West Australian Nut & Tree Crop Association (Inc.) Year Book10 -- 1985

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West Australian Nut and Tree Crops Association (Inc.)

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

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

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Editorial

The Yearbook enjoys a wide circulation and acts as a useful means of exchanging information about tree and nut crops. Many of the species of interest are not cultivated to a great extent, if at all. The increasing interest in non-cultivated species, or species which are 'new to a particular region is encouraging. This interest has produced a large number of publications which describe the species and which may give some clue as to how to grow it or how to eat the fruit or nut. For example, there is now a good supply of books on the lesser known subtropical and tropical fruit and nut species.

We should not think that this is sufficient. There is another dimension yet to be explored. We need to discover how these plants work. With this understanding we can then appreciate not only their products but how we might manage them to improve their quality and productivity and the lot of mankind on this planet. Some of the papers in this issue of the yearbook describe species which may be potential fruit or nut crops. Others include information on how plants work. We should not leave this side of things only to large research organizations with expensive laboratories. The essential components are a keen eye and a questioning mind. After all, who was hit on the head by an apple - or was it a nut?

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Editor

P.S. I apologise for the lateness of this issue - it was caused by circumstances both beyond and within my control.

Hazelnut Grafting

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This review examines the current state of hazelnut grafting, and the significance this technique has in relation to the growth of Australia's hazelnut industry.

Reasons for Grafting

Grafting of tree crop species may be desirable for various reasons. The major ones include -

1. Multiplying varieties that cannot be readily reproduced by other asexual methods.
2. Upgrading of established undesirable plants, e.g.,topworking.
3. Rootstock effects. For example, special rootstocks may tolerate soils prone to waterlogging or resist soilborne disease organisms. Others may allow growth control (e.g., dwarfing stocks) or improve bearing characteristics, etc.
4. Repair of injured trees.

Points 1, 2 and 3 are of great significance to hazel growers. Hazels are not easily propagated by cuttings, and grafting is a more efficient method of multiplication than layering. In Victoria grafting has proved to be a particularly useful technique for the multiplication of new quarantine releases, many of which have been suckerless. When grafting is purely a multiplication exercise and the stock is of no consequence then scion varieties can be grafted onto their own roots (Lagerstedt 1976).

The topworking of established trees may be desirable in the near future. Many Australian plantings are composed of unknown, poor varieties and seedlings. As better varieties become available topworking with them will enable upgrading of existing plants. In addition, our current knowledge of pollination is far from complete, and topworking programs may incorporate improved pollinators. However, topworking of hazels is not commonly practised as the success rate is low. Growers can readily supplement their income by the sale of suckers from orchard trees. However, growers with large plantings recognise the importance of discouraging suckers and training trees to single trunks. 'Non-suckering' rootstocks would make orchard management an easier task but at present our industry doesn't have access to approved non-suckering stocks.

Requirements for successful grafting

Conventional winter field grafting of hazelnuts rarely achieves a success rate over 10%. Winter field grafting fails with many temperate nut species because callusing of the union occurs slowly.

The isolated scion dehydrates because vascular connections are not quickly restored.

Temperature has direct bearing on rate of callus formation. Some temperate fruit trees for example apple, will develop callus at 4.5°C. However, most temperate nut tree grafts will not form callus at such low temperatures (Lagerstedt, 1981b). Sitton (1931; in Lagerstedt, 1979b) determined that optimum temperature for callus formation in black walnut was 27°C. The rate diminished at temperatures above and below this. The optimum temperature for maximum hazel callusing is also around 27°C (Lagerstedt, 1979b).

Grafting of hazels can be accomplished by use of 'hot-callusing' techniques. These techniques aim to produce successful unions by using temperature to increase rate of callus growth.

The 'hot-callusing pipe' developed by Lagerstedt (1981a) is the basis for the best known of the hot-callusing techniques. It consists of a PVC pipe (approximately 5 cm diameter) housing an inner pipe containing thermostatically controlled electric heating-cables. Grafted plants are placed perpendicularly across the outer pipe with each union contained in a slot. The unit is simple to construct and maintain, and is best located in a shadehouse but may be erected outdoors.

Hot air (27°C) generated by the inner pipe surrounds the unions while the rest of the plant remains at ambient air temperatures. During winter, cold ambient temperatures restrict development of the dormant scion buds, and prevent the early burst and scion desiccation that may occur if the whole dormant plant is placed in a heated environment. Experiments conducted using the hot-callusing pipe have achieved a success rate of over 90% (Lagerstedt, 1981b; Thomson, 1984). These results confirm the suitability of the hot-callusing pipe for use in commercial nurseries.

An alternative method for hot-callusing hazel unions was employed by Anadoliev (1976). Scion wood was machine grafted onto seedling stocks, and the grafted plants were stratified in damp pine sawdust, or fine shavings, at 38°- 40°C for the first 3-4 days, and 20°-22°C for the remainder of the callusing period. Percentage of good unions ranged from 75 to 95.

Successful glasshouse/polyhouse grafting of hazels can be achieved with careful timing and environment control. Trees may be grafted in late autumn and subjected to glasshouse temperatures around 27°C. At this time of year, the scion buds should not have gone through their rest period and shouldn't begin growth (Lagerstedt, 1979b). When callused, the tree is placed in cold storage to satisfy the rest period of the bud. Successful winter glasshouse grafting has been reported but very specific environment control is necessary to avoid the desiccation problem, and this method may not suit commercial propagators on economic grounds.

Two Victorian nurserymen graft hazels in polyhouses in early spring when temperatures have begun to rise.

At this time it is necessary to maintain high air humidity to protect new shoot growth. Stored dormant scion wood is used which usually leafs out in the first few days. The main advantage of spring grafting concerns the condition of the root stock. Buds are swelling, root growth has resumed, and the rootstock sap has begun to flow. Sap movement is important in inducing stronger callus growth.

Winter field grafting of some tree crop species has been achieved by the use of 'electric heat pads' that surround individual unions. An electric cable runs to each padded union. This is an uncommon technique that could be usefully employed in hazel grafting, e.g., topworking.

With all grafting systems the performance of the scion is very much dictated by the size of the stock's root system. Even though callusing is good, poor root development may lead to subsequent graft failure. Correct aftercare is also essential for success. Applications of various paints may be valuable in preventing drying of the union and scion.

Graft types

Budding (considered here as a variant of grafting) of hazelnuts is rarely practised Hartmann and Kester, 1975) and is generally not recommended (Dell, 1977). However, Manzo (1972) and Pathak *et al*. (1978) report that budding produced better results than grafting. De Rosa (1961) found shield (or T) budding to be unsatisfactory but late summer ring (or annular) budding using 1-year-old wood for both stock and scion gave good unions. Pathak et al. (1978) also budded 1-year-old wood (seedlings) in late summer. Chip budding showed most success (75%), followed by patch budding (65%), and shield budding (45%). The New Zealanders have had success with nursery chip-budding performed in February.

