* and *Z. mauritiana* that should be planted in the first instance. Both produce abundant fruit which are a rich source of sugars and, especially, vitamin C and they have the potential to supply the ever-increasing Asian population of Australian cities with fresh 'dates' as well as offering canning factories and the confection trade another eminently suitable material for export - particularly to Asia.

Any visitor to Asian markets can testify to the widespread sale of *Ziziphus* fruits, most of which are of marginal quality, having been grown under traditional horticultural regimes; the potential for providing markets with high-quality fruit is abundantly clear.

Finally, the potential of these trees to produce commercially exploitable pharmaceuticals also needs to be explored.

Zizyphus jujuba

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ROOT GRAFTING: A NEGLECTED TECHNIQUE WITH POTENTIAL

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There are many different techniques used for grafting and budding, and descriptions of most of these are readily available. But one method, root grafting, although a very old method is, I think, from the point of "propagation" very much neglected.

It is very simple, works well with all Apple cultivars, Cherries, Plums, Peaches, Nectarines and Pears. Many ornamentals may also be propagated by this method - Rhododendrons, Camellias, Wisterias and some difficult Conifers not easily produced by cuttings.

This graft can be made using a whole root or pieces of roots (see figures). For a **whole-root graft** it is advantageous that both scion and root be of the same size. Usually a whip and tongue graft is used, but wedge or saddle grafts can be quite satisfactory.

The length of the root should be not less than half the length of the scion. If both are the same length, even better. This will depend a lot on the internode of each variety or species, availability of material, and depth at which one intends to plant.

If scion and root are not of the same size, they will have to be matched on one side, possibly with the top bud of the scion in line with the matched side.

Pencil-sized 'root-scions' are ideal for this type of graft. Roots of larger diameter may lack fibrous roots, depending on the species, and be more difficult to take.

Due to the scarcity or poor quality of the big sized roots, most work is done using smaller root pieces, from 2-8 mm diameter and 40-80 mm long. I personally have grafted thousands of Apple trees in the past using root pieces with excellent results.

The diameter of the scion may also vary, from 3-20 mm, and the length as mentioned for the whole root graft.

The scion is split at the bottom by starting through the bud (Apple, Cherry etc.) or node ex- branchlet (Camellia, Conifers). This is very important. The cutting is then divided into two halves of equal consistency. If this operation is done properly, very often there is no need to bind the graft.

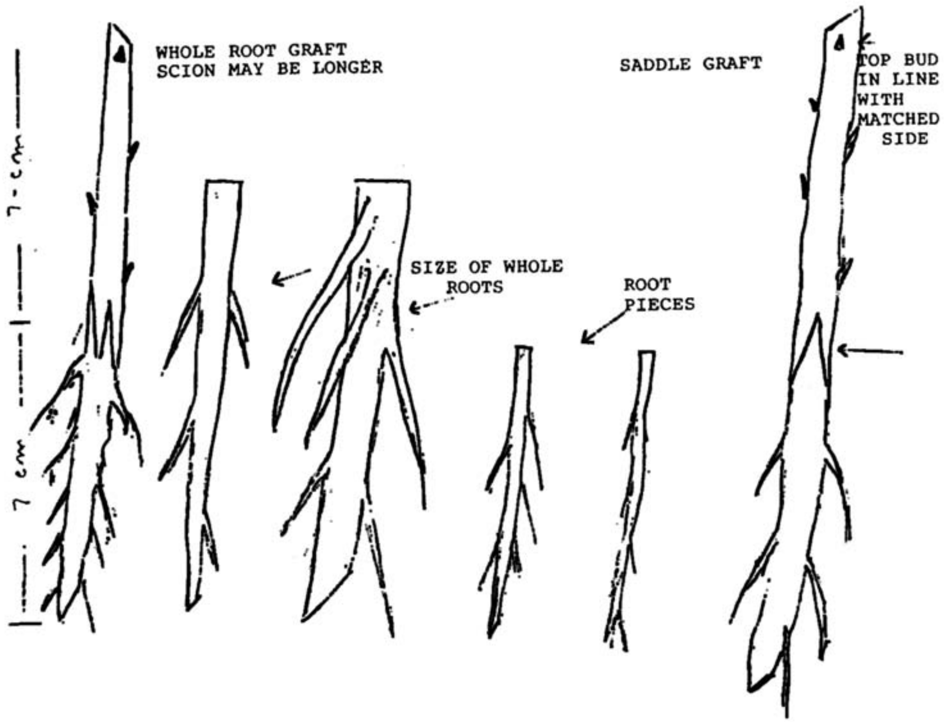
The best of two root pieces is cut wedge-shaped and slightly angled (8-15 mm long) and inserted into the split cutting on the bud or node side.

The second and smaller root in the opposite side is shaped in a similar fashion.

For a **two-piece root graft** the cutting needs to be at least 6 mm or above in diameter. For smaller cuttings, one root piece is more suitable.

Always remember to maintain the polarity of the roots in all the grafts. The best way to do it is to cut the root pieces across the bottom on a slant. If this procedure is always adopted no mistakes will be made.

For securing the graft, I have used with good results a 15-18 cm long piece of thread obtained from a hessian sugar bag or burlap. This material will decompose very easily and will not strangle the graft. I do not recommend budding rubber.

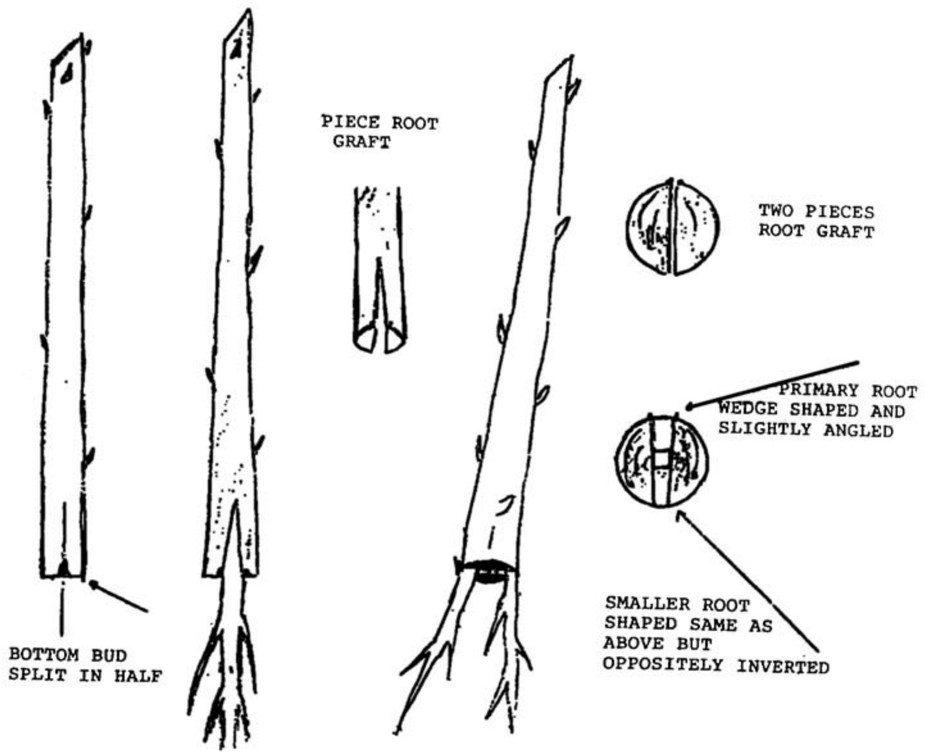


Planting out for deciduous trees depends a lot on the climatic conditions. For subtropical Western Australia, grafts may be planted as soon as ready.

For colder areas, early winter grafts can be stored at 5-8°C and planted out later, after 4- 10 weeks. Store them in a mixture of clean sand, perlite, peat moss and reasonably moist. Plants susceptible to crown gall may be dipped in a 'No Gall' solution.

I prefer to see all these grafts planted deep in a way that only two buds are exposed. Evergreen stock will have to be provided with a controlled environment to obtain a good take. With today's facilities - fog, mist, temperature control - the success of this type of grafted cutting has improved greatly.

I have noted over the years, that some plants, however reluctant to provide themselves with their own roots, will do so if a small root-piece is inserted at the bottom of them. In this case, wounding and application of rooting hormone will also help.



Others will produce roots better only on succulent successive young growth. You plant the graft at soil level and as the young growth starts, cover it with more soil so that the young roots can develop on the new growth. In this case the graft becomes a "nurse graft". Eventually the initial root may completely disappear.

When you are sure that this will occur on a particular plant, then you can use a rubber tie, this will strangle the initial root and allow the young plant to develop their own roots.

As you can see this system of grafting may be useful when conventional cuttings are not a proposition.

[Based on a talk given at a meeting of the International Plant Propagators Society, Perth, 1990].

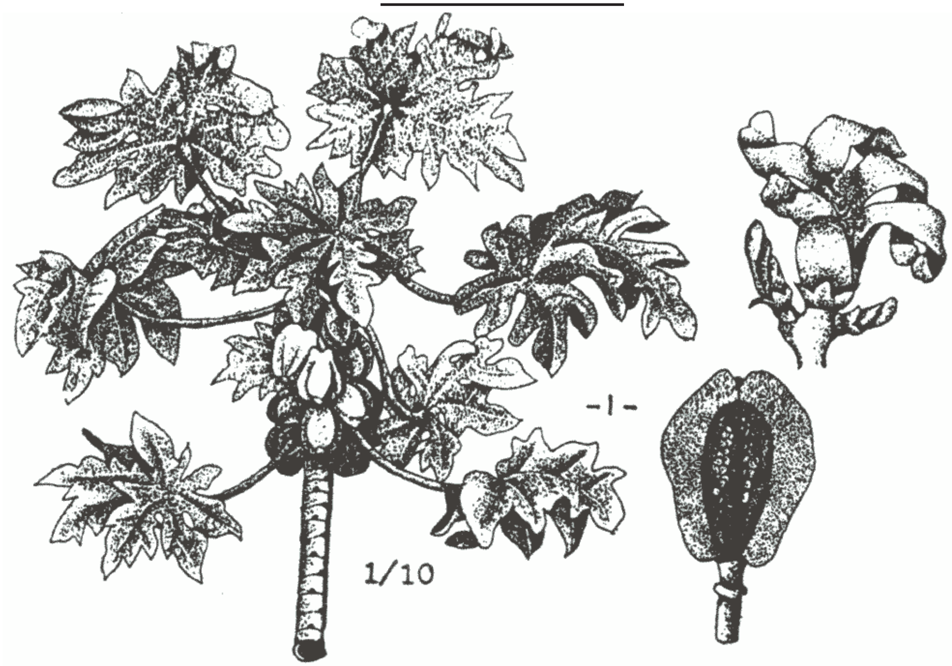
(*Editor's Note*)

As well as its use in the production of commercial plant varieties, the Bazzani method has great potential in reproducing rare and unusual plants.

If an uncommon plant is bought in from an interstate nursery, or released from quarantine, there is the opportunity to multiply it rapidly and get several plants for the cost of one. Take the plant out from the pot, tease out the roots, and select several end pieces. Cut these off and combine them with stem pieces from the top of the plant, using a two-piece root graft. I have done this myself successfully, with fruit plants which were just passing through my hands, taking a tiny piece of root and stem before passing them on.

Of course, with this method it does not matter whether the original plant is a seedling or is already a graft, perhaps using both a clonal understock and a selected top variety - you know the roots and the scion are compatible because the plant is there in front of you. If you happen to come across a bud sport or mutation, say a prostrate form of tagasaste, that form or sport can be multiplied up from just the one plant.

The method can also be used to propagate from a single unusual seedling, or a rare isolated plant discovered in the wild. It may be a bit more laborious to dig down to discover suitable root pieces in these cases, but the amount of material taken is so small there is no worry about harming a rare and possibly endangered plant - the technique can actually be used to increase the number of plants and reduce its endangered status.



Papaya or Pawpaw, *Carica papaya*

MUTUALISM-
A COSY STORY ABOUT A FIG AND A WASP

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Mutualism is the close relationship between two species of plants or animals in which each benefit from the association. Mutualism could hardly be more evident than in the case of the fig plant's association with its pollinating wasp. The development of the fig (*Ficus carica*) from a young bud to the mature fruit involves a series of developmental phases and interactions with the wasp (*Blastophaga psenes*). This article discusses the adaptations and co-evolutionary patterns that have evolved between these two organisms.

The common fig tree, regarded as sacred by the ancient Egyptians, Romans, and Greeks has had extensive scientific research carried out on it by botanists, zoologists, and evolutionists all over the world. Yet, while most of us relish the taste of a deliciously sweet and juicy fig, we may not appreciate the fascinating and extremely complex processes that occur during the development of that small, green bud into the mature, full fruit.

In one of his many scientific papers on this subject, Galil comments: "Fig biology reveals the incredible ability of natural evolution". (Galil et al.1973: 1113). In this discussion, I will follow Galil's work on the mutual relationship, and the close interdependence between the life cycle of the commercial fig, *Ficus carica*, and that of its pollinator, the fig wasp, *Blastophaga psenes*, and the complementary adaptations which have evolved in this association.

A BRIEF HISTORY

The evolution of the fig tree appears to have begun in the Cretaceous period, more than 100 million years ago (Galil et al. 1973). Condit (1949) recounts the history of the appearance and use of the fig tree by people, including the fact that paintings depicting the picking of figs have been found on the wall of a grave, Beni-Hassan, and in a similar tomb, which were dated to the 12th Egyptian Dynasty, 2500-2400 B.C. About 340 B.C., Aristotle described a small creature he called "psen" which pierced unripe figs, thus causing them to remain on the tree until mature.

This process of caprification, whereby pollen is transferred from the inedible fig specimen, or caprifig, by an insect (the fig vector) to the edible fig was later declared as useless by Gugliemo Gasparini (1845; fide Condit, 1949) who maintained that its practice should be abolished. Numerous scientists held the same opinion, until in 1899 the true nature of caprification was clarified by the successful introduction of the blastophaga into California, and by subsequent studies of the habits and life history of this insect.

THE BLASTOPHAGA

Blastophaga psenes belongs to the order Hymenoptera, in the family Agonidae. The generic name, *Blastophaga*, is derived from two Greek words, *blastos*, germ, and *phagein*, to eat. The specific name, *psenes*, was used by ancient Greeks for the fig wasp, or *Cynips*. Condit (1949) gives an account of the striking sexual dimorphism apparent between the female and the male: the female (Fig. 1) is, on average, 2.5 mm long, but may vary in size according to the caprifig from which she emerges; the body is glossy and black, and the wings have very few veins. The males are wingless, amber in colour, and have an attenuated abdomen that it is much longer than the head and thorax combined.

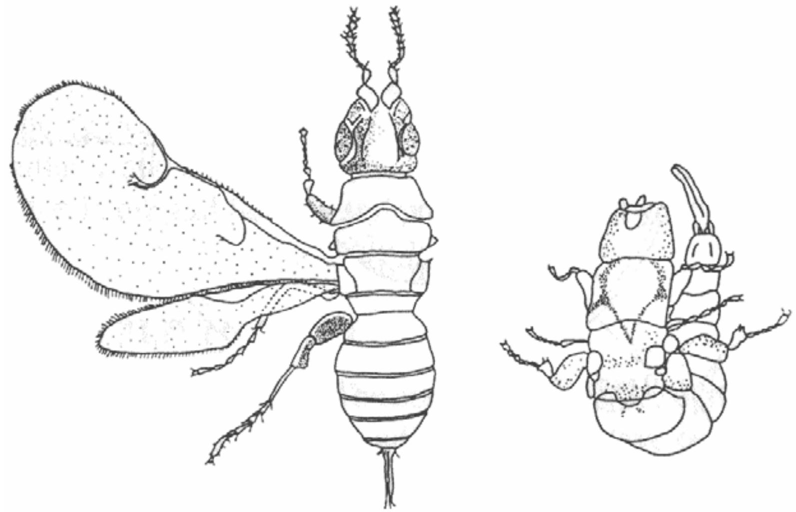

Fig.1 Blastophaga psenes: Female (left) and male (right)
[Adapted from Condit (1949)]

The males are also fewer in number than the females, and as S. E. Flanders once observed, there are from 10 to 15 males blastophagas for every 100 females (1945; fide Condit, 1949). The female lays from 300 to 400 eggs, each being deposited separately in a short-styled flower. Reproduction in the Hymenoptera is characterized by the production of males from unfertilized eggs and of females from fertilized eggs, a phenomenon known for a hundred years in the case of the honey bee (Condit 1949).

THE FIG

The fig plant belongs to the mulberry family, Moraceae, in which there are a number of species. Here we are concerned with the genus *Ficus*, especially the common and most extensively studied type, *Ficus carica*, which yields the well-known commercial figs. Weier et al. (1982) describe two types of fig trees, one that produces edible fig fruit and one that produces small, hard, inedible fruit (capri fig) , which serves as nothing more than an incubator of fig wasp larvae.

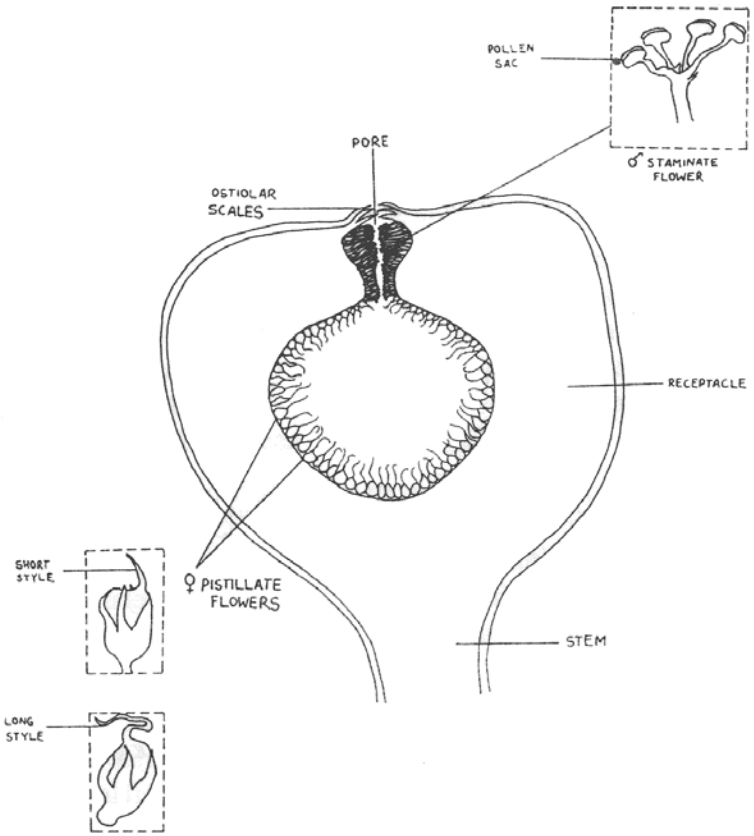

Fig.2. Cross-section of fig synconium
[Adapted from Weier et al (1986)]

The young fruit is hollow on the inside, wherein separate male and female flowers are arranged in a special inflorescence, or flower cluster. This hollow, pear-shaped structure is known as the syconium and ultimately becomes a fig at maturity.

Male flowers (fig. 2) are usually arranged near the small opening, the ostiole, at the upper end of the syconium, and the female flowers, much more numerous, line the interior. There are two types of female flowers: long-styled fertile flowers, and short-styled sterile ones (fig. 2). Long-styled flowers eventually produce a single, small, one-seeded, hard-shelled fruit called an achene. The fig itself is actually a collection of many of these achenes borne within swollen receptacles (fleshy stem tissue). Short-styled flowers, called gall flowers, do not

develop fruits but are used as egg-laying sites by the wasps, which pollinate the other flowers in the process of egg-laying. The parasitized flowers then become a mass of pulpy, abnormal plant tissue, the gall, on which the wasp larvae feed and in which they develop.

Not only are there three flower cluster types - male, long-styled female, and short-styled female or gall flowers - but there are also three distinctive types of syconium. Weier et al. (1982) give a concise account, as follows: the first type of syconium, produced in the spring, contains male flowers and gall flowers; female wasps emerge from overwintering in another type of fig, enter this first syconium and deposit eggs in the gall flowers. These eggs produce wingless male and winged female wasps later in the summer, which mate, and then leave the syconium (described in more detail, below).

On leaving the fig, the female becomes covered with pollen from the male flowers near the ostiole, at the tip of the fig. The second type of syconium, the true fig, bears only long styled fertile female flowers. The female wasp, searching for egg-laying sites in summer, enters these figs and pollinates the flowers inside but does not lay eggs because the styles are too long to suit the egg-depositing anatomy of the insect. The third type of syconium is produced in the autumn, and contains only short-styled gall flowers. Females do lay eggs in these, which develop in the gall flowers and produce the next year's fig wasps.

THE FIG - FROM BUD TO FRUIT

In the words of W. C. Allee (1949): "The complex life history of the insect, with wingless males and winged females, is accurately adjusted to the development of the successive staminate and fertile pistillate flowers of the fig." The developmental phases of the fruit, and the precisely-timed interactions of the wasp are truly intriguing events. Galil and Eisikowitch (1968a) summarized the full developmental course of the syconia in a series of phases [A-BF-C-D-E, Fig. 3], as follows:

PHASE A (pre-female): young syconium prior to the opening of the ostiole.

PHASE B (female): ostiolar scales loosen, female flowers ripen, sycophilous wasps penetrate syconium and oviposit into the ovaries.

PHASE C (interfloral): wasp larvae and fig embryos develop within their respective ovaries. Ovaries occupied by the larvae are transformed into galls.

PHASE D (male): male flowers mature, wasps reach the imago stage, fertilized female wasps leave the syconia via channels bored by the males.

PHASE E (post-floral): both the syconia and the seeds within them ripen. (Cited from Galil et al., 1970:775).

Only a part of the sycomore (ie, the true fig, *Ficus sycomorus*) syconia of the 'Balami' variety follows the full developmental course to produce large figs of the 'E' type. Galil et al. (1970) established the fact that many syconia do not reach the normal BF phase and do not open, their ostiolar scales remaining tightly closed. Such syconia, as the authors term the 'BS'= sterile B syconia, cannot be inhabited by wasps, but instead, swell very rapidly and within 3-4 days produce real parthenocarpic fruit. (It should be noted that the developmental cycle illustrated in Galil's 1977 paper did not indicate this, and thus is not included in this discussion.)

On leaving its native syconia (phase D, Fig. 3), the female wasp is attracted to the young receptive fig (phase B, Fig. 3). Galil (1977) states that certain fig varieties release specific attractants, which are detected by certain species of wasp. The unique structure of the fig ostiole also acts as a selective organ to specific species of wasp. These facts indicate the adaptations that have evolved, leading to the intimate 1-to-1 relationship between most *Ficus* species and their specific pollen vector.

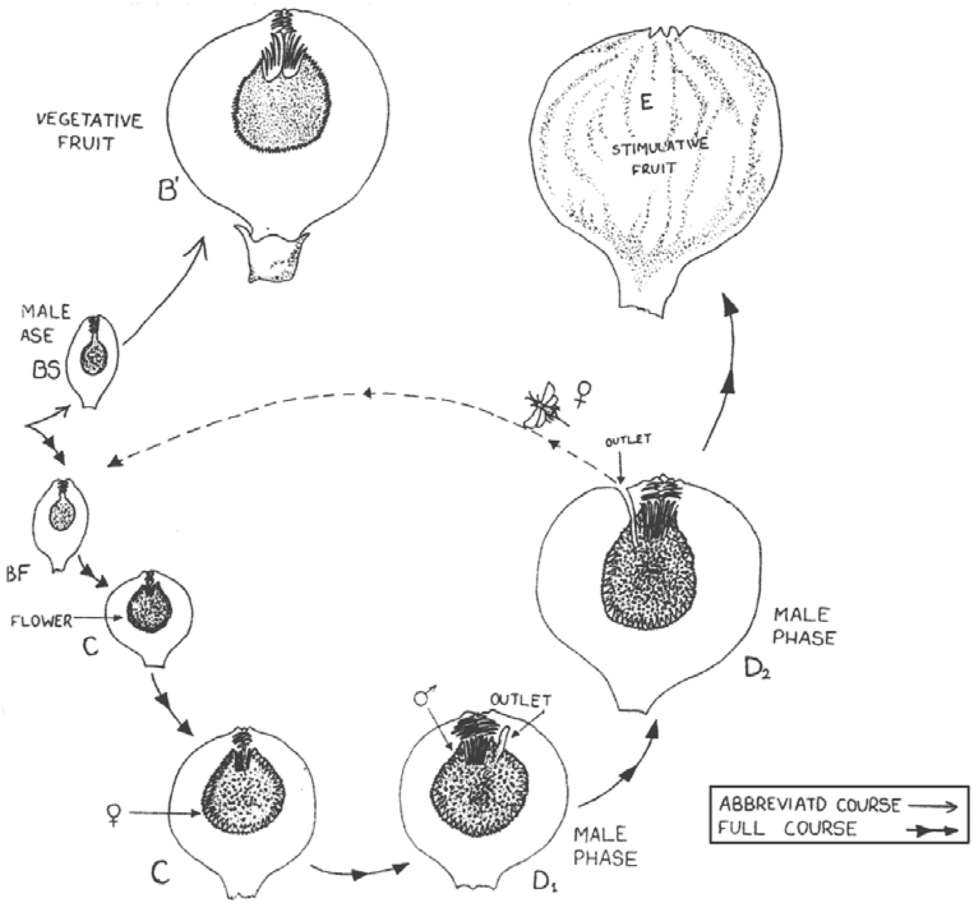

Fig.3. Developmental course of the synconia
[Adapted from Galil et al (1970)]

Once inside the syconial cavity, the female inverts its ovipositor into all available styles, unable to distinguish between long- and short-styled flowers, and in the process, it dusts pollen that had been carried in its thoracic pockets (identified by Galil and Eisikowitch, 1974) onto all receptive stigmas (Galil 1977). The short-styled ovaries harbour the eggs, whereas the styles of the long -styled flowers are much longer than the wasps' ovipositor, and hence

the egg does not reach the ovary. This is a remarkable feature of the fig, which has developed this mechanism to avoid over-brooding and ultimately destructive parasitism by the wasp larvae. Having lost its wings and antennal flagellae whilst entering through the ostiolar scales, the flightless wasp then dies within the cavity and the scales close, sealing the syconium once again.

The wasp eggs hatch at the interfloral phase (phase C, Fig. 3) and develop within the short styled ovaries. At the same time, the long-styled flowers give rise to seeds. During the male phase, D (Fig. 3) ripening of the stamens and hence pollen production, occurs in accordance with the emergence of the second generation of adult wasps. This is striking evidence of the two organisms' co-evolution to a mutualistic association. The insect ensures the most successful and efficient process of pollen transfer which is essential for the continual survival of the fig species. In return, it is provided with an adequate and safe environment for the developing wasps, essential for the wasp species' survival.

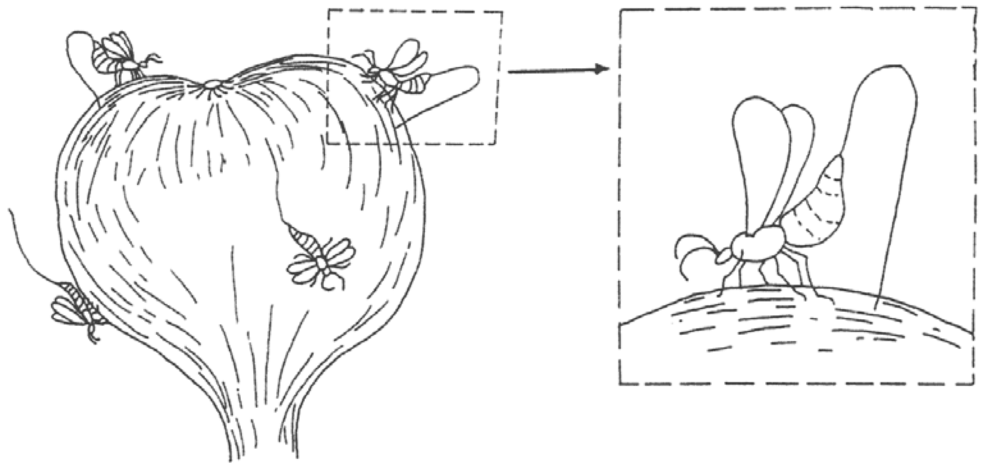

Fig. 5. Parasitoid wasp with ovipositor inserted into fig

Fig. 4. Parasitoid wasps on the surface of a fig

[Adapted from Begon et al (1986)]

The male wasps rupture the female-containing galls, and mate with females before tunnelling their way out of the syconium. The holes they make allow the carbon dioxide level inside the cavity (which was relatively high due to the respiratory levels) to equilibrate with the external atmosphere. This stimulates ripening of the fruit (Galil et al., 1973).

The females follow the males and, on passing the staminate flowers on their way, fill their thoracic pockets with pollen, and fly off in search of a young, receptive fig with which to start the whole cycle again. Except for the commercially bred figs (parthenocarpic type), habitation and pollination of the fig by the wasp is essential for growth (e.g., the common Smyrna fig can fruit only after pollination by *Blastophaga psenes*); otherwise, the fruit will drop off the tree during the juvenile stage.

The evolution of this complex system has progressed even further. Begon et al. (1986) describe a further wasp, a parasitoid (fig. 4), which lays eggs in the female flowers if the fig but is not involved in the pollination process (Fig. 5). This "cuckoo in the nest", although reared by the fig, offers nothing in return to the plant for this privilege.

Thus, as Begon et al. (1986) state,: " ... we see that the situation of the fig's biology represents one of the classics of co-evolution and of parallel evolution of mutualists and of parasitism". (p. 471). It is a truly fascinating story.

Acknowledgements

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THE REVIVAL OF AN AUSTRALIAN COFFEE INDUSTRY

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Abstract

A coffee industry is being reestablished in Queensland and northern New South Wales after a gap of 60-odd years. The new industry is unique in that most cultural operations, including harvesting, are mechanised as opposed to traditional hand practices. Capital is being substituted for labour.

The industry is in its infancy and experiencing many of the problems associated with development of a new crop and technology.

This paper presents information on current and planned research designed to establish a mechanised coffee industry. As well, problems encountered in attempting to mechanise an industry rich with tradition and high labour components are discussed

Introduction

Coffee is produced in approximately fifty countries around the world (6). World trade in coffee is over 60 million bags per annum (60 kg/bag) valued at US$12,000 million at 1981 prices (6). Brazil and Colombia are the world's two largest producers, supplying between 40 and 50% of the crop (6). Coffee is the second most valuable traded agricultural commodity world-wide, surpassed only by meat (2).

Coffee is not a new crop for Queensland, as a viable coffee industry existed in the 1890s-1920s, with centres at Kuranda in North Queensland, Mackay in Central Queensland, and Buderim in Southeast Queensland. At its peak there were about 180 ha of coffee in North Queensland alone (1, 4, 10). Quality was reported to be excellent, with good prices being obtained on the London market (1,3).

The Queensland industry declined for several reasons, including tariff removal following federation, frosts, lack of a domestic market centre, lack of technology, and competition with the developing sugar industry for cheap harvesting labour (3, 10).

In the late 1970s, commercial interest was regenerated following high coffee prices due to frosts in Brazil, and more importantly, development of a mechanical harvester in that country. Two former overseas growers independently selected the Mareeba/Dimbulah Irrigation Area of Far North Queensland as a suitable location to grow coffee for machine harvesting (9).

Currently 170 ha have been planted on 12 properties in the Mareeba area, 40 ha at Lakeland Downs near Cooktown, 40 ha at Yeppoon in Central Queensland, 15 ha at Bundaberg, and 12 ha in the Northern Rivers area of New South Wales. Current indications are that the area under coffee in Queensland could increase to over 300 ha in the next year, and further rapid expansion is likely if initial growers prove industry viability .•

The first commercial harvest was in 1984, by the Jaques Brothers, who subsequently built their own roasting and packaging factory for commercial marketing of their product. Six North Queensland growers are harvesting this season (winter 1988). The Australian industry is still very much in its infancy, and production is only 100-125 tonnes, compared with imports of 32,000 tonnes ($150 million).

Aspects of Production

Botany

Coffee belongs to the genus *Coffea* within the family Rubiaceae. There are over sixty species of coffee but only two are important. These are *C. arabica* and *C. canephora*.

C. arabica, referred to as Arabica, which originates from the mountain forests of Ethiopia, today comprises 75% of the world's coffee supply. Arabica is the best quality, high-aroma coffee used for fIltered coffee and for upgrading the flavour of Robusta coffee in the manufacture of instant coffee (9).

C. canephora, or Robusta coffee after one of its cultivars, is a relatively high-yielding lowland coffee native to equatorial Africa. It is an inferior coffee with low aroma and attracts lower prices. It is used mainly to give body to instant coffee and in blends (9).

Arabica is the species presently being grown in Australia. Robusta is not grown commercially as it is felt that the growth habit and very tight attachment of berries would prove very difficult for mechanical harvesting. However, trial plantings have been made and machine harvesting will be evaluated at a later stage.

Climate

Arabica coffee is best adapted to a climate having an average daily mean of 20-24°C.