Lagerstedt (1980) has found 'greenleaf chip-budding' performed in late summer to be superior to normal chip-budding. This new technique uses a chip of the current season's growth with bud and leaf attached. The chip is tied in the usual way, and the attached leaf is covered with clear plastic wrap (it may be necessary to paint this to avoid overheating).

The whip (or tongue) graft ensures considerable cambial contact and has been successfully used for bench grafting hazel material up to 2 cm in diameter. Pathak et a!. (1978) found a cleft graft suitable for use with year old seedlings. Lagerstedt 1979b) has successfully wedge-grafted hazels by machine, and the machine cut 'omega' graft is recommended by Anadoliev (1978). When preparing dormant hardwood scions for bench grafting the previous growing season's wood should be used.

Larger stocks are more suited to cleft and side grafts (Lagerstedt, 1979a) and these two grafts should be considered for topworking. Fregoni and Zioni (1965) examined ways of topworking 'Mortarella' onto 7 year old 'Tonda Gentile delle Langhe' trees, and found that crown grafting with the stock cut slantwise was inferior to normal crown grafting (48.2% success).

Micrografting (a modification of the nurse-seed graft) can be used with hazels. Young seedlings about 5 cm tall, are decapitated and a cleft cut is made along the longitudinal axis. Actively growing leafy shoot tips are used for scion material. The basal end of the scion is cut to a wedge shape and inserted in the cleft cut. Thin paraffin sheet can be used to bind the union (Lagerstedt, 1982). With optimum growing conditions unions are healed within 7 to 14 days, and scion growth resumes within 14 to 27 days (Lagerstedt, 1982). Generally the scion variety is layered onto its own roots because the performance of the seedling stock is unknown.

Rootstocks

As far back as 1841 *C. avellana* was grafted to the Turkish tree hazel *C. colurna* L. The Turkish tree was favoured as a rootstock because it is vigorous, has an extensive root system, and is non-suckering.

Several orchards on *C. colurna* rootstock exist in the United States, however, grafted plants have not been available there for over 30 years (Lagerstedt, 1979a). Lagerstedt (1979a) and Thompson (1982) observed that older 'Barcelona' trees grafted onto *C. colurna* seedlings declined in production and vigour as compared to self-rooted trees. Also, the Turkish stock tended to overgrow varieties if they weren't vigorous (Lagerstedt, 1979a).

The Turkish tree has several characteristics which make it undesirable as a nursery plant. Seed germination may take 3 years, seedlings often take 3 years to attain grafting size, and long tap roots with few laterals reduce transplant success (Lagerstedt, 1979a; Thompson, 1982). However, these problems could be largely overcome by propagation from cuttings.

Rootstock research in Oregon is now centred on stock other than *C. colurna*. Backcross populations combining *C. avellana* with *C. colurna C. chinensis* (non-suckering Chinese hazel) have been considered (Thompson, 1982). An Oregon (USDA) rootstock breeding and selection program was started over 15 years ago with primary objectives being to obtain non-suckering and easy rooting of cuttings. Fulfilment of this latter objective will allow production of a clonal rootstock thereby eliminating reliance on seedlings and their inherent variability.

Since 1980 the Oregon breeding program has centred on use of *C. avellana* cv. 'Fusco-rubra' as the male parent in crosses. 'Fusco-rubra' is a high yielding, red leafed cultivar. When combined with the right female parent (*C. colurna* x *C. avellana* selection) it is possible to obtain a non-suckering, red leafed rootstock selection that also roots readily (Lagerstedt; pers. comm.). Over a hundred Oregon selections are at various stages of propagation and evaluation, however, to date no selections have been released or named. In their 'scion variety' breeding program the Americans have been using 'Daviana' as a rootstock. 'Daviana' produces few suckers but is not completely suckerless. It has value as a research stock because it's a clonal, well-anchored tree which is tolerant of both bacterial blight and poorly drained soils.

The American opinion that *C. colurna* is an unsuitable stock is not fully accepted in Europe. In fact several workers (Maurer, 1975a,b; Rivals, 1979; Anadoliev and Bozhinova, 1982) recommend it. Rivals (1979) reports that the varieties 'Geante de lialle', 'Imperiale de Trebizonde, Fertile de Coutard' and 'Bollwiller' perform well on *C. colurna* rootstocks. Maurer (1975b) found that grafting onto a Turkish tree stock increased nut yield by 25-50% compared with own-rooted trees. Similarly, Bauckmann (1979) reports that in a four year trial with 7 varieties yields were 23.7 to 593.5% higher for trees grafted to *C. colurna* than for varieties on their own roots.

Anadoliev and Bozhinova (1982) go further and specify particular *C. colurna* rootstock forms for different single stem effects. For medium vigorous plantations 'Perunika 4', 'Perunika 20', 'Neseb "r 2' and 'Varna 2' are recommended while dwarf growth can be achieved with 'Sadova 3', 'Perunika 15' and 'Sadova 2'.

There are no compatibility problems with *C. colurna*, and in fact the European hazel (*C. avellana*) is graft compatible with all species of the genus (Lagerstedt, 1979a). The possibilities for intergeneric grafting within the birch family have been examined. It was once hoped that *Corylus* might be graft compatible with the suckerless genera *Carpinus* and *Ostrya*, however, this is not the case.

At the Horticultural Research Institute, Knoxfield, cuttings from a local suckerless tree with *C. avellana* parentage have been rooted. The material's potential for use as a rootstock is currently being assessed together with other non-suckering plants to be kept in a small collection at Toolangi Potato Research Station, Victoria.

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Growing Pecans

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Introduction

The pecan (*Carya illinoensis*) is a large, beautiful tree that produces bountiful crops of delicious nuts. The largest member of the hickory family, the pecan often grows to attain a height of over 30 m and a spread of greater than 24 m. Pecan is native to the central portion of the United States. Native pecans can be found growing from the Texas gulf coast north to the Mississippi river flood plains of Iowa. Outside of its range, pecan plantings have spread in the US to the arid southwest and the humid southeast.

Three conditions determine the success of a pecan tree planting: proper soil, adequate water, and proper cultivar selection. The leading cause for disappointing experiences in growing pecan trees is a lack of appreciation for the importance of providing the proper conditions for healthy tree growth.

Soils

Pecan should be planted in deep, well drained soils for best results. Two soil types are preferred by pecans. In the US, native pecans are primarily found growing in the deep alluvial soils along major rivers and streams. These soils are characterized by clay loam to sandy loam texture, good internal drainage, and a static water table that ranges from 3 to 7.5 m (seasonal range) below the soil surface. Soils with more than 1 m of friable topsoil provide a suitable upland site for pecans. These upland soils should also have a sandy clay subsoil which allows free penetration of both water and air. Good upland pecan soils allow pecan roots to grow throughout both topsoil and subsoil. Pecan trees will not preform well if planted on upland soils having either a clay pan or fragipan.