World wide it is grown in areas of mean temperatures of 13-27°C (7). Temperatures above 30°C or less than 10ºC retard growth and yield (8). Coffee is frost sensitive but the effect of high temperatures can be partially modified by irrigation.

Traditionally, coffee has been grown in areas of good rainfall. However, in most areas of Queensland coffee is being established in dry areas with either drip or overhead irrigation. Trees are established in full sunlight as opposed to the traditional use of shade.

Coffee is being grown in a range of climes and soils in Australia with the most suitable yet to be determined.

Cultivars

Initial plantings in Queensland were limited to cultivars available locally (Typica) or imported from Papua New Guinea (Bourbon, Arusha and Caturra). Additionally, some plantings have been made from seed of wild growing plants derived from the original plantations.

Newer plantings are concentrating more on Arusha and newer cultivars such as Mundo Novo, Catimor, and Catuai, selected from QDPI cultivar assessment trials.

Plant Protection

Australia is fortunate that it is presently free from the two most serious coffee diseases in the world, that is, coffee berry disease (*Collectotrichum coffeanum* var *virulans*) and coffee rust (*Hemileia vastatrix*). Coffee rust is now present in Papua New Guinea and could easily spread to Queensland despite stringent plant quarantine measures. However, a number of rust resistant lines have been introduced and control strategies devised in the event of a rust outbreak.

The only disease of consequence occurring to date has been Cercospora leaf spot (*Cercospora coffeicola*). This has been mainly a nursery problem and normally can be controlled by modifying nursery practices.

Insect problems have started to develop and are causing concern to a number of growers.

Green coffee scale (*Coccus* sp.), mealy bug (*Planococcus* sp.) and ants are the main problems. Withdrawal of effective pesticides for ant control has accentuated the situation.

Weeds have caused concern but are currently manageable.

Harvesting

The Australian coffee industry is unique because on all larger plantations most cultural operations (including harvesting) will be mechanised as opposed to traditional hand practices.

To facilitate mechanization of harvesting, coffee is planted at 1 x 4 m spacing (2,500 plants/ ha) from plants established in a nursery situation. For machine harvesting, a dry winter/spring period followed by heavy irrigation is essential to concentrate flowering and harvesting.

The choice of cultivar and mechanical pruning methods will have to dovetail with plans for harvesting. Plants are maintained as a single upright. Multiple leaders are not as effectively harvested. Appropriate pruning methods, that is, hedging, capping, and stumping, have yet to be resolved.

There are currently two harvesters in Australia: a fully imported Brazilian model, and a second fully automated machine which incorporates the Brazilian shaker mechanism and other improvements. The latter has been manufactured in Cairns by a local firm for one of the huger growers. Both harvesters are large, self-propelled straddle machines.

The harvesters have a shaker mechanism which removes the coffee berry by the lateral vibrating action of hundreds of fibreglass resin rods which are fixed radially to vibrating shafts. The vibrating action is achieved by two rotating eccentric weights located at the top of the vibrating shaft. The coffee berries are removed mainly by the vibration and short whip action of the fingers. Berries are then caught in a catching frame connected to a conveyor belt.

When correctly adjusted and driven by a skilled operator, the harvesters cause very little tree damage. Damage can be less than that which results from hand harvesting. Recovery rates are high and would appear to compare favourably with hand harvesting, that is, very little coffee is dropped on the ground.

Processing

The coffee berries are red or yellow (depending on cultivar) when ripe and 8-10 mm in diameter. For machine harvest, as many berries as possible must be ripe. Green unripe and black overripe dry berries are undesirable from a quality viewpoint.

Inside the coffee berry is the pulp and a parchment membrane which encloses the coffee or green bean (see Fig. 1). To obtain the green bean, the skin and pulp are removed by a combination of mechanical and fermentation means, followed by drying to about 11.5% moisture, and then hulling to remove the parchment and silver skin.

Coffee is generally sold as green bean, which is the stage ready for roasting. It normally takes six to seven kilograms of fresh picked berries to produce one kilogram of green bean.

There are two basic processing methods to obtain the green bean. The simplest method is 'dry method', where coffee is harvested overripe and then dried to 10-12% moisture. The dried skin, pulp and parchment are removed mechanically with a huller. The method produces 'mbundi' or 'raison' coffee, and is commonly used for Arabica in Brazil and with Robusta elsewhere. The resultant coffee is generally of a lower quality.

The most common method is the 'wet method'. Coffee is harvested as ripe berries, any mbundi floated off and the remainder passed through a pulper which removes the outer skin. The pulp or mucilaginous layer is then removed by a fermentating process, and the beans dried to 10-12% moisture. Once dry, the coffee is stored for several weeks, allowing equilibration of moisture in the seed, and then hulled and graded.

Most Australian coffee is processed according to the 'wet method' , or modifications of it. The best method (quality versus cost) for local conditions has yet to be determined. The method selected will depend to a large extent on the targeted marketing strategies of the industry.

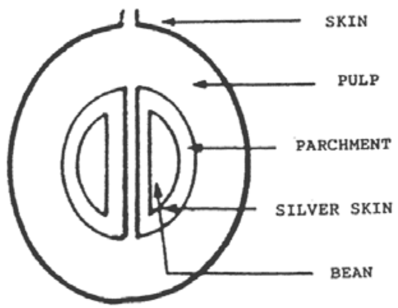

Fig. 1. Cross-section of a coffee berry

Economics

Coffee is not a quick return crop, due to the time lag before it starts producing and the high cost of plantation management. The lack of research and experience to develop cost-effective management strategies for the north Queensland environment makes the economics of coffee production difficult to predict. However, yields of greater than 2,000 kg green bean per hectare, with prices of $4/kg, have been proposed as benchmarks for a plantation of 20 ha to be profitable, where full costs are incurred (5).

Overseas yields of arabica coffee range from 300 to 4,500 kg/ha. In Queensland a yield objective of between 2,000 and 3,000 kg/ha of green bean is believed to be attainable.

QDPI Research

The initial coffee crops have been managed according to coffee growing literature or with the knowledge of people with coffee growing experience overseas. Unfortunately, many overseas practices have not worked under our climate and labour situations. All existing commercial plantings have experienced some agronomic and production problems. Yields have been disappointing and in most cases less than that required for economic success. Improved crop management to achieve a yield above 2,000 kg/ha is a high priority.

It has been recognized that considerable research and development is required to assist the successful establishment of this industry. In this regard, the Queensland Department of Primary Industries initiated a coffee research programme in Far North Queensland in 1982. This programme entered its second phase this year (1988) with special emphasis on developing coordinated projects on a broader range of key production, processing and marketing issues.

Cultivars

The initial aim of the programme was to import and select high yielding cultivars which would adapt to the region and be suitable for mechanical harvesting. Attainment of material possessing resistance to coffee rust was also an important criteria.

A total of 61 arabica and 10 robusta cultivars and selections have been established, firstly at Kamerunga Horticultural Research Station near Cairns, and in a replicated trial at Southedge Research Station near Mareeba. In the past three years, the better performing selections from these trials have been distributed for trial plantings in Innisfail, Atherton, Ayr, Bowen, Bundaberg, and the Northern Rivers area of NSW, as well as to growers. Planting in the various locations will help to determine the most appropriate areas and soil types for coffee production.

Data are being taken on growth rates, time and concentration of flowering, yield and of concentration of harvest. The resultant green beans are being sized and evaluated by QDPI and associated professional testers for cupping quality. Excellent yields have been obtained at Kamerunga, but yields at Southedge have been lower than expected. A number of promising lines such as Catimor, Catuai, and Mundo Novo have been identified and supplied to industry.

General Agronomy

The first trial and commercial plantings have revealed a range of agronomic management factors such as nutrition, weed control, insect pest management, pruning and training, irrigation methods and scheduling, sun scorch, overbearing dieback, and non-synchronized flowering and maturation, all of which will need to be addressed to optimise productivity.

It was initially felt, and subsequently shown, that nutrition, especially on the infertile granitic sandy soils of Mareeba, would be a problem. Consequently, a trial with nitrogen (3 rates), potassium (3 rates) and four cultivars was established. Strong responses to nitrogen with both growth and yield have occurred, Potassium application also has improved yield. The beans are being sized and cupping quality determined.

A programme has recently been initiated to develop better understanding of the growth and flowering mechanisms of coffee. The aim of this work is to synchronize coffee bud burst through a better understanding of the flowering physiology and to enable more precise plant manipulation through irrigation and growth regulators. This, along with selective mechanical harvesting, is felt to be a key research area and a prerequisite for efficient mechanical harvesting. Commercial results to date using timed irrigation alone to concentrate flowering have been erratic.

A programme has also been initiated to develop tissue culture for clonal propagation, thus allowing rapid multiplication of superior individuals and of rust resistant material if and when required.

A weedicide (Goal R) has been registered for use on coffee, and insecticides (Supracide R and White oil) for mealy bug control, while an integrated pest management programme for scale, mealy bugs and ants will be developed.

Engineering Aspects

Hand harvesting of small plantings for a gourmet or tourist market may be possible in some areas, as it has been in Hawaii. However, for any significant economic industry to develop, mechanical harvesting is essential.

The existing harvesters in Mareeba are expensive (more than $200,000) and likely to be beyond the reach of most small producers. QDPI, possibly in conjunction with NSW Department of Agriculture and private industry, plans to develop a small scale, tractor-drawn harvester for smaller coffee plantings. Development of greater selectivity in harvesting only ripe coffee is another priority area.

Coffee Processing

The traditional practices of handling and processing coffee berries have been developed in countries with low labour costs. Due to tradition, changes have been slow to develop.

QDPI believes that coffee processing can be further mechanized for Australian conditions.

Depending on the performance of harvesters in selecting only ripe berries, it may be necessary to develop selective colour sorting during processing to maintain qUality. A pilot scale 'wet processing' factory is also being developed at Walkamin Research Station to facilitate future R&D on engineering and quality aspects of processing.

Marketing

Thus far, little attention has been given to marketing of locally produced coffee. Some is roasted and packaged by individual growers, some is sold direct as green bean to gourmet outlets, and some is sold to major coffee companies.

An early marketing study and development of a market strategy would assist the industry to maximize its selling price and help focus research and development. The marketing tactics adopted by the Hawaiian processors, aimed at the gourmet and tourist markets, and maintenance of a premium regional brand name should be examined.

Summary

The Australian coffee industry is in its infancy and experiencing many of the problems associated with development of a new industry. Hopefully, the problems can be overcome and a significant local coffee industry developed. Replacement of 25% of imports would support a $40-50 million industry. Information from overseas based on traditional coffee culture is frequently not relevant to Australian conditions, and local expertise needs to be developed. Researchers, growers and processors have the opportunity to become world leaders in the development of a fully mechanized coffee industry.

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NEW PLANT PRODUCTS - USING AUSTRALIA'S GENETIC HERITAGE

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INTRODUCTION

In his essay 'On the Origin of Cultivated Plants', Vavilov in 1926 sought to explain the development and diversification of agricultural plants by proposing that they had developed from 8 centres of origin (46). Though his ideas have been modified over the years, and we now know that the pattern is more diffuse and complex than was originally envisaged, the complete omission of Australia from these conceptual models of plant domestication has implanted the idea that the Australian flora has nothing to offer.

It is true that the Australian Aborigines practiced virtually no agriculture, though for example their care for the plots which yielded yams has been termed 'proto-agriculture'. Replanting of the shoot portion to allow resprouting was widely practiced, sometimes reinforced by religious superstitions. The times of harvest were tightly controlled .and in places extensive areas were harvested. Near Hutt River, Grey in 1837 (14) saw an area several miles in extent where the number of holes from yam digging made it difficult to walk across the land.

The idea that the Australian flora has little to offer was thus generated from Vavilov's concepts of centres of domestication, the lack of agricultural activity on the part of the native inhabitants and the idea that they led a miserable existence during which, despite endless toil in search of food, they were constantly on the verge of starvation and wracked by disease. This concept has been challenged by studies which suggest that at least in some areas they may have enjoyed the 'original affluent society' in which both males and females tended to work for 2 days with every third day a holiday (38). As to why the Aborigines did not initiate agricultural activity we have this telling reply (3):

"You people go to all that trouble, working and planting seeds, but we don't have to do that. All these things are there for us, the Ancestral Beings left them for us. In the end, you depend on the sun and the rain just the same as we do, but the difference is that we just have to go and collect the food when it is ripe. We don't have all this other trouble".

It is interesting to find that a large number of the food plants used by the Aborigines are members of genera for which domestication has been successful elsewhere in the world(15). Thus there is potential for utilizing Australian species for improvement of cultivars developed overseas, and this applies not only to genera of food plants (Table 1), but also to those used for floriculture, industrial products or fodder. Genera that have been used in this way

include *Nicotiana*, *Glycine*, and *Gossypium* (29). Our knowledge of the genetic relationships between the Australian species and the cultivars needs to be investigated before we can assess the level of contribution that the Australian genomes might make.

It is estimated that there are some 25,000 species of seed plants in Australia. The tide of opinion is swinging towards the possibility for direct use of some of these plants, rather than just as contributors of genes to plants domesticated elsewhere. This opinion has been catalysed by popular programmes such as the TV series 'The Bush Tucker Man', newspaper articles, and the publication of several recent books on bush food (18,26) and medicine (9).

TABLE 1 : Some genera that include one or more species harvested for food by Australian Aborigines(15).

Acacia	*Cyperus*	*Grewia*	*Nymphaea*	*Solanum*
Adansonia	*Dactyloctenium*	*Haemadorum*	*Ocimum*	*Sorghum*
Aleurites	*Digitaria*	*Hibiscus*	*Oryza*	*Spondias*
Alocasia	*Dioscorea*	*Ipomoea*	*Oxalis*	*Sporobolus*
Amaranthus	*Dolichos*	*Lagenaria*	*Pandanus*	*Tacca*
Amorphophallus	*Eleocharis*	*Lepidium*	*Panicum*	*Terminalia*
Araucaria	*Eleagnus*	*Linum*	*Physalis*	*Trigonella*
Boerhavia	*Eleusine*	*Loranthus*	*Piper*	*Typha*
Bowenia	*Eragrostis*	*Lucuma*	*Podocarpus*	*Vigna*
Calamus	*Eriochloa*	*Luffa*	*Polygonum*	*Vitex*
Canavalia	*Eucalyptus*	*Marsilla*	*Portulaca*	*Vitis*
Capparis	*Eugenia*	*Mucuna*	*Rubus*	*Zamia*
Chenopodium	*Ficus*	*Musa*	*Rumex*	*Zizyphus*
Citrus	*Gastrodia*	*Nasturtium*	*Sambucus*	
Cucumis	*Geranium*	*Nelumbium*	*Sesbania*	

This paper will look at the reasons why the time is now ripe to more fully explore the Australian flora for species worth domesticating, the range of products possible, the time frame and cost of developing new products, and the problem of protecting our 'genetic heritage' .

INCENTIVES FOR RESEARCH AND DEVELOPMENT

With the increasing world population it might be argued that additional and alternative food sources are required. This is not a strong argument , as food distribution rather than food production needs to be improved, and if we were really serious about producing more food we could do so immediately by stopping producing nonessential crops such as tobacco, coffee, tea, and cut flowers (16) or investigating leaf protein more thoroughly. However, in affluent societies there is a move to a more vegetarian diet, and pressure to provide new foods and flavours.

In Australia there is a desire to develop an Australian culinary identity, as much for the benefit of tourists as for the locals. It would be ironic if the food of the Aborigines, who could be described as people who "eat to live", becomes the food of the foodies who "live to eat". However, some of the potential new food products are able to grow in the rangelands controlled by Aborigines. We have therefore the possibility of improving the nutrition of these people by encouraging the cultivation of traditional foods·and adding to the income of communities by sale of cultivated and bush-collected foods. Another market pull is towards natural, rather than synthetic colours and flavours (even if, as scientists, we may sometimes think that this consumer preference is irrational). There is also a growing demand for other 'natural' products such as insecticides or drugs.

A second reason to believe that it is timely to invest in domestication of native plants is the deterioration of the environment, even without superimposing the predicted effects of the CO_2 increase and the damage to the ozone layer. The problem of supplying water to Australian cities means that greater use should be made of arid-zone species in the landscaping of domestic and public amenities landscaping. The destruction of forests through acid rain or indiscriminate logging means that fast-growing Australian species have a role to play in plantation forestry.

Thirdly the small share that Australia presently holds in the world market for floricultural products (0.06%) and the importance of novelty in this market means that there is great potential for development of new floricultural products. With our current knowledge of breeding through selection and hybridization, manipulation of the genome, propagation through conventional and *in vitro* methods, we are surely in a good position to capitalize on the opportunities available.