Pecan trees will grow and thrive in soils that range from slightly acid to slightly basic (pH 6.0 to 7.5). Special precautions to avoid zinc deficiency must be taken if trees are grown in sandy soils or soils with a basic pH (7.0 and above). Under these soil conditions foliage sprays of zinc are necessary to promote optimum tree growth.

Water needs

Pecan trees will grow without irrigation in regions that receive an average of 760 mm of rain per year. But ample water throughout the growing season is necessary for good tree growth and regular nut production. Mild drought conditions affect nut quality. A water stress before nut shell formation causes nuts to be small, whereas, stress after shell hardening leads to poor kernel filling. Severe drought will cause nut abortion, premature defoliation, and will decrease the prospects for a nut crop the following year.

To ensure annual crops of high quality nuts, supplemental irrigation should be considered.

Pecans growing in river or stream flood plains are frequently subjected to seasonal flooding. Excessive water is injurious to pecan trees only if the internal drainage of the soil is poor and water stands for extended periods of time. Pecan trees grown in poorly drained soils will exhibit symptoms similar to drought stress. Standing water prevents movement of oxygen into the soil. Roots need oxygen to perform their vital functions of water and nutrient uptake. A lack of oxygen in the soil inhibits water uptake and trees become water stressed.

Selection of cultivars

Selection of cultivars is the most important decision that must be made when establishing a pecan planting. The following criteria should be considered when choosing pecan cultivars that will be adapted to your area.

Nut Maturity. Nut maturity in pecan is indicated by the splitting of the shuck and separation of nut from shuck. Freezing temperatures before shuck split cause the shuck to remain firmly attached to the nut, so that it never opens. These nuts are known as 'sticktights' and are unmarketable. In order for pecans to be successful, shuck split should occur before the average date of first autumn freeze.

Full Kernel Development. Shuck split is not the only indication that a pecan cultivar has become fully mature at the time of frost. In areas of relatively short growing season, adapted cultivars will have plump, well-filled kernels at first frost. Cultivars, which require a long growing season for kernel development, will often split their shucks at frost or shortly after when grown in short season regions. Although these nuts would be harvestable, kernels are usually shrivelled and not fully formed.

Rate of kernel development in pecan is controlled genetically but is influenced by the accumulation of heat units during the summer months. Summer heat, especially high night temperatures, is necessary for proper kernel development. Early-maturing cultivars can be distinguished easily from late-maturing cultivars even in mid-summer. The nuts of early-maturing cultivars need fewer heat units and start a rapid increase in size soon after pollination, whereas nuts of late-maturing clones require more heat and expand at a much slower rate. When autumn approaches the kernels of early-maturing cultivars are well-developed, while the late-maturing nuts are still filling their kernels. If an early autumn freeze occurs, leaves and shucks of late-maturing clones are killed and kernel development is left uncompleted.

Productivity.. The nut producing capacity of a cultivar is very important. A cultivar able to produce a nutcrop every year is far more desirable than an alternate bearing cultivar. In addition, a cultivar that produces a large crop of medium size nuts will yield more nut meat than a cultivar that produces only a few 'jumbo' sized nuts.

Flowering and Pollination. Pecans have separate male and female flowers which are located on different parts of the same tree. Male flowers appear as 75 to 100 mm long catkins which hang from one-year-old woody branches. They first appear green then turn yellow when shedding pollen. Catkins turn brown and fall from the tree after all pollen is released. Female flowers look like miniature pecans and are borne on the end of the current seasons new growth. On the tip of the female flower is the stigma which may be either red, orange or green. The stigma becomes glossy with fluid when receptive to pollen. Pollination occurs when pollen is transported by wind to the stigma of the female flower.

Periods of pollen shed and stigma receptivity for a pecan cultivar usually occur at different times. Cultivars that shed their pollen before their stigmas become receptive are called protandrous. Cultivars whose stigmas become receptive before pollen shedding are called protogynous. A protandrous cultivar should be planted closer than 75 m from a protogynous cultivar to ensure pollination of both cultivars.

Nut Size and Quality. Nut size and quality are the most important criteria for selecting cultivars, especially if nuts are grown for home use. Positive nut characteristics include: less than 176 nuts per kg, more than 50% kernel, high oil content, light straw-coloured kernel, no adherence of shell parts, and slow development of rancidity.

Pecan Cultivars. The pecan cultivars listed in Table 1 are a sampling of popular cultivars being grown in the different areas of the US pecan growing regions. If you are starting a new pecan orchard it is best to choose 4 to 6 cultivars with different maturity dates in order to find those best adapted to your area.

Table 1. Pecan Cultivars

Cultivar	Maturity Date (1)	Nuts per kg	Percent Kernel	Flowering Habit (2)
Colby	very early	149	42.8	g
Peruque	very early	180	58.6	a
Posey	very early	154	51.6	g
Giles	early	164	51.7	a
Major	early	177	48.9	a
Pawnee	early	117	59.5	a
Shoshoni	early	125	51.6	g
Maramec	mid	108	56.7	g
Mohawk	mid	103	54.4	a
Wichita	mid	116	60.5	g
Cheyenne	late	138	59.0	a
Desirable	late	110	55.0	a
Kiowa	late	99	57.5	g
Stuart	late	110	55.5	g

1. Maturity dates, Very early = matures in areas with 180 to 190 frost free days (FFD). Early = 191 to 200 FFD. Mid = 201 to 210 FFD. Late > 211 FFD.
2. Flowering habit, a = protandrous. g = protogynous

Methods of Establishing Pecan Trees

Pecans should be given plenty of room to grow. Establish trees 9 to 10.5 m apart. At this spacing, the branches of adjacent trees would not start to crowd each other until they are 20 to 25 years old.

Pecan trees can be established in three ways:

1. transplant grafted trees
2. transplant seedling trees, graft 2-3 years later
3. plant nuts, graft 3-4 years later.

The advantages and disadvantages of each of these methods are described below.

Grafted trees. Transplanting grafted trees of desired cultivars is the quickest way to produce pecans. Trees can be expected to start bearing nuts within 4 to 6 years after transplanting. This method has the greatest establishment costs but offers the quickest returns.

Seedlings. Seedling pecan trees can be purchased at a very low cost or can be grown in a home nursery. Seedling trees must be grafted to desired cultivars beginning 2 years after establishment. Nut production should begin 4 to 6 years after grafting. Starting a pecan planting with seedlings offers the advantage of lower initial costs. Further, cultivars, not available through commercial nurseries, can be established.

The longer wait until nut production and the need to graft are possible disadvantages to establishment with seedlings.