AREAS OF GENETIC RESOURCES

Food

It is in the area of food that a lot of publicity has recently been focussed. Bush foods are already in use (32). In Sydney, Rowntrees restaurant has a 'theme' of bush food, and Qantas has featured wattle-seed ice cream, and lamb with the plum from *Podocarpus elatus*. Other companies such as Kurri- Kurri Foods produce jams and chutnies, and bush food has been used as a promotional feature overseas for tour advertisements or sale of Aboriginal art. Those who promote use of bush food are keen to secure regular sources of supply and to avoid devastating bush harvesting.

Where might success be most quickly found?

I suggest that nuts or other hard woody fruits that transport and store well might be easiest to develop and market. The only domesticated Australian food plant, the Macadamia (*M. integrifolia* and *M. tetraphylla*), gives encouragement, even though it must be remembered that present success with Macadamia is related to the fact that it has been in cultivation now for almost 100 years, having been planted in Hawaii about 1892. Other species of Proteaceae with potentially good nuts are *Athertonia diversifolia*, said to have an excellent flavour similar to Macadamia; *Hicksbeachia* (ivory silky oak or monkey nut); and for drier areas *Grevillea annulifera* which has small seeds similar to almonds in texture and taste. The seeds of many other species of Proteaceae are disappointing, often being bitter because of cyanide or insipid to taste. It is impossible to know if cyanide-free mutants of species at present unpalatable would be tasty, although investigations of *Macadamia whelanii* and *M. praealta*, which have very large, exceptionally bitter, nuts up to 5 cm in diameter, would seem worthwhile (18,22).

From other families, species with potential include *Sterculia quadrifida* (bush peanuts) and *Araucaria bidwillii* (bunya pine). Other species from which toxic compounds would have to be removed during domestication are the bush cashew (*Semicarpus australiensis*), the kurrajong, and sandalwood. The difficulty of extracting *Pandanus* seeds makes it unlikely that these would ever be domesticated, even though they were highly regarded by Aborigines (18). The advantages that nut crops have in keeping and transport qualities, low bird predation, and the possibility of use in agroforestry, are somewhat outweighed by difficulties of harvesting, and the long generation time in any improvement programme.

Many native fruits have common names like quince, plum, cherry peach and so on, but with the exception of figs (*Ficus*) and raspberry (*Rubus*) they have no botanical relationship to their exotic namesakes, and only the faintest resemblance in appearance or taste. Some of the soft fruits of the Australian bush are only edible when over-ripe, and this makes them difficult to market except for eating directly off the bush. Many have a degree of bitterness, sourness and fibre that is not acceptable and would require a long period of breeding to improve. There is a world of difference between 'edible' and' saleable' .

Despite this, a fleshy fruit will soon be released. Peter Hardwick of Wilderness Foods in Byron Bay, NSW, is releasing a selection of *Carpobrotus* called Noolli (which certainly sounds more attractive than pigface), which has been selected for juicy fruits with a long stem to enable harvesting. It is said to taste like a cross between a strawberry and a kiwifruit, bears 8-12 months after planting, and is drought and salt tolerant (32). A company run by Vic Cherikoff called North Australian Resources has started plantations of billy goat plum, *Terminalia ferdinandiana*, a rich source of vitamin C.

The quandong is a species into which CSIRO's Division of Horticulture has put considerable effort for improvement of the flesh (34,39). Initially the kernel too was being developed as an alternative product, but methyl benzoate can give some nuts a most objectionable aftertaste, and questions about the safety of consumption of some of the unusual fatty acids (e.g. santalbic acid) in the oil of the endosperm has made development of the nut doubtful (Dr G Jones, Deakin, pers. comm.).

Analysis of native foods has shown many to have high nutritive value (5), but it is likely that in 'improving' the fruits and seeds, food value may change. For example, when cereals are selected for increased seed size, this is usually as a result of increased endosperm, and therefore accompanied by a fall in relative protein content. Similarly improvement of sweetness of native fruits may well lead to a drop in overall nutritive value.

The problem of the toxic properties of many bush foods, and the understandable reluctance of the modem consumer to spend days leaching, baking and otherwise detoxifying products leads me to the point that when introducing a new food one must be certain that it contains only low, or no, toxic or carcinogenic compounds. Interestingly, both in Australia and America (21) the guidelines for the introduction of new food additives appear more rigorous (involving a requirement for toxicological and pharmacological testing) than those for the introduction of anew food plant. The fact that the plant has been commonly used in diets is helpful. Rightly or wrongly, use in traditional Aboriginal diets is probably nor given as much weight as use in western diets. However, the distinction between a food and a food additive is blurred. *Terminalia* plums are a food; these plums in a chutney are a food additive.

One approved food additive derived from the Australian flora is beta-carotene from the alga *Dunaliella salina*. The salt lakes of Australia have provided the selection screen for high yielding lines that are now grown commercially by two companies and provide exports worth over $2 million each year (4). To be legally safe in introducing a new food, one must first ensure that it is produced and handled under hygienic conditions (bush collected food might be a little suspect in this regard), and then apply to the National Health and Medical Research Council for assessment of the new food.

An instructive example of a new crop being re-introduced into Western diets is the Sweet White Lupin. The Western Australian Health Food Standards Regulations state that lupin flour shall not contain more than 200 mg/kg of alkaloids, but in order to satisfy overseas trading partners that John Gladstone's cultivars are so low in alkaloids that they are safe for human consumption, the Grain Pool arranged for samples to be examined by an internationally recognized toxicological body - the British Industrial Biological Research Organization. Following WHO criteria, tests were carried out, such as 90 day feeding trials with rats and AMES tests with *Salmonella* for mutagenesis (Michael Jackson, Health Dept. WA, pers. comm.). For an important crop like lupins the 50,000 pounds sterling needed for this testing was a good investment; it is doubtful that producers would be able to afford such expense for minor food crops.

Another method which gives some slight legal protection is to warn the consumer of possible danger. However, while we have more and more stringent regulations about food additives, ego the level of erucic acid in rapeseed oil, the level of trypsin inhibitor in soybean meal, etc, it is unlikely that we will be able to introduce new food plants with little restriction.

Drugs

It is in this area that success is most problematical. The odds against a new active compound becoming a drug that meets present-day standards are about 3000 to 1 (13). Drug companies need considerable resources to be able to carry out the exhaustive investigations of mutagenicity, teratogenicity, animal toxicology and clinical studies associated with promising compounds. The compounds have to be shown to be both safe and effective. The initial research costs may be a surprisingly small part of the total cost.

A recent estimate of the timing and cost of bringing a new product to the initial sales stage showed 3 years of development and testing ($13.3 million) followed by 9 years of organization of sales and market start up ($12.0 m) and manufacturing start up ($30.0 m) (44). The cost of introducing a new compound for veterinary use, for the health food market, or as a nonprescription medicine is rather less, but still considerable. Researchers who have identified promising compounds from the Australian flora may therefore experience great difficulty interesting pharmaceutical companies in developing their results further. This has been found by Dr Gwyn Jones of Deakin University, who discovered that the quandong kernels used by Aborigines to treat scalp wounds have active compounds, but that support for further research on the medicinal properties has been hard to gain.

Between 1974-1981 a Swiss Company, Roche, surveyed the marine algal flora of Australia and found a large number of active compounds of therapeutic value. In this case the research has not yet been followed through because the company withdrew support when it had to restructure due to a totally unrelated problem - Valium (2,35).

When the flora is surveyed for new drugs, the intention is wherever possible, to chemically synthesize the compounds discovered rather than to set up plantations and have supply subject to the vagaries of climate, pests and political change. Thus the agricultural and horticultural industries may not benefit even if an AIDS cure were found in Australian plants (American scientists at Beltsville and Bethesda are strongly interested in *Castanospermum* for this purpose). Only 25% of drugs used in America are of natural plant origin.

That there are useful drugs in Australian plants no-one doubts. There are species known to have antibiotic properties, to control dysentery, or to contain useful alkaloids and contraceptives (18). It is interesting that species common to Arnhem Land and the Indo Malaysian region very frequently (89% of species) are put to the same medicinal use by indigenous peoples.

The Australian drug plants that are harvested commercially yield compounds that are the same or similar to those already accepted in medicine - they do not produce compounds unique to the Australian flora. Examples are *Duboisia leichhardtii* and *D. myoporoides*, whose leaves yield scopolamine, hyposcyamine and other alkaloids; *E. macorhynchia*, which yields rutin (a product which may not survive competition with the Chinese product from *Sophora japanica*); and *Solanum aviculare* and *S. laciniatum*, which are widely planted in Russia for steroids and are probably the only Australian plants to appear on a Russian postage stamp (9).

One interesting apparent omission in the range of bush products are effective insecticides. The Aborigines appear to have used smoke as a deterrent against flies in wounds, and have not used plant substances to avoid pestering by flies or other body parasites. This is in contrast to natives of Africa and Central America (31). Perhaps the use of plants for insecticides develops along with agriculture and the need to control pests on cultivated plants, domestic animals, and in stored food.

Forage

The highly salt-tolerant perennial shrubs in the genus *Rhagodia, Kochia*. and *Atriplex* are recognized as valuable fodder with good palatability and high protein content (47), and exceptional tolerance to dry and saline conditions. The South Africans have developed a cultivar of old man saltbush, *A. nummularia* (cv 'de Koek'), which has been re-introduced into Australia and is popular around Dubbo. Research in Western Australia by Clive Malcolm, however, indicates that selections of *A. amnicola* from the Gascoyne and Murchison River basin region have even more potential. Two cultivars have been developed, Meeberry and Rivermore.

In the book 'Under-Exploited Tropical Plants with Promising Economic Value'(33) another Australian species is included - *Cassia sturtii*, which has been found to have potential as a fodder shrub in the Negev in Israel, yet is rarely grazed by cattle or sheep in Australia. One wonders whether there are hidden long-term problems with this species, or perhaps if the animals have a different rumen flora enabling them to utilize this species in Israel but not in Australia.

Seaweeds and Seagrasses

The marine flora is often neglected when considering our genetic resources. Reference has already been made to the commercial use of the salt lake alga *Dunaliella*, and the survey of marine algae for drugs. The Aborigines made little use of algae, occasionally eating brown or green algae and using fibre from sea grasses. Other cultures, particular in Asia, make extensive use of seaweeds as sources of food, medicine, animal fodder and agricultural fertilizer. In Australia at present there is only a cottage industry, on King Island in Bass Strait, where the bull kelp *Durvillea* cast up on the beach is harvested for alginate. Trawling for seaweeds is very costly, but seaweed farming using mesh and rafts is common in Asia. An Esperance company, Australian Underwater Research and Development Investigations, is establishing feasibility trials of 'farms' of *Gracilaria* for agar production at Albany.

Another technique that may be even more valuable is growing macroseaweeds on land on shelves provided with a fine mist of seawater. Annual yields of up to 140 dry tons per hectare have been recorded (27). The seagrasses occasionally elicit interest for harvest of the durable fibres in their leaf bases, both preserved in the sediment and from living stands. During the war the possibility of harvesting *Posidonia* from South Australia was investigated, but it was decided that the resource base was too small for continued commercial viability. Today the environmental degradation that would result from destruction of the seagrass beds would be unacceptable.

With predicted changes in sea temperature and sea levels, long-term investment in mariculture may be risky.

Plants for Floriculture, Ornamental Horticulture, and Turf

The high potential of many native species for the floriculture and nursery industry is shown by the diversity of species and volume of material bush-harvested (7,36,37), and the increasing enthusiasm for cultivating native species as described in several books (12,23,46) and a recent conference 'The Production and Marketing of Australian Flora', conducted by the W A Department of Agriculture. The size of the world market in cut flowers (around $US2S,OOO million), the need for novelty in the market, and the range of beautiful species in our flora, leaves no doubt that many Australian species could repay cultivation. John Considine's recent paper at ANZAAS(8) described the criteria which must be applied to the abundance of available material so as to select those most likely to succeed in the world market (Table 2).

TABLE 2: Criteria to use to select plants from the Australian flora most likely to be successful as cut flowers or pot plants(8).

Soft
Small
Attractive
Low Scent
Long lasting
Cold tolerant
Disease tolerant
Low allergenicity
Variety of colour forms
Herbaceous or small shrub
Controllable flowering season
Simple agronomic requirements

It is in the area of floriculture, in kangaroo paws, that we have a good example of a successful recent domestication. In WA, Steven Hopper and Keith Oliver investigated the range of form in the various species of *Anigozanthos* and the hybridization possible. This was complemented by breeding work in the Eastern States by Merv Turner and at the University of Sydney. The discovery that fast mass propagation of superior clones was possible launched the product. The *in vitro* work was done by Ellyard at the Canberra Botanic Gardens, and Stuart Newton and myself at Murdoch. Phil Watkins and Linda Penny at the WA Department of Agriculture, and Peter Goodwin in Sydney, then did research on the cultivation practices for these plants. Work has also been done on disease resistance by Dr Sivasithamparam at the University of W A, and by the W A Department of Agriculture on market research and post harvest physiology.

Research in private companies such as Plantex (Aust) and Biotech Plants has led to the release of new cultivars better adapted as cut flowers (e.g. cvs Big Red, Big Yellow and Harmony) or to pot-plant production (e.g. cv Mini pearl, the Bush Gems range, and the Bicentennial Kangaroo Paw), and refinement of the *in vitro* propagation methods. This example shows the level of input that is necessary both for the breeding and commercial cultivation of a new product, and the benefit of open access to research results. In developing other species or groups of species even more effort may be necessary - kangaroo paws domesticated relatively easily.

Many other Australian species are being investigated for use as foliage plants for interior decorating, and some grasses are being investigated which may reduce the necessity for mowing (*Danthonia* and *Pennisetum*), or which are tolerant to brackish-saline irrigation water (*Distichlis distichophylla*).

Wood and Paper Pulp

The development of so-called paperless office systems has not reduced the demand for paper pulp. It is estimated that by 1997 the demand for pulp in Japan will have doubled to 5.5 million cubic meters per annum. The requirement for firewood too is important, being particularly high in developing countries. In SE Asia many countries have already cleared more than 50% of their forested areas(1) and you are all aware of the environmental damage and social conflict being caused by logging. In response to this Thailand has curtailed all harvesting from native forests, and is encouraging other countries to do the same. Many countries are setting up plantations of both native and exotic species. Australia was one of the later countries to start eucalypt plantations (17,48) with the result that we are only now beginning to have available superior selections from the first harvesting cycles. Experience overseas indicates that cloning superior trees can dramatically improve yield and reduce the harvest cutting cycle time, but it must be complemented by conventional breeding to ensure the long-term improvement of plantations (25,30).

At Murdoch we have been part of a team effort involving CSIRO, UWA, Plantex (Australia), and PPM, with Alcoa as co-ordinator, to select and clone superior pulp trees (*Eucalyptus globulus* and E. nitens) and trees resistant to saline waterlogging (*Eucalyptus*, *Acacia*. *Melaleuca* and *Casuarina* species) and mycorrhizal fungi appropriate to these species(19). This research has indicated the feasibility of utilizing our genetic resources in this way, and we are now at the stage of putting in field trials in Australia and overseas, and surveying the export market possibilities with aid from an Innovative Agricultural Marketing Programme grant.

The Western Australian CALM/Hardwood Share-farming Scheme, to plant at least 100,000 hectares over 10 years with *E. globulus*, offers local farmers an opportunity to invest in pulp production and at the same time help control the salination of our water supplies(40). The salt tolerant species that we have selected will have the effect of reducing salt encroachment and could provide valued firewood from wasteland in developing countries.

One worrying feature is the development of an anti-eucalypt lobby, apparently originating in the Indian state of Karnataka in the early 80's, and being propagated by journalists and environmentalists. The thrust of their argument is that eucalypts increase water runoff, prevent undergrowth, do not enrich the soil, consume water copiously and lower the water table, and poison the soil; in short that eucalypts do nothing but environmental harm. Unfortunately papers disproving the claims, and showing how species might be selected depending on whether or not one wants to lower the water table (eg.10, 11), have not been given as much exposure as papers promoting the bad image.

Tannin

Annual world production of tannin is at present around 350,000 tons. A large proportion comes from South Africa, where the Australian species *Acacia mearnsii* (black wattle) has been grown in plantations since 1884. The product is used not only for tanning hides, but extensively for adhesives and resins. However, it is likely that even if political instability in South Africa led to a breakdown in supply, Australia would not be able to compete to fill the market, as other countries with cheap labour, such as India and Thailand, are already establishing plantations of this Australian species.

Eucalyptus oil

It is surprising that Australia is a net importer of *Eucalyptus* oil, exporting high cineole oils, but importing industrial grade oils, mostly from Spain and Portugal. Some of the oil is re exported after blending with the local product(24). *Eucalyptus* oil was perhaps Australia's first industrial product, a sample from *E. piperita* being shipped from Port Jackson in 1788. Current production is largely from *E. polybractea* in natural stands. Research at Murdoch by Alan Barton has examined within- and between-species variation in oil content and composition of a large number of West Australian species. Promising species that are good or better than *E. polybractea* include *E. kochii* subsp. *kochii* and *plenissima*(6), and seedlings from selected trees have been planted in field trials at the Wongan Hills Department of Agriculture and on private land.

At present the establishment of plantations solely for the purpose of producing oil cannot be justified financially (41) and experience elsewhere shows that a combination of harvest for wood and oil from the same plantation is rarely successful. Thus although *E. globulus* is the basis of the South African oil industry, it is unlikely that we can combine the CALM *E. globulus* plantations for pulp with harvest of oil from leaves. However, planting of high oil eucalypts in catchment areas for salinity control may be a viable option. Certainly there is world-wide interest in the product, as some 25 patent applications are filed each year involving *eucalyptus* oil or cineole. Australia should be able to gain more than 10% of the annual $20 million market for cineole for the pharmaceutical industry.

Other Essential Oils

The *Melaleuca* oil industry has the potential to develop into a $20-25 million industry within 8-10 years(42). Teaco International of Santa Barbara California report that their monthly sales have risen from below $1,000 per month in 1987 to over $100,000 per month. Based mainly on *M. alternifolia*, the industry is at a transition stage from harvesting from natural stands to plantation production. Apart from its well-known bacteriocidal activity, the oil is used as a perfumery toner and nutmeg substitute(42).

The beautifully-perfumed Western Australian *Boronia megastigma* is collected from the wild, but it is possible that harvesting from the wild will be phased out. Plantations have been established in Victoria and Tasmania, and more recently in Western Australia. The oil is used in cosmetics and as a food additive to give fruit-type flavours. The University of Tasmania together with their state government and private enterprise has set up a company, 'Essential Oils of Tasmania' , which is conducting a programme of research and development for crops including *Boronia*, for which they have developed several cultivars with desirable plant architecture for mechanical harvesting, and with different oil characteristics for perfumery(20). *B. purdieana* and *olearia* are also being investigated and numerous species hold promise(28). However, it may be necessary for growers to combine resources to carry out the necessary scientific and market research and the advertising. The cost of flower production from plantations has to be lowered to make sale of flowers for oil economic, and further use of the oil as a food additive promoted, as 'Essential Oils of Tasmania' claim that they will be filling 95% of the world market requirement for perfume oil by 1990. Growers in Western Australia have not yet decided whether the long term future of their plantations is for oil or cut flowers.

Hydrocarbons

Numerous Australian species contain appreciable levels of 'hydrocarbons' or 'resins' and every time there is an oil crisis interest in these species rises, particularly if one is looking for plants capable of growing in the more arid areas, where their development would not compete with more conventional agricultural crops. Data are limited, but it appears that exotic species such as guayule (*Parthenium argentatum*) offer more potential than any Australian species, and that if agricultural land can be used, oil seed crops are more competitive economically(43).

PROTECTION OF AUSTRALIA's PLANT GENETIC RESOURCES

Australia's Gift to the World?

Agricultural production in Australia is at present almost completely dependent on exotic plants and animals domesticated elsewhere. It has been traditional for Australia to export seeds or plants of Australian material freely for scientific research, for aid to overseas countries, or as gifts to cement sister-city relationships (e.g. *Brachycome multifida* from WA to Hyogo Prefecture in Japan). It is difficult to quantify the flow as it comes from seed export companies, botanic gardens and herbaria, agriculture and forestry departments, CSIRO, and Universities. For example, the CSIRO Seed Centre despatches some 14,000 seedlots p.a., 55% to overseas countries.

Opportunities have been lost in the past through lack of vision (*Macadamia* to Hawaii, *Solanum* to Russia, Waratah to New Zealand) or lack of cheap labour (*A. mearnsii* to South Africa, and *Eucalyptus* to various countries). For some of the products being developed now in floriculture and forestry, parallel development of these industries overseas may complement activity in Australia by making products available over a longer time period or in greater volume than we are able to provide.

Thus, I would suggest that a ban on export of genetic material is unlikely to be universally popular and impossible to enforce. Exchange of material for the purpose of basic research will always be necessary and the distinction between basic, applied and commercial research are becoming more and more indistinct. The alternative strategy of a vigorous programme of research and development that provides leadership in commercialization and ensures a continuous flow of new improved material onto the market is one line of defence.

Plant Variety Rights

The introduction of Plant Variety Rights gives another line of defence, as it has provided incentive for breeders to develop cultivars of Australian plants, and will result in new lines being placed on the market in an orderly way, with potential users being given adequate data to assess the qualities of the new lines compared with older related varieties. The initial legislation had a severe drawback for breeders associated with horticulture, forestry and ornamental plants, in that asexual propagation of registered varieties was not prohibited if the

product of the plants (fruit or flowers) were sold and not the plants themselves. It is likely that the legislation will be modified to give the breeder control over asexual propagation (plant Varieties Journal 2(1), while not precluding farmers from keeping seed for the next year's crop. Plant Variety Rights cannot, of course, be given to collections taken from the bush, some deliberate breeding must have been imposed. The timetable for inclusion of genera of Australian native species means that some are already covered and that all should be covered by mid 1990 (Table 3).

TABLE 3: Proposed Timetable/or Inclusion of Genera in Plant Variety Rights Regulations

(Plant Varieties Journal 2(1) 1989)

April 1988	*July 1988*	*January 1989*	*July 1989*	*March 1990*
Anigozanthos	Artanema	Acacia	All fruits	All native
Macadamia	Chamelaucium	Callistemon	nuts and	ornamentals
	Decaspermum	Casuarina	herbage	
	Eucalyptus	Dubosia	Banksia	
	Grevillea	Dryandra	Boronia	
	Lechenaultia	Macropidia	Carpobrotus	
	Melaleuca	Piper	Darwinia	
	Orchids	Teleopea	Pimelia	
	(all genera)	Thryptomene	Verticordia	

It is appropriate that in February 1989 the first Australian Plant Variety Rights were granted to H., M. and D. Bell for two varieties selected from seedlings of a hybrid *Macadamia integrifolia* x *tetraphylla* (Varieties Hidden Valley A4 and A16). Applications accepted but not yet finalized include a kangaroo paw selected from seedlings, possibly from *Anigozanthos bicolor* and *A. humilis* (variety Firefly); and three varieties of *Lechenaultia* - the imaginatively named *L.formosa* varieties Fantail Flamingo and Fantail Starburst, and *L. formosa* x L. *biloba* hybrid Fantail Ultraviolet, all bred by G. Lamont of the NSW Department of Agriculture (Plant Varieties Journal 1(2), 1(4). I look forward to the day that Australian breeders patent a cultivar of a New Zealand species, to retaliate for the New Zealanders patenting Waratah as Kiwi Rose.

There are still some problems to be solved with Plant Variety Rights. It is difficult to register a dioecious variable strain such as *Atriplex* as it is hard to define it morphologically, even though it may have some highly desirable characteristics such as salt tolerance or ability to volunteer from seed. There is also a problem with forest tree clones where a large number of clones should be included to keep up the diversity of the long-lived species. The plants are devoid of morphological markers and will need to be described on the basis of laboratory techniques. Isozymes have been used to help define varieties but as yet no variety has been approved on the basis of DNA fingerprinting. Further, it will be unnecessarily cumbersome to register each of perhaps 50 clonal lines which may be required for clonal diversity; the group of clones will have to be registered together.

SUMMARY

Only a small proportion of the 25,000 species in the Australian flora are being utilized commercially, and some of these are more highly utilized outside Australia. The recent media exposure of Aboriginal foodstuffs and medicines has given rise to somewhat unrealistic expectations of riches to come from the introduction of such native products. These expectations have to be tempered with the realization of the problems of regulation by the NHMRC on food and food additives and the high costs for introduction of a new drug.

The genetic resources in the Australian flora will most easily be turned to profit from use of native plants in floriculture, ornamental horticulture, forestry, forage, and essential oils.

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[Based on a paper presented at the 5th Australian Agronomy Conference, Perth, February 1990]

NATIVE FRUIT TREES OF SOUTHERN BRAZIL

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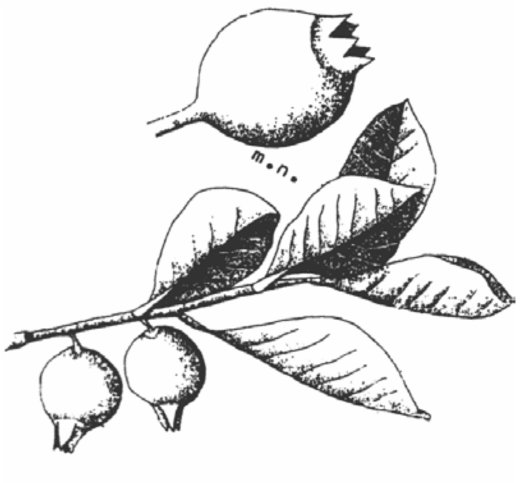
The three southernmost states of Brazil, which are Paraná Santa Catarina, and Rio Grande do Sul, are subtropical, extending south from the Tropic of Capricorn to around 34°S latitude. As they lie on the east coast of the continent, they are roughly comparable to the east coast of Australia from Rockhampton down to Sydney.

Also similar to Australia, the land rises from the coast up to low mountains and plateaus, which attain a maximum of about 2000m in height. So it would not be unreasonable to expect species from the list of native fruits which follow to grow in comparable subtropical areas of Australia [Editor].

CHERRY GUAVA, ARAÇAZEIRO (*Psidium cattleyanum* Sab.)

This is a tree of variable size, which, according to growing and climatic conditions, can vary from 1.5 to 5 m in height. The fruits are globose yellow or red berries, tasty, with a diameter of about 1.5 cm. The plant is found in South and Southeast Brazil, Uruguay and Argentina.

This species has a variety with pear-shaped fruits - botanically it is known as *Psidium cattleyanum* var. *littorale* (Raddi) Mattos.



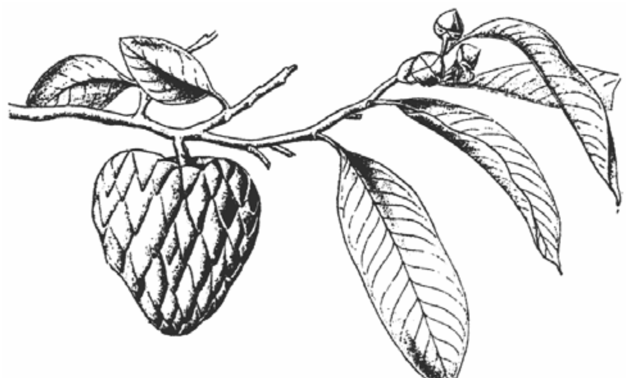
Psidium cattleyanum

BUSH GUAVA, COUNTRY ARAÇAZEIRO (*Psidium australe* Camb.)

This araçazeiro is found in the field on clay or clay-silica soils, excluding rocky places. It is a sub-bush, 30 cm high, and fruits heavily. Generally it forms stubs and has a lignotuber type growth. The fruits are delicious, with a yellow-green colour, glabrous, smooth, globose, about 2cm across. The plant is found on the uplands and the central depression of Rio Grande do Sul state, and on the upland prairies of Santa Catarina State.

ARITICUM (*Annona cacans* var. *glabriuscula* Fries)

The Ariticum is a member of the custard apple family (Annonaceae) that is found from Rio Grande do Sul to Rio de Janeiro States on coastal land. It forms a tree about 7m high. The fruit is about 10 cm across. The pulp is tasty and sweet, but with purgative proprieties.



Annona cacans

MONKEY BANANA (*Porcelia macrocarpa* Mart.)

This is another Annonaceae that could be interesting for orchards. It is a branching tree, about 6m in height. It is found along the southern Brazil coast, and on the north of Santa Catarina Island. There is a tree in full production in the Botanic Garden in São Paulo. The pseudo-fruits are found on the extremity of a long and thick peduncle, similar to a banana cluster. Each one is like a small banana fruit.

BAPORETI (*Myrciaria rivularis* var. *baporeti* (Legr.) Legr.)

This member of the Myrtaceae is found only in the west of Rio Grande do Sul state and in northeast Argentina, in a very restricted area. It is a small tree which produces black, globose, smooth, fruits, the size of large grapes. The fruit is sweet and tasty.

BUTIÁ-DA-SERRA (*Butia eriospatha* (Mart. ex Drude) Beccari)

This palm tree is typical of some upland areas of Santa Catarina State. Its height varies from 3 to 6m, and fruiting is heavy. The fruit is yellow, with the size of a cherry, but with a bigger stone. The pulp has some acidity, but it is tasty, depending on the sugar level of the particular variety. It is used for making home-brewed liquor.

WILD CHERRY (*Eugenia involucrata* DC)

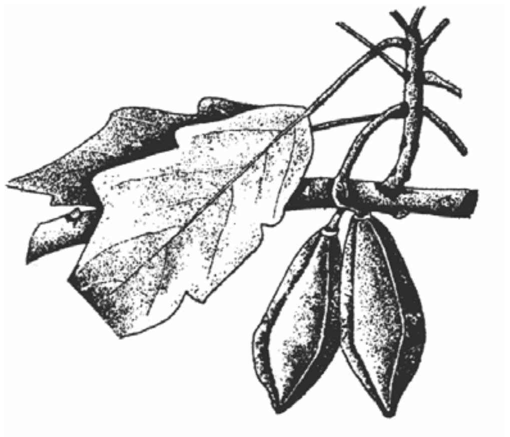
A tree of medium size, with a height varying from 10 to 15m, but with slow growth, taking a long time to start to produce. It is found in the southern part of Brazil, with an extensive but irregular distribution.

The fruit is very similar to the commercial cherry of the Rosaceae, but generally has two seeds, and shows highly characteristic bracteoles at the base. The taste is characteristic and highly appreciated.

FEIJOA, GOIABEIRA SERRANA (*Acca sellowiana* (Berg) Burr.)

This fruit of the Myrtaceae is native to part of Uruguay, and to Rio Grande do Sul, Santa Catarina, and Paraná states in Brazil. It is a fruit tree that has been improved and cultivated in different places around the world, mainly in New Zealand, which already has 500ha in commercial orchards. The fruit is a green berry, with size and shape variable, and can weigh up to 200g per fruit. The pulp is ice colour, tasty and succulent.

GUAVIROBEIRA, GUABIRABA (*Campomanesia guaviroba* var. *insulae* (Legr.)) This fruit of the guava family is found on coastal land, from the north of Rio Grande do Sul state to the south of Santa Catarina Island. The fruit is a orange-yellow berry, very tasty, with size of a jaboticaba fruit (2-3cm), probably the biggest and the best of this genus.



Carica quercifolia

SMALL FOREST PAPAYA (*Carica quercifolia* Solms.)

This is found from Rio Grande do Sul to São Paulo state. It is a plant of forests and brush woods , and fertile soils. It grows in the Cfa and Cwa climate types (Koeppen classification). It is a small tree from 2 to 4 m of height, with a soft trunk. Its fruits are sweet and tasty, with the form and shape of papaya (pawpaw), but in miniature .

STONE PASSIONFRUIT (*Passiflora foetida* L.)

This species and its varieties are found over almost the whole of Brazil, except on the seacoast and the Amazon. On the uplands of Rio Grande do Sul and Santa Catarina states this Passifloracea is found in stony places (hence its common name) and in the fields, growing close to grain plants. It has very short trunk and shoots, bushy, but highly productive. The fruits are delicious, with a green colour, a clear tonality and slightly yellow. The surface is very hirsute.

MARACOCK (*Passiflora elegans* Sims.)

This plant is a robust climbing passionfruit, and is highly productive. It is found in the southern part of Brazil. Its fruits are round, delicious berries, about 2.5-3cm in diameter.

PRAIRIE PEACH (*Hexachlamys humilis* Berg)

As its common name indicates, it is found in the native prairie, in a large area, but discontinuous. Thus, it is found in the southeast of Rio Grande do Sul, the north of Paraná, and the interior of São Paulo state. The plants grows to around 15 cm in height. It yields 1-3 fruits on each small plant. Its fruits are big and pear-shaped, about 2.5 - 3 cm across. It is similar to Forest Peach. It has a juicy pulp. The plant can be grown in pots.

FOREST PEACH (*Hexachlamys excelsa* (DC) Mattos)

This fruit belongs to the Myrtaceae family. It is a tree that can reach 10 m in height and is highly fruitful. It is found from the South of Rio Grande do Sul through to São Paulo and Mato Grosso states in Brazil, and also in Uruguay, Argentina, Paraguay and Bolivia. This species has the largest distribution in the genus.