Nuts. Stratified nuts can be planted in place to establish seedling pecan trees. These trees will need to grow 2 to 3 years before they are large enough to graft over to the desired cultivar. Starting trees from seed has the same advantages an disadvantages as starting trees with seedlings but have an extra year added to the establishment time.

Transplanting Pecan Trees

Transplant both grafted trees and seedling trees in early spring as soon as the soil can be easily dug. Trees should be planted as soon as possible after receiving them to prevent roots from drying. Before planting trim off about 1/3 of the top growth. Prune off broken or rotten roots and cut the tap root to 600 mm. Tap root pruning of one-year-old seedlings is unnecessary. Cutting back the tree before transplanting encourages strong regrowth. Dig your planting hole large enough to fit the entire root system. Hold the tree in position and fill soil in around the roots making sure the fibrous roots are spread out in their natural positions. The tree should be planted at the same depth as it was in the nursery. Water the tree in after transplanting. Do not place soil amendments or fertilizers in the planting hole.

Weeds must be controlled in a 1 m area around the newly transplanted tree. For large plantings, the entire orchard should be kept free of competing vegetation. Complete vegetation control can be achieved by shallow cultivating, application of herbicides, or by mulching. In late spring, spread 250 g of ammonium nitrate fertilizer around the tree over the entire weed free area. To ensure survival, keep the tree well watered throughout the growing season and especially during droughty periods.

Starting Trees from Nuts

Pecan trees are easily grown from properly stratified nuts. Nuts for planting should be collected during the autumn harvest season. Choose nuts that are large and well filled. Stratify the nuts in moist sand by placing them in layers about 75 mm deep and holding them in a cool room (2 to 5°C) for 90 to 120 days. Be sure the nuts are kept moist throughout the stratification process to ensure uniform germination after planting.

Three methods can be used for growing seedlings for later use in establishing a pecan orchard. They are:

1. growing trees in place
2. establishing a nursery
3. growing trees in containers

Growing Trees in Place. After the danger of spring frosts has passed, plant 3 to 5 nuts in each location you desire a tree. In a well prepared seed bed, plant your stratified seed 50 to 75 mm deep. Be certain to mark the area where nuts are planted and to keep the area weed free. During the first year, select the strongest growing tree and remove the others by cutting them off below the root collar.

Fertilize the seedlings in early summer with 100 g ammonium nitrate fertilizer per tree location. Water trees throughout the growing season.

Establishing Trees in a Nursery. Choose a deep sandy loam soil for a pecan nursery to facilitate digging and transplanting. Prepare a fine seed bed for the nursery area in early spring. Plant stratified seed 50 to 75 mm deep, 0.6 m apart, in rows at least 1.3 m apart. Keep the nursery weed free and well watered. Side-dress the nursery rows with N fertilizer in early summer. Nursery grown trees should be dug for transplanting in late winter of the following year. When digging one year old seedlings be sure to dig at least 400 to 460 mm deep and preserve as many fibrous roots as possible.

Growing Trees in Containers. The best containers to grow pecan seedlings are 100 mm square and 400 mm deep. Use a potting soil mixture that allows free movement of water through the pot. Plant a single stratified nut 50 mm deep in each pot. Pots should be placed on wire screen benches so that any roots growing out of the pot will be air pruned. Pecan seedlings grown in containers need daily waterings and a careful fertilizer schedule similar to all containerized nursery plants.

Containerized pecan seedlings must be protected during the winter from freezing. After trees become dormant in the autumn move the pot-grown trees to a protected area where winter temperatures stay between 2 and 7°C. Transplant these trees into the field in early spring of the next growing season.

Care of Non-Bearing Trees

Your objective in training a young pecan tree is to develop a strong trunk and healthy root system. Adequate soil moisture throughout the growing season and proper fertilization are keys to strong, vigorous tree growth. Water young pecan trees when conditions become dry by soaking the entire rooting zone deeply once a week. Nitrogen fertilizer should be applied twice a year, before budbreak and in late spring, at the rate of 500 g of ammonium nitrate per 25 mm of trunk diameter. Spread the fertilizer over the entire rooting area. Keep the area around the tree weed free to ensure maximum benefit from water and fertilizer applications. For large plantings, keep the entire orchard free of weeds during the summer. A winter annual cover crop should be established in the autumn and tilled in the next spring.

Tip pruning helps shape the young pecan tree and promotes the formation of a strong trunk. Tip prune in the dormant season by clipping off 75 to 100 mm from all terminal growth. When the tree starts its growth in early spring, these cuts force buds to break along the entire branch. This gives the tree a more dense appearance and greater leaf area. Tip prune again in mid-summer, this time do not prune the central leader. Cutting all lateral branches back stops their growth and channels their photosynthetic energy into strengthening the trunk. Lower lateral branches should be left on the tree until they are 25 mm in diameter. Remove these lower laterals as the tree grows until you have a tree with 2.4 m of clear trunk.

As the tree becomes larger, tip pruning becomes more difficult because of the size of the tree and can be discontinued. The tree should start to bear nuts at this time.

Care of Bearing Trees

Healthy, vigorous trees produce the highest quantity and quality pecans. Maintaining a strong growing tree is also the best defence against attacks from insects and diseases. Water, fertilizer, and pest control are the keys to healthy tree growth.

The importance of providing adequate soil moisture throughout the growing season has been discussed. Pecans require 25 mm of water each week from bud break to nut maturity. Fifty mm per week may be closer to optimum during the heat of the summer months. Natural rainfall can be supplemented by flood, sprinkler or trickle irrigation.

Annual nut production relies on applications of nitrogen fertilizer. Nitrogen should be applied just before bud break at the rate of 110 kg N/hectare. Pecans grown on upland soils require slightly higher nitrogen rates.

Rosette or zinc deficiency is a common problem if pecans are grown in soils with a pH above 7.0 Symptoms include a rosetting of the terminal growth and small misshapen leaves. Zinc deficiency is easily corrected with 4 applications of either zinc sulphate or NZN (a formulation of Zinc Nitrate and Urea manufactured by the Allied Chemical Co., Omaha, Nebraska, USA) at two week intervals starting at leaf burst.

Few insects and diseases attack pecans when they are grown outside of their native range

and the range of closely related species. Aphids, stink bugs and wood boring insects should be the only insect problems in Western Australia. Growers should carefully scout their pecan plantings for signs of insect activity and take appropriate steps only if a problem exists.

A permanent ground cover of cool season grasses and legumes should be established in the bearing pecan orchard. Once the trees start to bear, the shading of the tree canopy helps reduce the competitiveness of a ground cover. The permanent ground cover should be kept mowed throughout the growing season. In the home orchard, a well kept grass lawn serves as the ground cover.

The only pruning necessary on bearing pecan trees is the removal of dead or injured limbs. In addition, low hanging branches should be removed to allow free movement of persons and machinery around the tree. If a pecan orchard is established at a 10.5 m spacing, tree thinning will become necessary after 20 to 25 years. Remove one half of the trees when the branches of adjacent trees begin to overlap.

Equipment for the Pecan Orchard

As with all agricultural endeavours, farm equipment makes pecan growing easier and more efficient. The equipment suited to pecan production varies with the size of the pecan planting. In Tables 2 and 3 I give suggestions for the type of equipment that can be economically justified for the number of trees in the orchard.

Table 2. Equipment needed for pecan orchard establishment.

	number of trees in orchard			
orchard operation	2 to 25	25 to 120	120 to 4000	4000+
general use horse power	lawn +garden power tools	9 kw garden tractor	18 kw to 30 kw tractor	30 kw to 60 kw tractor
planting	shovel	shovel	pto driven soil auger	pto driven soil auger
weed control	hand sprayer	back-pack sprayer	back-pack sprayer	back-pack sprayer
orchard floor management	lawn mower	garden tractor mower or tiller	disc, harrow	disc, harrow
insect, disease, + Zn def. control	hand sprayer	back-pack sprayer	3pt, pto 400L sprayer	3pt, pto, 400L sprayer

Table 3. Equipment needed to manaqe bearing pecan orchard.

orchard operation	number of trees in orchard			
	2 to 25	25 to 120	120 to 4000	4000+
general use horse power	lawn + garden power tools	9 kw garden tractor	20 to 30 kw tractor	30 to 60 kw tractor
orchard floor management	lawn mower	garden tractor mower	1.5 m, 3 pt rotary mower	3 to 4.5 m rotary mower
insect, disease, + Zn def. control	4 kw, home garden sprayer	9 to 12 kw, 5 MPa, sprayer	3 pt, 400 L mist sprayer	400 to 500 L mist sprayer
nut harvest	poles, hand gather	poles, tarps	trunk shaker, tarps	trunk shaker nut harvester

Harvesting and Storing

The green shucks surrounding the nut should split open sometime in early to mid autumn. Although the nut is fully mature at this time it is still "green" and needs to dry further before being gathered. As the nut dries, the shucks will turn brownish-black and curl away from the nut, exposing the pecan. Pecans will fall from the tree when they are fully dry. Harvest should begin when the first nuts drop to the ground. At this point you can hasten the natural drop by shaking the tree or limbs causing nuts to fall. Home orchardists can use long poles to jar limbs and cause nuts to fall. For orchards with over 120 trees, a tractor mounted tree shaker should be purchased to help hasten the harvest. Pick pecans off the ground as soon as possible and store in a cool, dry place. Small pecan producers can spread tarps under the tree before they shake limbs to make gathering easier. Only the large pecan producer can afford to purchase mechanical nut harvesters.

Over 70% of the pecan kernel is composed of unsaturated fats which can become rancid in room temperature storage. To maintain highest nut quality, shell out all your pecans and store the kernels in the freezer. Kept frozen, pecan kernels can be kept a year or more.

Some Nut-bearing Plants in Papua New Guinea

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Summary

Trees, and a vine, with edible nuts, available in Papua New Guinea and mostly traditional foods are described, and the uses, quality and properties of the nuts discussed. Species treated are *Pandanus jiulianettii, Inocarpus fagifer* (Tahitian chestnut), *Castanopsis acuminatissima, Pangium edule, Finschia chloroxantha, Macadamia integrifolia* (Macadamia nut), *Aleurites moluccana* (Candle nut), *Omphalea gageana, Terminalia catappa* (Tropical almond), *T. impediens, T. kaernbachii* (Okari), *Canarium indicum* (Galip), *C. kaniense, Anacardium occidentale* (Cashew nut). Colour-slides of the plants, in most cases with close-ups of the fruits and other parts, are available from the author.

Introduction

A nut is defined as a "hard and indehiscent 1-seeded fruit" (Jackson, 1926). For the purpose of this survey, the definition has been stretched to include fruits with more than one seed and even, in one case (*Pangium*) a berry, but one in which the seed is large, oily, and is treated like the kernel of a nut.

The kernel of an edible nut is the seed. It may include endosperm usually oily or starchy, or it may be an embryo only. It often contains a large amount of fat, making it a concentrated energy food, and is usually a useful source of protein, vitamins and minerals. The seeds of plants often contain toxic substances; some seeds used as food are poisonous in various degrees, and must be processed in some way to make them safe to eat. Trees require little care, so nut-bearing trees are an asset to village people. Some nuts have potential as exports, but no trade has developed so far.

The coconut, *Cocos nucifera*, is, for the present, ignored. It has its specialists and a very extensive literature. Breadfruit, *Artocarpus communis* J.R. and G. Forst., is no more a nut than *Pangium*, but its seed could be regarded as one. However, discussion of this genus, with *Parartocarpus*, can hardly be confined to a short paper. Only woody plants are considered here. The peanut, *Arachis hypogaea* L., is therefore excluded.

The following plants (arranged in family order, following Hutchinson, 1959) are discussed:

Pandanaceae	*Pandanus jiulianettii* Martelli
Leguminosae	*Inocarpus fagifer* (Parkinson) Fosberg
Fagaceae	*Castanopsis acuminatissima* (B1.) ADC.
Flacourtiaceae	*Pangium edule* Reinw.
Proteaceae	*Finschia chloroxantha* Diels
	Macadamia integrifolia Maiden & Betche
Euphorbiaceae	*Aleurites moluccana* (L.) Wilid.
	Omphalea gageana Pax & Hoffm.
Combretaceae	*Terminalia catappa* L.
	Terminalia impediens Coode
	Terminalia kaernbachii Warb.
Burseraceae	*Canarium indicum* L.
	Canarium kaniense Lautb.
Anacardiaceae	Anacardium occidentale L.

***Pandanus jiulianettii* Martelli**

Tree 10-30 m high, branched, with large prop-roots; trunk diameter to 30 cm. Leaves strap-like, to 3 m long x 10 cm broad, with upward-directed prickles along the margins and midrib. Flowers dioecious, male and female on separate trees. Male flowers whitish in dense spikes, soon withering; no perianth, stamens numerous. Female flowers in dense heads; no perianth, ovary 1-celled and containing 1 ovule, surmounted by a flat stigma. In fruit the heads (syncarps) are ellipsoid, 30-35 cm long, 25-30 cm in diameter, on a stout stalk. The individual fruits (drupes) are up to 10 cm long, 1.5 cm across; when ripe, they separate from one another easily. The weight of a mature head, with stalk, is recorded as 16 kg (Bowers, 1963).

The kernel (seed) consists mainly of oily endosperm, with a small embryo. When fresh, it has a flavour resembling coconut, but sweeter. The nuts are stored above the fireplace. Presumably some drying takes place, which would slow down deterioration.