It is found in many soil types, from sandy to clay and stony, but always in fringe forests, hillside forests and rarely in 'cerrado' type forest. It grows in many climates, but mainly in the Cfa and Cwa systems of the Koeppen classification.

PITANGA, PITANGUEIRA (*Eugenia uniflora* L)

In fertile soils this tree can reach more than 6 metres in height. It is found on the southern seacoast and uplands of Brazil, and also extends to Uruguay, Argentina and Paraguay.

The fruit is a small red berry of variable size and shape, weighing about 5 g. It has a very thin skin, and low pulp yield due to the size of the seeds. It has a characteristic flavour, sweet and pleasant. It is used also in alcoholic drinks and jellies.

Eugenia uniflora

PRAIRIE PITANGA (*Eugenia pitanga* (Berg) Kiaerskcu)

This small pitanga is found in Rio Grande do Sul state, in Alegrete, Cacequi, São Francisco de Paula, and Santana do Livramento counties, in siliceous and related soils. It reaches a height of around 15 cm. Its fruits are like those of *Eugenia uniflora* in shape, flavour and colour. It is a hardy plant due to its lignotuberous root.

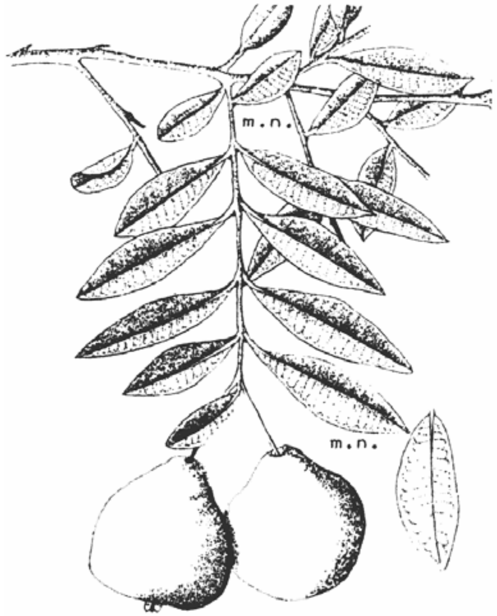
SETECAPOTES (*Campomanesia guazumifolia* (Camb.) Berg)

Of the species that have this common name, this is the one that produces the best fruits. It is a small tree from the Araucaria forests. It produces very early in fertile soils. Plants observed in cultivated conditions, with a height of 1.3 m, already produce in abundance. The fruit is a yellow pubescent berry with a flat shape and the size of a plum.

UVALHEIRA (*Eugenia pyriformis* Camb.)

This is a tree that reaches about 10 m in height. Its geographic distribution extends from Rio Grande do Sul to São Paulo state in Brazil, and to northeast Argentina and eastern Paraguay. The fruit is a yellow-green berry, very juicy, about 15 g in weight.

This species of interest for its timber quality and its abundance in yielding. The fruits are widely used for preparation of jellies.



Eugenia pyriformis

DWARF UVALHEIRA (*Eugenia pyriformis* var. *uvalha* (Camb.) Legr.)

This variety reaches 1.2-2.5 m in height. It has a geographic distribution limited to São Paulo state. It is a plant that is in danger of extinction. Rarely it is found cultivated in some back yards, in São Paulo. It has a high density canopy with high and abundant number of shoots. Its fruits are much bigger than the typical species.

BACUPARIZEIRO (*Rheedia gardneriana* Pl. et Tr.)

This forms a small tree, about 3 m high. It is found in rainforests and Atlantic coastal forests. It is very ornamental and is planted in parks and gardens. Its fruits, each having 1-2 seeds, are eaten out of hand or used for making jellies. Its distribution extends from Rio Grande do Sul to São Paulo states.

JABOTICABA, JABOTICABEIRA (*Myrciaria trunciflora* Berg) [See cover illustration] This tree, which reaches a height of 10-20 m, is today rarely found in forests, but frequently found in back yards or in small orchards due to its highly quality fruits. These are sold in local markets, but they lose flavour very rapidly.

The fruit is a globose berry, 2 cm in diameter, hairless and black skinned, with 1-3 seeds. It is eaten fresh and also used for making jellies and alcoholic drinks. The tree has the peculiarities of flowering in abundance directly on the trunk and thicker branches, and may flower many times during the year, depending on the climate conditions.

SANDALWOOD (*SANTALUM SPICATUM*) IN WESTERN AUSTRALIA

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Sandalwood grows mainly in arid areas from just north of Carnarvon (latitude 24°S), down through the Shark Bay/Kalbarri area and inland through the wheatbelt (including Northampton, Toodyay, Northam, York and Narrogin), and the goldfields (including Wiluna and Laverton districts), nearly to Esperance. It occurs up to the eastern fringe of the main forest above the Darling scarp, but is not found naturally on the sand plain. However, there are many hundreds of healthy planted specimens in a number of suburbs around Perth right to the coast.

Also there are two plantations, each containing 90 three-year old trees, at Jarrahdale (an Alcoa rehabilitation site, with a large variety of hosts - herbs, bushes and trees) and at Clackline (Muresk Institute of Agriculture), with Jam (Acacia acuminata), and weed hosts.

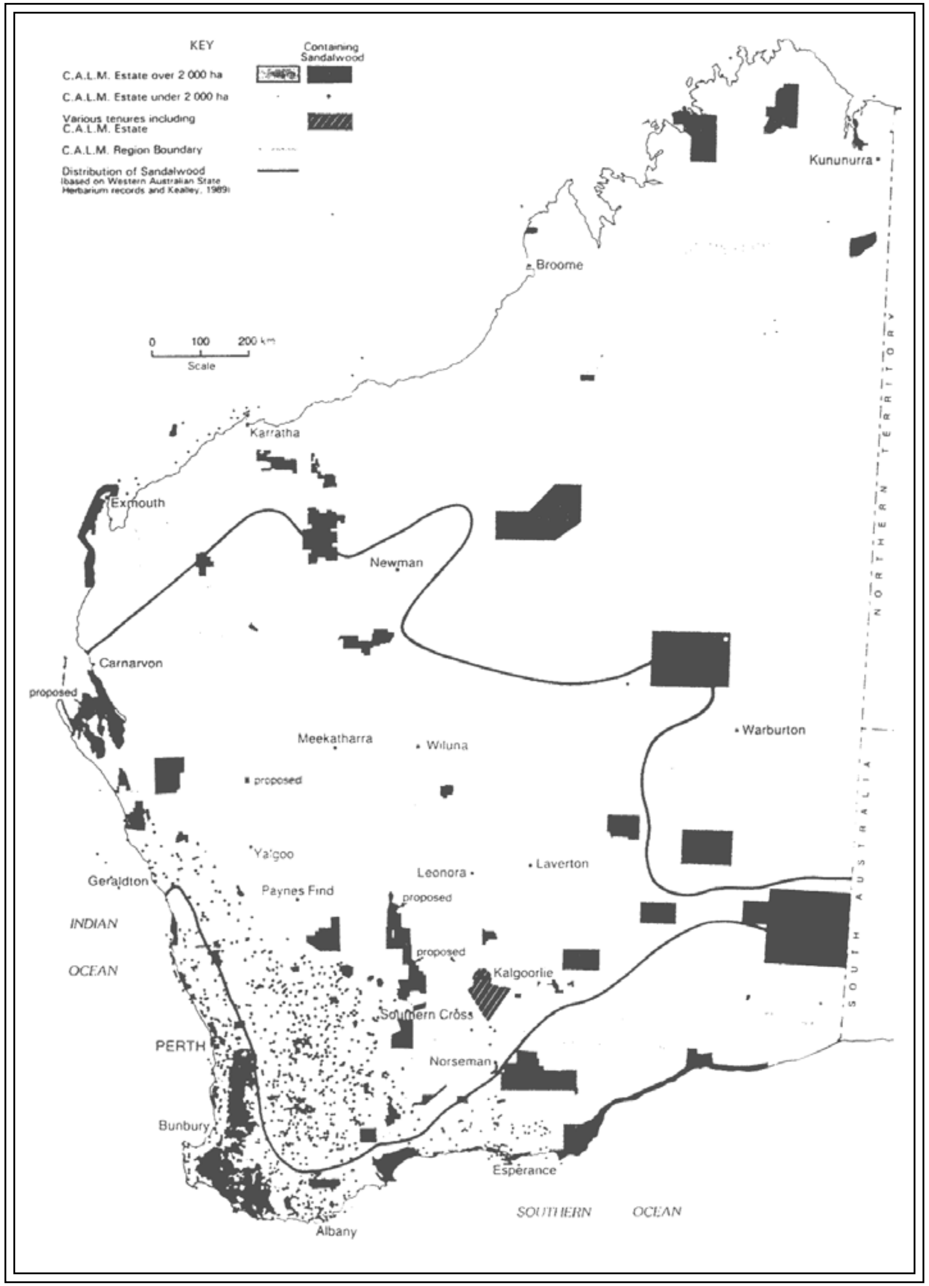
Its range once extended into South Australia, to north of the Flinders Ranges. It does not occur naturally anywhere else in the world.

In its natural arid habitat, sandalwood is slow growing, often taking from 50-90 years or more to reach a harvestable size (trunk diameter 125mm at a height of 150mm from the ground). Under irrigation growth is much faster. I have seen trees reach 2.5m in 6 or 7 years. At maturity the tree is usually 3-4m tall, although I know of one of 7m on the Monastery property at New Norcia, and specimens 8m tall have been reported.

The trees often look scraggy, with dead branches or dead sides and a sparse canopy. The bark is rough and grey and the branches are stiff and spreading. Mature leaves are grey-green, lanceolate to narrowly elliptic and flat, 20-70mm long and a bit fleshy (coriaceous). They are penniveined and have an opposite decussate arrangement on the stem.

Leaf size can vary considerably between trees from different areas. Younger leaves are usually broader, less fleshy and brighter green. Flowers normally develop early in the year, and the majority of the fruit ripen about October or November. In dry years trees may not flower or set seed at all, or the process may be delayed or the crop reduced. Irrigated trees can set seed from 4 years old, but flowering probably takes considerably longer in nature.

Inflorescences are usually panicles with flowers arranged in triads. Buds form as tight green 'boxes' which open in a well-defined progression to reveal flowers which generally have 4 tepals (fused petals and tepals) and 4 stamens with introrse, bilocular anthers. The ovary is inferior. A small style and a bilobed stigma are set centrally in a cup-like disc on a receptacle. This disc has many glands which produce a good supply of glistening nectar.



Distribution of Sandalwood (*Santalum spicatum*) in Western Australia
(from Loneragan [1990])

The flowers have a mild but distinct carrion scent. The nectar and the perfume attract ants, wasps, bees, flies and roaches as conspicuous visitors. As flowers age they lose their green colour and become progressively deeper red. There is enormous wastage of flowers; relatively very few give rise to fruit. The fruit is green and thinly fleshy as it forms. The epicarp turns from red to brown with maturity, with the mesocarp becoming cardboard textured.

When mature, the fruit (drupes) are very big, usually over 20mm across, and heavy, weighing about 3g. The endocarp is brown, smooth, hard and woody, usually 15 to 20mm in diameter. There is copious endosperm and the seed has no testa.

Although young seedlings grow well for the first few months without hosts, the tree is semi-parasitic, needing nourishment from other plants to grow to maturity. Cup-like attachments called haustoria develop on the roots of sandalwood. When these meet an obstacle such as another root, the haustoria grow over the host root and a connection forms between the conducting tissue of both plants. Although it is uncertain how the host contributes to the welfare of the Western Australian sandalwood, there is some tentative evidence from work on another species of sandalwood (the Indian sandalwood), that nitrogen, phosphorus and possibly some amino acids may be taken from the host.

The nut, as many of us know first hand, is edible. It has long been eaten by people in the country. Analysis of the kernel shows that it has very similar protein (18%), carbohydrate (16%) and fat (60%) contents to most other commonly used nuts such as walnuts and brazil nuts. The sandalwood kernel has a fairly bland flavour and a chewy texture. A number of studies have looked at the best way to prepare the nuts - plain, roasted, salted or used in cooking or muesli bars. Before promoting the sandalwood nut as a food, though, it is necessary to test whether it contains any chemicals detrimental to human metabolism.

Of course, rather than eating the nut it can be grown into another sandalwood plant. Although not essential to break the hard shell of the sandalwood nut before planting, a number of studies have shown that cracking often assists more uniform and quick germination. The nut shell can be fractured by using, for example, a saw, pliers, hammer or vice. The kernel is best left in the shell. Seed from good batches germinate well in the field, pots, or sand trays, providing they do not dry out.

Batches of seed collected in different years and localities seem to vary a lot in their ability to germinate - some batches give 90% germination and others maybe only 10%. Unless stored in a cool room under optimal conditions, seed is best not kept for more than a few years because of the loss of viability. Nuts can be successfully germinated in trays of coarse sand. Seedlings can be grown in pots using a good quality potting mix. A 1:1:1 coarse sand:fine sand:peat mixture has proved satisfactory in many trials.

Germinants should be planted out by about 4-6 months of age, before the fast growing root system becomes constricted by the pot. If necessary, fungicides such as Benlate, Previcur, or Thiram can be used to control fungal infections. The use of a complete liquid fertilizer such as Thrive, or a long-life fertilizer such as Osmocote, has been shown to be beneficial at the pot stage.

After germination in the field, seedlings can easily dry out and die, especially over the first summer. Conditions which reduce heat and increase the availability of water are desirable. It was found that planting in the shade of host trees (50-80% in controlled trials) gives seedlings a better chance over the first summer. Shade at this time helps to moderate water loss and avoid desiccation.

Growth in water catching sites also assists survival, but areas subject to flooding should be avoided. Good sites are slopes and lowlands near granite outcrops. Evidence from naturally growing trees at Shark Bay and other areas suggests that sandalwood may show tolerance to salty situations. Commonly sandalwood grows on slightly acidic sandy loam soils, but it appears to tolerate a range of conditions.

Fire and herbivores must be kept out of planting sites. Sheep, rabbits and feral goats can be eliminated with adequate fencing. Planting in spots about 3m-4m apart to give about 625-1000 spots/ha is reasonable. Soil in the immediate planting spot should be loosened, but it is best not to cultivate too widely, nor to bum just before planting - the roots which are potential hosts, and leaf litter which will protect and form a mulch, may be removed.

Plant about five seeds per spot. Seeds should be in place before the start of winter rains so that seedlings have every chance to be well established before the heat and drought of summer. Cracked seeds may get a head start on uncracked ones in this respect. When planting, a mixed selection of hosts is recommended. Small or temporary hosts should be put very close to sandalwood in the same pot or planting spot. Such plants as *Alternanthera*, tomato, Prickly Moses, or lucerne are possibilities, but the selection should be made from species that grow well in the area where planting is to be made.

Sometimes weeds may serve the purpose of initial hosts. Sandalwood should be placed about 0.5-2.0m from larger, more permanent, potential hosts, depending on the size of the host. Many wattles (Acacias), such as *A. aneura*, *A. acuminata*, and *A. tetragonophylla*, are known to be good hosts. Many other species may be good hosts. Sandalwood certainly grows in association for example with allocasuarinas, melaleucas, eucalypts, herbs, and grasses.

If the site has been cleared, it would be best to plant hosts the year before planting sandalwood, and to leave any colonisers as well. Once sandalwood seedlings have made attachments to hosts they seem to be more robust and able to withstand extremes better. The sandalwood may benefit not only from the roots of the host but also from the shelter it provides.

Sandalwood trees are valued mainly for their perfumed wood and extractable oils. It is only the heartwood, however, which contains oil, and it cannot be smelled until the wood is cut or burned. The sandalwood of old, known for more than 3000 years, is *Santalum album*, which grows in India, the Malayan archipelago, and in Indonesia. This is the species popularly known as Indian Sandalwood. It was used by Egyptians, Sumerians, and Babylonians to purify and perfume temples - balls of sandalwood were found in Tutankamun's tomb.

Aztecs and Incas in South America used incense, and 3000-year old deities in the Indus Valley have been found stained with incense smoke. Indian sandalwood is not believed native to Australia, although a few isolated trees are known to be growing up on the far north coastline of the Northern Territory. We now also have specimens in Perth and a few small trial plantations up at Kununurra.

There are many species of sandalwood (*Santalum*) in Asia and the Pacific regions, some with fragrant wood, some without. In W A there are 4 naturally occurring species: Sandalwood (*S. spicatum*), Quandong (*S. acuminatum*), Plum bush (*S. lanceolatum*), and Bitter quandong (*S. murrayanum*). Plum bush has a low concentration of oils, and has from time to time been exported. At the moment this species is being harvested in Queensland in small amounts.