The species is endemic to New Guinea, and is found throughout the mainland. In cultivation, it is reported from 1500 to 2500 m. Wild plants occur in the higher part of this range; their nuts are not (or very little) used. There are intermediate forms, with useful kernels which are, however, hard to extract. These plants are preserved, and sometimes transplanted to more convenient positions, but not given further care. Superior plants are carefully tended. These also are variable, and some have nuts with a soft' shell which is easily broken in the fingers.

Pandanus is important to highland people, from both nutritional and cultural viewpoints. In addition, trunks and prop roots are used in building, and leaves as thatch. Those of *P. jiulianettii* are considered to be superior to most in the ‘karuka’ group, at least in the Western Highlands (Bowers, 1963).

Pandanus conoideus Lamk, a ‘marita’, is much cultivated, but its fruit cannot be considered as a nut since it is the endocarp, outside the pyrene (stone) which is used as food.

***Inocarpus fagifer* (Parkinson) Fosberg Aila (Pidgin), Tahitian Chestnut (English)**

A tree, to 30 m, but most specimens seen are from 10-20 m; trunk usually fluted; branches somewhat pendulous. Leaves simple, alternate, oblong, rather large, 30-40 cm long. Flowers bisexual, white, small, in simple or branched spikes from the axils; calyx 2-3 lobed, petals 5, alike, joined at the base, 1-1.5 cm long. Fruit indehiscent, irregularly flattened-ellipsoid, often ribbed, yellowish-orange when ripe, 6-10 cm long, 5-10 cm wide, to 4.5 cm thick; one-seeded. Seed to 7 cm long, 5-7 cm wide, about 3 cm thick.

The seed is eaten after roasting or boiling. An analysis of the seeds gave 7% of fat, 10% protein, 80% non- nitrogenous substances (which would be mainly starch) and 2.5% ash (Burkill, 1966). According to the same source, the seed is best eaten slightly before maturity. The tree is cultivated throughout the coastal regions of Malesia arid on the Pacific Islands. It may be found throughout Papua New Guinea at low altitudes, mainly near the sea or along large rivers. Wild populations occur, and another species, *I. papuanus* Kostermans, has been described. Its seed is much smaller than that of *I. fagifer* and it does not seem to be used at all. The fruit is dispersed by bats, which gnaw the pericarp. The seed is often damaged by insect larvae.

***Castanopsis acuminatissima* (B1.) A.DC.**

A tree to 35 m tall, often with numerous coppice shoots about the base. Leaves simple, alternate, ovate-lanceolate to elliptic, acuminate, 5-15 long, dark shining green above, brownish or silvery beneath. Flowers separately male and female, monoecious (both sexes on the same tree). Male flowers very small (to 2 mm long), light brown or cream coloured, in slender spikes (catkins) 5-10 cm long. Female flowers greenish, scattered on an axis to 10 cm long. The nut, as it develops, is enclosed in a rough, woody cupule. At maturity the nut is ovoid, pointed, brown, slightly hairy, about 1.5 cm long, and emergent from the cupule for about half its length. The single seed is composed mainly of 2 large cotyledons.

The kernel is eaten, at least in some areas; there are not many reports. The nut is small; entire, it weighs less than 1 g, the kernel less than 0.5 g. At Okapa, Eastern Highlands, it was recorded as “eaten raw or cooked in bamboo” (Hamilton, 1956). From Pomio, East New

Britain, it was reported that the seeds were commonly eaten after boiling, and that some children, against the advice of their elders, persistently ate raw kernels. This seemed to lead to mouth ulcers, emaciation and anaemia (Baalen, 1960). These effects could be due to the presence of tannins, often found in members of the family Fagaceae.

C. acuminatissima occurs from India to China and Taiwan, throughout Malesia to New Britain. In Papua New Guinea it is widespread, often common, in mountain forest, from 500 to 2500 m. The wood, which is durable in its habitat, and splits easily, is used for building and fencing.

Pangium edule **Reinw.**

Smallish to large trees, specimens to 40 m are recorded; usually buttressed, with a dense crown. Leaves large, 10-40 cm long, ovate-cordate, dark green, shining above. The tree is polygamous-dioecious; male and female inflorescences are on different trees, but a male inflorescence may have one or more flowers (the highest ones) bisexual, so "male" trees also bear fruit. Male flowers in short racemes; petals 5-8, pale green about 2 cm long, stamens 20 or more. Female flowers usually solitary, the petals somewhat larger than in the male flowers; staminodes (sterile stamens) few or up to 20. Fruit ellipsoid or more or less pear shaped, 15-20 cm long, with a brownish, rather rough surface. Seeds up to 20, closely-packed, irregularly triangular-ovoid, mostly 4-6 x 2-3 cm, enclosed in a white fleshy aril. The seed-coat is hard and ribbed; it is greyish when fresh and darkens when weathered. The white flesh of the kernel consists mainly of oily endosperm.

The whole tree is rich in hydrocyanic acid, and is therefore extremely poisonous; a few fresh leaves in a jar make an effective killing-bottle for insects. The fresh leaves or seeds or oil from the seeds, are used as insecticide and antiseptic and to preserve meat (Sleumer, 1954). The oil from the seeds is used for cooking, lighting and for making soap. The flesh of the seeds is widely used as food, but must be carefully processed, by roasting, washing in water, underground storage, etc., before its final preparation as food. The seed-coats are used as rattles in sing-sings. The tree occurs throughout Malesia, the Bismarck Archipelago and the Solomons, and in the New Hebrides and other Pacific islands, in forest or preserved on cleared land, sometimes semi-cultivated. In Papua New Guinea it is found from sea level to 1000 m.

Finschia chloroxantha **Diels**

Tree to 30 m tall, but 5 m specimens have been seen flowering and fruiting. Leaves alternate, simple, entire, more or less elliptic, 10-40 cm long, parchment-like or somewhat leathery. Flowers bisexual, light golden yellow, in racemes from the axils or from leafless branches. A tree in full flower can be spectacular. Fruit more or less compressed globose, 3-5.5 x 2.5-4.5 cm, yellow at maturity, soon turning black; exocarp thin, fleshy, endocarp hard, woody. Seeds 2, flattened, circular in outline; cotyledons thick, fleshy.

The seeds are eaten after cooking, and are apparently widely used, throughout the range of the species. A single seed (rather a small specimen) was found to weigh just over 3 g. The species occurs throughout New Guinea and the Solomons, on the Am Islands and in the New Hebrides; it is also reported from Palau Island, Micronesia. In Papua New Guinea it is widespread, from low altitudes to above 1800 m. It is sometimes planted near villages.

Macadamia integrifolia **Maiden & Betche Macadamia Nut**

A tree forming a dense, rounded crown, 20 m or more tall. Leaves lanceolate with toothed margins, to 30 cm long, solitary, paired or in whorls of 3. Flowers bisexual, in racemes to 30 cm long, off-white. Fruit about 2.5 cm across, the leathery exocarp dividing into 2 valves at maturity; nuts spherical, brown, shining, about 2 cm across. The kernel is white, pleasant-tasting, and may be eaten raw or cooked.

A native of Australia, the species has been cultivated commercially, there and in the Hawaiian Islands. The shell is fairly thick and very hard, but a 'soft-shelled' variety was developed in Hawaii and is now available in Australia. The tree could not be expected to thrive in Papua New Guinea at low altitudes, but should do well between 500 to 1500 m. A specimen was seen in 1950, in the Hube area of the Finschhafen subdistrict, Morobe Province, at an altitude of about 1000 m. The ground underneath the tree was littered with broken shells, and the nut was praised by the local people - "like coconut". Nevertheless, it has been very little planted.

Aleurites moluccana **(L.) Willd. Candle Nut**

Tree, to 30 m tall. Leaves alternate, often crowded near the branch tips, variable in shape and size, from small and lanceolate to large, broad and lobed; when young, densely greyish-hairy, the hairs falling from the upper surface as the leaf ages, so that mature leaves are dark green above, greyish green beneath. Flowers small, white, in dense terminal panicles, separately male and female, monoecious (both male and female flowers on the same tree). Fruit to 5 cm across, fleshy, enclosing a single nut. Nut irregularly globose, ridged at one end, about 3 cm across. Shell 3 mm thick, very hard; kernel white, soft oily, weighing up to 5 g in local specimens.

The nuts contain a moderately poisonous toxalbumen (Burkill, 1966) and may produce severe vomiting and diarrhoea if eaten raw, though they are sometimes eaten without ill-effects (Everist, 1974). In Papua New Guinea they are usually roasted before eating. In Hawaii they are roasted, powdered and mixed with salt and chili as a relish (Neal, 1965). The oil from the seed is a drying oil, but slower to set than linseed oil; it is the main oil for paint in China (Burkill, 1966). The nuts, threaded on a skewer of wood, will burn like a candle, hence the name.

A. moluccana is native in the Moluccas, New Guinea and Australia, and naturalised elsewhere. It is cultivated throughout Malesia to India and China, and in the Pacific. In Papua New Guinea, it occurs from low altitudes to about 2000 m.

Omphalea gageana **Pax & Hoffm.**

A large woody vine, high-climbing; red sticky exudate from the wood when cut. Leaves alternate; juvenile leaves deeply 5-lobed; adult leaves simple, elliptic to ovate, 7-20 cm long, the tips blunt or acuminate; 2 small glands at the base of the petiole. Inflorescence a panicle, with linear leaf-like bracts to 5 cm long; these are characteristic. A monoecious species; flowers separately male and female, but on the same plant, the male flowers on lateral parts of the panicle, the female flowers more or less central; all flowers small, yellowish green.

Fruit slightly broader than long, about 6 x 5 cm, with 3 rounded lobes; pericarp thick, fleshy; seeds 3, irregularly flattened orbicular, about 2.5 x 1.5 cm, covered, when fresh, with a cream coloured aril; seed-coat 1-1.5 mm thick, hard, ridged, brown; kernel white, consisting of copious endosperm surrounding 2 broad, thin cotyledons.

The kernel is eaten after cooking, either alone or as a relish with other food. A single kernel, fresh, weighs about 3 g.

The genus *Omphalea* occurs in America, Africa, Asia and Malesia; *0. gageana* is endemic to New Guinea, so far as is known. There are not many collections, probably because the vine is usually inaccessible in the forest canopy; it seems common enough in the Lae area, and is said to be much-used in the Mime Bay Province. Most reports are from low altitudes, but it is known from Okapa, Eastern Highlands Province at about 1800 m.

***Terminalia catappa* L. Tropical almond**

Tree to 40 m, but usually much less; branches in whorls, more or less horizontal. Leaves obovate, fairly large, to 25 x 15 cm; the old leaves turn light brown or red, and few red leaves can usually be seen in the crown. Flowers bisexual in small terminal spikes, white or cream coloured, about 3 mm long. Fruit flattened-ellipsoid, 5-7 x 3-4 cm, usually surrounded by a ridge or flange; pericarp fibrous, rather spongy, the inner part hardened to a stone around the seed. Seed white, mainly composed of the leafy, coiled cotyledons.

The kernel is edible, but is not much used; it is very small, about 0.75 g, and not easy to extract. It yields an oil said to compare with almond oil (Brown, 1951), but commercial production seems unlikely. *T. catappa* occurs naturally from tropical Asia to Australia and Polynesia, and is now planted throughout the tropics. It is found in most coastal regions of Papua New Guinea, as a beach tree, and planted in towns and villages.

***Terminalia impediens* Coode**

Tree to 40 m tall, branches in younger trees horizontal, in whorls, finally making a spreading crown with heavy branches; twigs thick. Leaves clustered at twig-tips, obovate, mostly about 20 cm long, 10 cm wide, sometimes with reddish-brown hairs beneath. Flowers about 7 mm long, bisexual, whitish green, in spikes. Fruit red or purplish-red when ripe, ellipsoid, about 8 x 5 cm, the outer part fleshy-fibrous, the inner part a thick woody stone, which splits on germination into 2 unequal parts. Seed about 5 x 1 cm, spindle-shaped, mainly composed of 2 coiled, leaf-like cotyledons.

The kernel is edible. It has a pleasant taste and can be eaten raw; the weight, fresh, varies from 1 to 1.5 g. The fruits may be left until the outer fibrous covering has rotted away; the stones then are not difficult to break.

The tree is endemic to New Guinea, and has been reported mainly from the north western part of Papua New Guinea, the Sepik, Madang and Morobe Provinces, with a few collections from the Central and Gulf Provinces. It occurs in lowland forest; there is no evidence that it is cultivated, but trees are preserved when land is cleared for gardening. In the forest trees can be located by the stones from the fruit, which lie on the ground for a long time before they decay.

***Terminalia kaernbachii* Warb. Okari**

Trees similar in appearance to *T. impediens*. Leaves clustered at the twig-tips, obovate, 20 x 10 cm more or less, with persistent reddish-brown hairs beneath. Flowers in erect spikes, usually densely hairy. Fruit ellipsoid, somewhat flattened, about 10 x 7 x 5 cm, red or purplish-red when ripe, outer part fleshy fibrous, inner part a thick woody stone, which splits into two almost equal parts at germination. Seed to 8 x 2 cm, with 3-4 coiled, leaf-like cotyledons.

The kernel is of high quality, and sought after as food. It appears that the tree has a long history of cultivation and selection; smaller kernels weigh only 1.5 g, other up to 10 g. The flavour may be improved by light roasting. With salt, this may also improve the keeping quality. The nuts could certainly be sold overseas if they could be exported in good condition, but at present the production is barely sufficient for local needs.