A fifth species, *S. obtusifoliium*, is also native to Australia. It occurs naturally in limited areas of New South Wales and Queensland. The perfume from all those species of sandalwood which contain oils is very similar. However, the W A sandalwood contains only about 2% oil in its heartwood, whereas the Indian and Fijian heartwood contains around 7% oil.

Early settlers in W A realised the value of the tree, and in the 1840s the wood was the single biggest export earner for the state. When gold prospectors or farmers were down on their luck, they supplemented incomes by simply harvesting the natural resource and sending it by dray, truck, or rail to be shipped, usually from Fremantle.

Until after the first world war, collecting of sandalwood was largely uncontrolled - somewhere between about 4000 and 9000 tons per annum were usually exported, although in 1919/1920 the amount reached 14,355 tons. Various moneys were collected by the government in the form of taxes, royalties and license fees, usually accompanied by the loud protestations of sandalwooders.

After the 1920s more order and control was brought to the industry by the government today harvesting and sale of sandalwood is still a viable industry, but it is highly regulated. CALM (the W A Conservation and Land Management Department) assesses sandalwood in the field. Data such as numbers and density of living and dead trees, rate of regrowth, amount of cleared land, and presence of herbivores has been used to set limits on what can be harvested and from where it can be taken.

An inventory in 1984 found 117,000 tonnes of merchantable wood, an amount that would keep the industry going at present levels for another 60 years. The Australian Sandalwood Company in turn locates and maintains markets for all wood harvested. It is presently considered well within environmentally acceptable limits to harvest 2000 tonnes/year.

Last year 50% of this was dead wood and 50% green wood. Every harvester (puller) has to be licenced. There are about 20 pullers who employ licenced assistants. Each has to fulfil his own quota exactly from his own designated area. All pullers have to adhere to minimum tree size restrictions, and no harvesting is allowed within specified distances from roads, tracks, habitation, and watering points.

The wood is debarked in the bush, cut into short lengths, and transported to a factory near Fremantle, where 80% of it is either chipped or powdered and then put into sacks. Together with the 20% left as logs, the sandalwood is shipped to Taiwan, Hong Kong, Singapore, Malaysia and Thailand. It is all used for making joss sticks.

At present sandalwood export earns about $10 million/year gross, with over $6 million going as royalties, overheads, and profit share taxes to the Western Australian State government - this amounts to 90% of the net profit. Indian sandalwood, having greater quantities of oil in its wood, is currently the main species used for oil extraction in Asia.

Between 1917 and 1921 a local man, Mr Braddock, steam-distilled oil from WA sandalwood. He was succeeded by Mr Marr, who established Plaimar, a company which used solvent extraction to obtain the oil (1922-1971). All the oil was exported. In 1961 a record amount of over 13,000 pounds was sold.

Today it is not economic to extract oil from W A sandalwood. However, if newly established trial plantations of Indian sandalwood in Kununurra are successful, oil may once more be extracted in Australia. Small quantities of the Western Australian sandalwood are used by craftspeople to make bowls and other ornaments. Not only is the wood very fine grained, taking a beautiful finish, but it also has the distinctive sandalwood perfume.

For decades sandalwood research has been slowly ongoing, mainly in the Forests Department (since assimilated into CALM), CALM, and Curtin and Murdoch universities. Studies have focussed mostly on germination, pot and field establishment, and host requirements, with some flowering, fruiting and kernel-as-food research in later years. Much more work has been done in Asia on the closely related Indian sandalwood. Some of that experience may relate closely to the W A species.

From 1980 on, numerous research projects at universities have been funded by the Australian Sandalwood Company, through its research arm, the Sandalwood Research Institute. Starting in 1990, for each of the following 5 years, the Institute allocated $100,000 to four sandalwood research projects at Murdoch, Curtin and Melbourne Universities. In 1988 a project known as Sandalwood Conservation and Regeneration Project (SCARP) was initiated by CALM and the sandalwood industry, with funding derived from the export of sandalwood.

The aim of SCARP is to improve the conservation status of sandalwood by development and management (in particular establishing a sandalwood reserve system), research, plantation establishment, developing infrastructure for the industry, and public education and awareness.

My work at the Australian Sandalwood Company is largely aimed at promoting an awareness of the importance of sandalwood (*Santalum spicatum*) as part of Western Australia's heritage, as a tree to be planted in reforestation programmes, as a specimen tree, and as a tree of commerce. I distribute glossy pamphlets which give a little general information about the tree, suggesting why and where it could be planted, and interested people can obtain more information on sandalwood from me.

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DATE PALM CULTURE IN WESTERN AUSTRALIA

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Plant Descriptions

The Date Palm (*Phoenix dactylifera*) has only a single growing point. Growth is fairly slow and the maximum height extends to 15 to 20m. Leaves live for three to seven years and are 3-7m long, with several hundred stiff folded leaflets arising at different angles. There are large spines on the leaf stalk near the attachment with the stem. The trunk bears fibre between the leaf stalks and this insulates the tree from extremes of temperatures.

The plant is dioecious, i.e. male or female flowers are produced on separate trees.

The date is an attractive ornamental tree for parks and large gardens and can also be used as a windbreak or shade tree for other crops.

Dates may be eaten fresh or used to produce syrup, alcohol, wine, confectionary and dried 'chips'. When dried to 20% moisture, dates contain 60 to 65 per cent sugar and small amounts of protein, fibre, minerals (iron), pectins and vitamins.

World Production

The date palm has been the staple diet of the peoples of Northern Africa and the Middle East countries since the beginning of history.

The chief commercial areas, in order of production, are Iraq, Arabia, Algeria, Iran, Egypt, Libya, Pakistan, Morocco and Tunisia. There is also an important industry in California, USA.

Australian Production

Dates are produced semi-commercially on a very small scale at Alice Springs and Halls Creek.

4000 tonnes of cured dates were imported in 1964. This quantity could be produced from an area of 300 hectares. However, there are no commercial producers in Australia.

In Western Australia, there would appear to be vast areas of land which are suitable for the culture of this crop. Dates have grown and cropped satisfactorily in all of the warm and fairly arid parts of the State, ranging from the Pilbara, through the Gascoyne and Murchison Districts, to as far south as the Kalgoorlie area.

Research Work in Western Australia

At Gascoyne Research Station, Carnarvon, various plantings have been made since 1940 with offshoots and seedlings derived from the USA. In 1984, the only surviving named varieties were Khadrawy, Halawy, Thoory and Zahidi. Except for Khadrawy, these are too old to produce offshoots for propagation by offshoots.

In addition, numerous seedlings of named varieties have been investigated. The best selections from this evaluation are being maintained and mainly comprise Sayer selections.

Experimental work on dates ceased in 1973 when it was considered that the priority rating for research on this crop was low. However, the existing plantings are being maintained.

Difficulties in Commercial Production

Research work has shown that good yields of quality dates can be produced in Carnarvon. However, dates have not been produced commercially in Western Australia for the following reasons:

Planting: Prior to the 1980's, the ready supply of good planting material was the biggest obstacle to commercial production. In Australia, only offshoots were available for the production of true to type plants but these are slow to bulk up and there are only a few plants of named varieties in Australia.

It is now possible to produce varieties cheaply and quickly by tissue culture, but so far this system has not been used on dates in Australia. However, tissue culture is used to propagate many other types of plants in Australia.

Land Area: An economic date garden would comprise a very large land area and expensive irrigation facilities would be required.

Time to Cropping: Date offshoots take three to five years to yield their first crop and do not commence full production until eight years of age.

Labour Demand: It is popularly believed that dates are a hardy crop and require little care and attention. In actual fact, dates require specialised knowledge and much labour. Considerable work is entailed, especially in propagation, leaf despining, hand pollination, bunch thinning, bunch covering, harvesting and processing. Field operations also become more difficult with tall palms.

Bird Damage: Birds have resulted in 80 per cent damage to the crop in some years, and so far no satisfactory control has been found.

Processing: Processing requires specialised knowledge which is only obtained by experience. Complex and expensive machinery is needed which is beyond the resources of small operators.

Climate Requirements

For proper maturing of fruit, the date requires prolonged summer heat without rain or high humidity during the ripening period.

The date palm will withstand extreme climatic conditions. Growth ceases below 12°C, but no permanent injury will arise even with freezing temperatures as low as -7°C. The average daily maximum temperatures in the leading date growing countries ranges from 27 to 32°C. However, dates can withstand temperatures as high as 48°C.

Due to the absence of a taproot, the odd plant may be uprooted by cyclones. At Carnarvon, fair to good crops have been harvested in cyclone years.

Soil Requirements

Dates may be grown on a wide variety of soils. The date palm will grow in soils containing more alkali or salts than many other plants will tolerate. However, yields and quality are reduced under saline conditions.

Propagation by Seeds

Dates may be grown from seeds, offshoots or tissue culture. Seedlings have the disadvantage that half of the palms will be male and produce only pollen and not fruit. Sex determinations of the palms are not possible until four to eight years after planting and the seedlings have to be planted very closely in order that surplus males may be removed at a later date.

The biggest disadvantage with seedlings is that they do not reproduce the characters of their female parent and usually produce fruit of poor quality.

When a seedling palm appears outstanding in any way, it can be propagated by offshoots, or by tissue culture. These will always reproduce the parent type. Seed propagation is convenient for ornamental purposes. Seedlings grow slowly and should be raised in a nursery for two years prior to planting out.

Propagation by Offshoots

Propagation of named varieties, whether male or female, is possible with offshoots. These will be of the same sex as the parent tree.

Offshoots appear from axillary buds at the base of the palm, although a few varieties will produce offshoots which are 1 to 3 m high on the main trunk. Offshoots are few in number and are only produced during the first eight to ten years of growth. They are heavy (10-35kg), expensive to transport, and are often difficult to establish when transplanted. Diameter of the base should be 20-35 cm.

Offshoots should remain on the parent palm for three to four years before they are detached. To promote rooting whilst still attached to the main palm, the base of the offshoot should be in contact with moist soil for at least a year before cutting. For offshoots slightly above the soil surface, this can be accomplished by mounding the soil. For high offshoots, soil may be held around the base by means of boxes, but unless very valuable, these offshoots are more often allowed to become fully mature on the palm and then placed in a nursery for rooting. Boxing is a difficult process and frequent hand watering is required to keep the soil moist.

Removing Offshoots

The cutting of a date offshoot from the parent palm requires care and skill which can only be acquired by experience. Apply water before cutting to make the operation easier. Cut the offshoot from the parent palm using a large chisel with a blade 11 cm wide, 23 cm long and 2 cm thick and a handle 1.25 m long and 3 cm thick. Two men are required for the cutting operation, one handles the chisel with the flat side towards the offshoot and the other drives the chisel with a sledge hammer.

Planting Offshoots

The lower leaves are removed and 10 to 12 young leaves around the bud are retained and tied close together with heavy twine. The leaves should also be shortened by two thirds of their length.

Plant offshoots containing roots as soon as possible. With aerial offshoots, dry out the cut surfaces for a few days before planting.

In Carnarvon, the best time for planting is October and November.

A spacing of 9 x 9 m is recommenced. Dig holes which are 60 cm in diameter and 45 cm in depth. Place the offshoot with about half of the bulb diameter in the soil. Wrap hessian around the lower part of the leaves.

For the first few months, water every few days to keep the soil moist around the offshoot. Take care that water does not reach the loose fibre near the bud. Use mulches to conserve moisture.

Propagation by Tissue Culture

Plant tissue culture is a method of propagation of plants by growing small sections of dissected plant tissue on artificial media in sterile conditions.

In the 1980's, overseas research work showed that date palms can be propagated successfully by tissue culture. This offers a ready means of quickly propagating large numbers of plants which are true to type and can be transported in small tubes cheaply over large distances.

Varieties

Varieties may be classified into soft, semi-dry and dry types. These have high, medium and low moisture contents respectively.

The soft types have a low sugar content and as they are subject to mould development, they must be well cured and kept in storage under refrigerated conditions. The dry types have a high sugar content but are tough to chew and have a poor wrinkled appearance. They are not commercial in European countries. The semi-dry types have characteristics in between the soft and dry types.

In California, the semi-dry date Deglet Noor is the most important, but there are also plantings of the soft dates, Ehadrawy, Halawy and Saidy and the semi-dry date, Zahidi.

Of the offshoots tested at Gascoyne Research Station, yields and quality of the Zahidi and Ehadrawy varieties have been good. Quality of the Halawy and Theory (dry date) varieties has been poor. Sayer (soft date) has been the most outstanding amongst the seedling selections.

Watering

For the first few months, plants are watered from a single furrow 60 cm on one side of the plant. In the second year, the plants are furrow watered from both sides of the palms. From then on, furrows are progressively moved outwards each year to just beneath the canopy of the outermost leaves. From the sixth year onwards, water is applied in bays 1.5 to 2 m wide on both sides of the palms.

The date has a deep fibrous root system which may extend to 6 metres deep. The plant is thus extremely drought resistant. However, for maximum yields and quality, a large amount of water is required, i.e. 20,000 kl/hectare per year, either from rainfall or irrigation. Water mature plants every 10 days in the warmer months and every 21 days in the cooler months.

Dates may also be watered by low level sprinklers, which give fairly even watering and save labour compared with flood watering.

Dates withstand waterlogged conditions and grow well with their roots in running water, or in soils with a high water table.

Dates will tolerate water salinities up to 6000 mg/1 total soluble salts, but yields and quality are greatly increased with fresh water.

Weed Control

Control weeds by hand cultivation or by using weedicides.

Paraquat and diquat are desiccant type (contact) weedicides which will give good control of annual weeds. They have no toxic effect in the soil and will not kill weed seeds germinating in bare ground. Spray in overcast conditions or in the late afternoon, every two to four months. It should be ensured that the spray does not touch the leaves of the date palm. Proprietary mixtures of paraquat and diquat can also be used (Sprayseed, 'Paradi' or 'Tri-Quat').

Glyphosate ('Round-up') is similar in action to paraquat and diquat, but will kill both annual and perennial weeds.

Soil-residual weedicides should not be used on date palms.

Fertilizing

The date palm will crop well in soils of only moderate fertility. Higher yields may be obtained by fertilizing with 0.5 kg urea or 1.0 kg sulphate of ammonia. The maximum rates should be 5 kg urea or 10 kg sulphate or ammonia at ten or more years of age.

Apply fertilizer in October.

Pruning

In August and prior to pollination, all dead or partly dead leaves should be removed. Generally, trees are pruned such that the stalks of the lowest leaves are horizontal. If carried out properly, the tips of mature bunches will reach as far as the lowest leaves in the following year. The optimum number of leaves on a date palm is 100.

De-spine the leaf stalks adjacent to the developing flowers prior to pollination. This makes it easier to pollinate flowers and handle the fruit bunches. A sharp pruning knife with a long curved blade mounted on a handle is used for this purpose.

Remove surplus offshoots as soon as possible when trees are small.

Insect Pests

Black ants may attack the ripening bunches. Apply Heptachlor to the main stems of the palms.

Small (4 mm long) brown-black nitidulid beetles may damage ripening bunches. Spray Maldison (Malathion) twice before harvest to give control. Bunches are also fumigated after harvest to remove nitidulid beetles and ferment flies.

Plant sucking bugs (1 cm long) are reddish-brown insects which have damaged bunches in some areas. Control with Maldison. The worst pest on dates, *Farlatoria blanchardi* (date scale) has not been recorded in Western Australia.

Bird Pests

Little Corella cockatoos (*Cacatua sanguinea*) and small 'Silvereyes' (*Zosterops gouldi*), may cause extensive damage to ripening dates. Cover bunches with hessian covers, which drop 30 cm beneath the bottom of the bunches, to give some control from bird attack. Fruit covers with small-mesh wire cages also give satisfactory control, but are difficult to operate.

Mammalian Pests

In the Pilbara, flying foxes seriously damage bunches, which should be covered with wire cages.

Nematodes

The date palm is susceptible to damage by the root knot nematode (*Meloidogyne javanica*).

Drip-feed fenamiphos ('Nemacur') at 20 1/ha into the irrigation water in October to control this pest.

Diseases

The fungus *Graphiola phoenicis* may attack the leaves, forming numerous small dark-brown or black cylindrical elevations from which yellow spore dust escapes. This disease may be found throughout the year, but is only of minor economic importance. It is worst in conditions of high humidity.

Sex Determination

Date palms will not flower and show their sex until three to eight years after planting.

With both sexes, the flower structure consists of a branched spadix which arises from the axils of leaves produced during the previous year. It is protected in the early stages of emergence by a hard, rough sheath which initially is pale green but becomes brown as the flower structure extends in size.

The flower structure and flower stem of the female palm are much longer than those on the male palm. The main flower stem is 1 to 1.25 m long and the flower structure is 70 cm long. The flower structure consists of from 60 to 120 strands with small white florets grouped irregularly along the strands.

The shorter male flowering structure bears more flowers than the female palm and carries strands varying in length from 15 to 30 cm. Each strand bears thousands of small florets, There are twice as many strands on the male flower structure compared with the female flower structure.

Pollination of Flowers

Dates are not insect pollinated. Wind pollination can occur where male palms are close to female palms, but yields and quality are inferior compared with hand pollination, which is the accepted method in commercial date production.

One male palm should supply enough pollen to hand-pollinate 40 to 50 female palms. It is important that some male palms flower before the first female palms.

With other crops, the character of the male parent has no effect on fruit characteristics following pollination. With the date palm, pollen from different males can affect the size of fruit, size of seed and time of ripening, but has no effect on flavour. Selection of suitable male palms is therefore important and these should be propagated from offshoots of vigorous male plants.

Male flower clusters should be cut as soon as the brown sheath begins to break. If the pollen is not to be used immediately, it should be dried carefully and may then be kept for two or three months at normal room temperatures. Pollen can be retained for the following season if it is placed in an open jar within a larger airtight container which contains 0.2 kg anhydrous calcium chloride for every 1.0 kg dried pollen. The container is stored at 4°C in a household refrigerator.

The female palms are ready for pollination two to three days after the opening of the female flowers. In Carnarvon, flowering is from end of July to the beginning of October.

The best method of pollination is to place one to two teaspoons of dry pollen in a household flyspray container, which is used to spray the pollen over the female flowers. Alternatively, pollinate by shaking pollen above the female flowers from a muslin bag or by tying two or three strands from the male flower structure amongst the female flowers.

Fruit Thinning

Fruit thinning is necessary to increase fruit size, improve the quality and prevent delayed ripening of dates, to reduce the weight of the fruit bunches and to insure adequate flowering the following year. Commercially, fruit is thinned either by bunch thinning or by reducing the number of bunches.

Thin bunches when the fruit is about 6 mm in diameter. Thin by reducing either the number of fruits per strand or the number of strands. The tips of all strands should be cutback to remove about one third or slightly more of the total number of flowers or fruits. In addition, entire strands should be cut out from the centre of the bunch.

Remove bunches at the time of bunch thinning. Remove all bunches which are small or have a poor set. As a guide thin young palms to one bunch per 10 leaves, five to nine year old palms to one bunch per eight leaves and mature palms to one bunch per six leaves.

Pulling Down The Bunches

At the same time as bunch thinning and removal, the bunches are pulled down through the leaves and the fruit stalk is tied to the mid-rib of one of the lower leaves. This prevents scarring of the fruit and supports the bunch as its weight increases.

Harvesting

The four stages in the growth and ripening of the fruit are as follows:

a. *Kimri* - from pollination to the fruits maximum size in the green stage.

b. *Khalal* - when the fruit changes from green to the characteristic colour of the variety just before the fruit starts to ripen.

c. *Rutab* - when the fruit is in the succulent, translucent stage.

d. *Tamar* - the cured prune-like date.

High humidities or rainfall will result in fruit cracks and 'blacknose' on the fruit during the Khalal stage and fermentation and mould development during the Rutab stage.

Knowledge of the correct time for harvesting may only be obtained by experience for each variety. With some varieties, fruit is picked individually when it ripens on the bunch, whilst with others, the bunches are picked entire. Soft varieties are cut when 33% of the fruit on a bunch are in the Rutab stage. Dry dates are left to fully ripen on the palm. At Carnarvon, harvest from February to April.

Yields

At Gascoyne Research Station, between six to 14 bearing bunches per palm were harvested per year. Bunches ranged from 3 to 20 kg in weight on individual palms, and yields from 10 to 20 tonnes per ha.

Heaviest yields are obtained when palms are 12 to 15 years old.

Processing

Processing requires expensive and complex machinery and individual knowledge and experience for each variety. Processing operations normally include fumigation with methyl bromide against insects, cleaning, grading, artificial ripening, dehydration or hydration (depending on variety), packing and storing.

Ripening on a Small Scale at Home

Where insects are not a problem and conditions are warm and dry, it is preferable to allow the fruit to ripen (become translucent) on the palm. Where conditions are not so suitable, the bunch should be cut when 10 per cent of the fruit has started to ripen and allowed to fully ripen in a warm and well-ventilated room.

Ripe dates must be cured to destroy insects and reduce the moisture level so that the storage life is increased. Cure by heating in an oven at 35 to 50°C until the dates are soft and pliable. They may then be placed into a semi-air tight container and kept in a refrigerator for several months, or at room temperatures for several weeks.

GROWING EXOTIC FRUITS IN A MEDITERRANEAN CLIMATE

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There is considerable interest in growing exotic fruit in the Perth Metropolitan area, both as home garden plants and for commercial crops. Many of these fruits hail from tropical areas and represent a challenge to the grower, both in getting the tree or shrub to grow, and to produce a crop. The selection of more cold tolerant varieties and the use of a few special tricks to produce a microclimate have broadened the range of choices of plants enormously.

Overseas travel by Australians, particularly to South East Asia, has exposed many Aussie taste buds to the wonders of Lychee, Mango, Rambutan and the smell, if not the flavour, of Durian ("Tastes like heaven, smells like hell! "). Perth is the second most multicultural capital city in Australia, we have a particular large Asian population, many of whom are keen to recreate part of their old home in their new surroundings. Another factor is the desire of keen fruit growers to try something 'different'.

In addition there has been something of a Chef-led revolution as restaurants and home cooks compete to produce an exotic addition to the dinner table. Commercial growers are attracted to exotics because of the high price they command, particularly early in the cycle of introduction. These factors may explain the demand and interest, but how can you transplant a tropical lowlands, jungle grower, to hot and dry Perth?

Perth's metropolitan area has a number of slightly different climate zones. The following statistics showing rainfall, temperatures and strong wind occurrences, place Perth in an Australian climate prospective:

MEAN MONTHLY RAINFALL (mm)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Perth	8	12	20	46	124	183	174	137	80	56	21	14	875
Darwin	404	430	349	63	35	8	1	2	19	73	116	313	1813
Brisbane	164	160	143	86	71	68	55	47	47	76	96	134	1147

MEAN DAILY MAXIMUM TEMPERATURE (°C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Perth	30	31	29	24	21	19	18	18	20	22	25	28	24
Darwin	32	31	31	32	31	39	30	31	32	33	33	33	32
Brisbane	29	29	28	27	24	21	21	22	24	26	28	29	26

MEAN DAILY MINIMUM TEMPERATURE (°C)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Perth	19	19	17	14	12	11	9	9	10	12	14	17	14
Darwin	25	25	25	25	23	21	20	22	24	25	26	26	24
Brisbane	21	21	20	17	14	12	10	11	14	16	19	20	16

MEAN MONTHLY STRONG WIND OCCURRENCE

(Number of strong wind days)

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL
Perth	2	2	2	2	2	3	3	3	2	2	2	2	27
Darwin	1	1	1	1	0	0	0	0	0	0	0	1	5
Brisbane	0	0	0	0	0	0	0	0	0	0	0	0	0

Perth is a very windy city, buffeted in summer by hot easterly winds from the arid interior. In winter, storms, accompanied by strong winds, usually blow in from the North West. The closeness to the sea prevents fast frost incidence in about half of the coastal plain. Even areas adjacent to and on top of the Darling scarp experience relatively mild winters - however there is sufficient chilling hours in these regions to grow cherries, plums and apples fruitfully.

Traditional fruits grown on the coastal plain include citrus - oranges, lemons, mandarins - apricots, Japanese plums, olives, mulberries, loquats and figs.

Widening the Range by Climate Modification

Here's an example of the system initiated by a Pickering Brook poultry farmer for establishing avocado (*Persea americana*) in an inhospitable environment. On top of the Darling Range (altitude 100 m above sea level), the property is subject to heavy winter frost and gale force gully winds in the summer. Loamy soil is enriched with poultry manure 3 months before planting.

One-metre-high grafted trees are planted in September (Spring) so as to allow a whole growing season, through to April/May, to establish. A climate shelter consisting of a 1.5 m high circle of ring-lock wire-mesh covered sides and roof with hessian cloth. Low-throw jet sprinklers are used, not just for establishment, but for the mature trees also.

Side dressings of poultry manure are applied to boost growth. As the trees begin to grow and push against the hessian, it is removed, top first and then sides. No pruning to shape is

undertaken - and given the gangly habit of the avocado, the resulting tree often has branches dragging on the ground. Initially this produces a low flat shape, and this is very wind stable. As they mature the trees produce more upright growth and become more of a standard shape. Pruning off the lower and horizontal branches to create a traditional shape early on led to a number of expensive disasters, where 2-3 year old trees snapped off at the graft in heavy storms. My friendly poultry farmer picks 20 -30 fruit from trees, only 18 months old, following this system.

A creek running across the middle of the property acts as a frost drain. He's planted this area with frost tolerant Fuerte. Varieties that are less tolerant, such as Hass, Bacon, and Sharwill, are planted further up the slopes. The essences of this system are- timing of planting, wind protection and shade, adequate moisture, nutrition and gradual weaning of the young plant so that it can handle conditions better as it matures.

In the home garden, microclimates can be created by planting in the shelter of buildings and other trees. Frost damage is reduced further by covering the lower stem (the weed zone) with rolled corrugated cardboard, or several sheets of newspaper, tied on. Individual climate shelters of shadecloth or hessian similar to the commercial one described above also help to trap humidity. An alternative that we have recommended for our customers is a Grow Tube, this consists of a clear plastic film sleeve that slides over 3 stakes surrounding the young tree. It aids establishment by cutting down wind and frost damage and increases humidity.

During summer a cuff can be created in the base of the Grow Tube and this, when filled with water, increases humidity again. Some protection from stock munching is also afforded. Many home gardeners plant shelter belts along the windy edges of their property to protect tropicals from excessive wind and to increase humidity. With many tropicals we've discovered that once they've survived two winters, then as a semi-mature tree they can cope with extremes very successfully. One example is Papaya or Paw Paw (*Carica papaya*).

Cold and wet winters often encourage stem rots and root rot. Solar-heating the root zone can make the difference to survival in the early years. A layer of black plastic film is placed over the soil to extend beyond the drip zone. Rocks or bricks are placed on this plastic, both to hold it down and to create a support for a second layer of plastic film - in this instance clear material is used. The principle - black plastic draws any heat from the sun and the clear plastic plus the airspace between acts as a heat trap. These layers also keep out the rain so that the soil is kept fairly dry.

Choosing plants from likely climatic regions

Many tropical fruits, from South America for instance, grow at high altitudes. These fruits are already partly adapted to cooler climates and can often be stretched just a bit further to grow around Perth. Some of the best examples are Custard Apples (*Annona atemoya*), Cherimoyas (*Annona cherimola*), Feijoa (*Feijoa sellowiana*), Tamarillo (*Cyphomandra betacea*), Surinam Cherry or Pitanga (*Eugenia uniflora*), Capulin cherry (*Prunus serotina* var *salicifolia*), Soursop or Guanabana (*Annona muricata*), Jaboticaba or Brazilian Tree Grape (*Myrciaria cauliflora*) and White Sapote (*Casimiroa edulis*).

Not all the fruits that are perceived as exotic come from tropical climates. Examples are the Chinese Jujube (*Ziziphus jujube*), Raisin Tree (*Hovenia dulcis*) and Sweet Persimmon (*Diospyros kaki*) now referred to as Fuji fruit. All come from quite cool areas of China, all are successful trees in the Perth Metropolitan area.

There are same tropicals, however, that defy all efforts at successful cultivation at this latitude. Unfortunately they are the most exotic of the Asian fruits --- the glorious Mangosteen (*Garcinia mangostana*), the smelly Durian (*Durio zibethinus*), and the fascinating Rambutan (*Nephelium lappaceum*). Add to them the Coconut (*Cocos nucifera*), although a few survive as indoor plants in pampered locations, and Cashew nuts (*Anacardium occidentale*). Perhaps a double skin plastic hot house with some supplementary winter heating might do the trick, but this is not really practical given the size and time to first crop.

Many of the new exotics have yet to become an acquired taste, but as more growers try them they will increase in popularity. Examples are Drumsticks (*Moringa oleifera*), Rosella (*Hibiscus sabdariffa*), Rose Water Apple (*Syzygium aqueum*), Wampee (*Clausena lansium*), Java Plum (*Syzygium cumini*) and Ber or Indian Jujube (*Ziziphus mauritania*).

Commercial orchards have been set up to grow the following crops in areas adjacent to Perth: Babaco (*Carica pentagona*), White Sapote (*Casimiroa edulis*), Lychee (*Litchi chinensis*), Fuji Fruit (*Diospyros kaki*), Cherimoya (*Annona cherimola*), Mango (*Mangifera indica*), Avocado (*Persea americana*), and Nashi fruit (*Pyrus pyrifolia*).

We believe that one new and relatively untapped source of new 'exotics' will be Australian bush fruits. Some varieties that are just creeping into the consciousness, other than the well known Macadamia nut (*Macadamia tetraphylla* and *Macadamia integrifolia*) include Midyim (*Austromyrtus dulcis*) - plants of this are growing here, so far no fruit seen. Then there are native Finger Limes (*Microcitrus australasica*), Riberry (*Syzygium luehmannii*) - one of the best-flavoured lilly-pillies - and the Burdekin Plum (*Pleiogynium timorense*). I've tasted a few of these fruits after storage and they are quite pleasant.

Perth has not yet seen the development of speciality bush food restaurants as yet - however, given the lead we have seen from the eastern states, this must follow soon. Just an aside - one of the hottest new flavours (I mean popularity-wise) in ice cream is wattle-flower flavour. Ironically, the candied wattle flowers are imported from France, where these Australian Acacias are grown in plantations.

It's pretty amazing when you gather these growing experiences together, the wide range of fruits that can be grown in such a mediterranean climate - when one is determined to succeed. In fact there is no doubt in my mind that fruit explorers are alive and well in Perth.

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2. **Cherikoff**, V. & Isaacs J. (1989). *The Bush Food Handbook*. Ti Tree Press, Australia.

[Based on a paper given at an International Plant Propagators Society conference, Perth, 1989]

Submission of Articles

The WANATCA Yearbook is devoted to useful longer articles, likely to have continuing reference value, about any aspects of nuts, fruits, and other tree or perennial crops.

Articles would be gladly received from any source - there is no requirement to be a member of WANATCA. If the text is available on a computer or word-processor disc (Macintosh is preferred), this is greatly appreciated.

The WANATCA Yearbook is produced at the Tree Crops Centre for the West Australian Nut & Tree Crop Association Inc.

Please send articles or enquiries to:

The Editor. WANATCA Yearbook, PO Box 27, Subiaco. WA 6008. Australia

WEST AUSTRALIAN NUT & TREE CROP ASSOCIATION (Inc)

Founded in 1974, the Association has built up a wide membership among professional growers, amateurs, researchers, horticultural bodies, libraries, nurseries, and investors. Members are based throughout the State, all over Australia, and in many overseas countries.

Membership fees cover subscriptions to all WANATCA publications. Currently these are: a quarterly magazine, **Quandong**; the **WANATCA Yearbook**; and the **Australasian Tree Crops Sourcebook**.

Quandong has details of forthcoming Association meetings, events, and field trips, book reviews, news items of interest, reprints of short articles drawn from world-wide sources, members' comments and queries, and notes on sources of trees, seed, materials and services.

The **WANATCA Yearbook** is our major research publication, with original articles of permanent interest. It is indexed as part of the global coverage of the U.S.-based Biological Abstracts Service.

The **Australasian Tree Crops Sourcebook (ATCROS)** is our major reference work, containing regularly-updated tables of all sorts of useful material about tree crops (common and botanical names, growing conditions, recommended areas etc.), membership lists, lists of useful tree crop organizations world-wide, and a commercial-sources list, acting as a Directory of Tree Crop Services for the whole of Australia, New Zealand, and adjacent areas. Relevant services (e.g. seed suppliers) are listed world-wide.

There are various classes of **membership**. The standard grade is **Full Membership**. It is open to individuals, families, and any form of organization (companies, research units, libraries, etc.). New Full Members will be accepted on application; no entrance fee is charged. **Student Membership** is a concessional rate for current-year students unable to pay full rate. **Sustaining Membership** is a special grade for those supporting the aims of the Association who are able to give extra financial help to achieve those aims. **Life Membership** is available to existing individual members of at least 3 years standing who wish to commute all future payments into a single sum. **Overseas Members** are welcomed and pay no more, although they may optionally receive publications by air-mail for a small premium.

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West Australian Nut & Tree Crop Association Inc

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