The species is endemic to New Guinea; records of wild specimens are known, from lowland forest in the south eastern part of Papua New Guinea (Coode, 1978). It is preserved in garden land, and cultivated near villages. It has also been planted in Australia and Sri Lanka, and possibly in America.

***Canarium indicum* L. Galip**

Tree to 40 m tall, buttressed. Leaves alternate, compound, with 3-8 pairs of leaflets and a terminal leaflet; leaflets 7-35 x 3.5-16 cm, often acuminate; persistent stipules at the base of the petiole, varying in shape, 4 cm long x 1.5 x 3 cm wide, or much larger, margin more or less fringed. Dioecious, flowers male or female on separate trees; inflorescence a terminal panicle; petals 3, free, creamy-yellow, in male flowers 1 cm long, in female flowers to 1.5 cm long, hairy. Ovary 3-celled, but usually only one seed develops. Fruit blackish purple when ripe, ovoid, round to slightly triangular in cross-section, to 6 cm long x 3 cm across. The fleshy endocarp dries and splits to expose the nut, to 5.5 cm long, 2 cm across, brown, smooth, rounded triangular in section with more or less acute ribs at base and apex. Seed 1, the other ovary-cells flattened; endosperm absent, cotyledons lobed.

The kernel is of high quality, and may be eaten raw or lightly roasted. Average specimens weigh about 3 g. One analysis shows the main constituents as 72% fat, 13.5% protein, 7% starch; the seed coat should not be eaten as it carries some substance producing diarrhoea (Burkill, 1966). The nut is important as an item of diet for village people, and can find a ready sale in towns. As with okari, the production of galip does not really meet local demand. It could have export potential, but the kernels become rancid rather quickly. The nuts of cultivated races vary in size and quality.

The species would no doubt repay investigation and selection.

C. indicum is native to the Moluccas, New Guinea, the Bismarck Archipelago, the Solomon Islands and the New Hebrides, and is cultivated in eastern Malaysia and the Pacific. In Papua New Guinea it is widespread in lowland forests and improved races are cultivated, particularly in the Bismarck Archipelago and the Madang Province.

The name *C. indicum* appears in literature as occurring in western Malesia, but the species there has been separated as *C. vulgare* Leenhouts on the grounds that Linnaeus used a mixed collection as the type. In *C. indicum* the stipules have toothed or fringed margins, and remain in place until the leaves age; in *C. vulgare* the stipules have entire margins and fall early, and the trees are more slender in all their parts (Leenhouts, 1959). There is a lengthy discussion in Burkill (1966) under the name *Canarium commune* L. This is an illegitimate name, published later than *C. indicum* L., for the same material. As used by Burkill it applies both to *C. indicum* and *C. vulgare*.

Canarium kaniense **Lauterbach**

Trees to 40 m, sometimes with buttresses. Leaves similar to those of *C. indicum*, leaflets acuminate; stipules not long-persitent, elliptic to obovate, 1-8 x 0.5 to 4 cm, the margins toothed or fringed. Flowers a little larger than in *C. indicum*. Fruit ovoid, 5-6 x 3-4 cm, blue-black when ripe. Nut 4-5 cm long, sharply triangular, 2-2.5 cm across.

The species is endemic to New Guinea, so far only collected in the eastern part, at altitudes from sea level to 1000 m.

The variety g*lobigerum* Leenhouts has globose fruits about 5 cm across, the nut rounded-triangular in the basal part, sharply angled near the tip. The kernel is oily with a pleasant taste. The tree is apparently cultivated in the Northern and Morobe Provinces.

Anacardium occidentale **L. Cashew Nut**

A small, branching tree. Leaves alternate obovate, 6-15 x 4-7 cm, dark green, leathery. Flowers in spreading panicles, polygamous, with male and bisexual flowers on the same tree. Petals pink, 1-1.5 cm long; stamens 7-10, one longer than the others; ovary 1-celled. Fruit kidney-shaped; nut, about 2.5 cm long, borne on a pedicel which at maturity is about 5 cm long, fleshy, yellowish and edible. Seed about 2 cm long, oily.

The kernel, which is soft, with a pleasant flavour, is a major article of commerce in some countries. The skin of the nut contains phenolic compounds which may cause blistering of the skin; individuals vary in their susceptibility and seem to become sensitised by successive contacts. The irritant substances are volatile and are removed by roasting the nuts before processing; the fumes may cause inflammation of mucous membranes. The "cashew-apple, the succulent fruit-stalk, may be eaten fresh, in preserves, or used for making wine or vinegar.

It causes irritation of the throat in susceptible people.

The cashew nut is native to tropical America. It is now widely cultivated throughout the tropics, and industries have developed in Africa (at least in primary production) and India (where the nuts are processed). The tree does well in the more fertile areas of lowland Papua New Guinea, but no sort of industry has developed.

Other species

The nut-like fruits of several other wild trees are used in Papua New Guinea, e.g. *Heritiera littoralis* Dryland., along foreshores, *Elaeocarpus womersleyi* Weibel in mid-mountain regions, and the seeds of *Sterculia schumanniana* (Laut.) Mildb. in the lowlands. However, they do not show much potential for improvement. The list could no doubt be expanded considerably. There are also nuts overseas which could be introduced, including the Brazil nut and its allies. Some attention to selection and propagation of indigenous species, and introduction of desirable exotics, could considerably increase this valuable food resource.

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The Cashew in Australia - Tropical Tree Crop of the Future

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AUSTRALIA

Introduction

Cashews are not grown commercially in Australia, which imported nearly A$20 million worth of these kernels in 1984/85 for the dessert and confectionery market (Table 1). As ornamentals and backyard fruit trees cashews have grown in the semi-arid tropics of northern Australia for many years. Ecological conditions of these areas are similar to that of the cashews native environment. Recognising the crop's potential in this region, its evaluation was begun in the early 1960's near Darwin, NT, in the early 1970's in the humid tropics south of Cairns, Q., and at Broome, WA, in 1978. Poor quality genetic material, inadequate crop management and unsuitability of the humid tropical climate of Queensland prevented adequate assessment of its agricultural potential. The improved international market of the early 1980's caused by a decline in world production (Table 2) has revived interest in cashew in northern Australia. A pilot farm joint venture between CSR Ltd. of Australia and Twentieth Century Foods of Singapore is currently being developed east of Darwin, with technical support from the Northern Territory Department of Primary Production. The Singapore company has also negotiated to commence a pilot farm at the Ord River Irrigation Area (ORIA) in north-east Western Australia in 1986. Technical support will be provided by the Department of Agriculture of WA, which has also received a research grant from the Reserve Bank of Australia for a three year study of cashew.The establishment of a domestic cashew industry is the aim of these initiatives.

Table 1. Australian cashew kernel import statistics.
Source, Australian Bureau of Statistics (PBS).

Year	Quantity (tonnes)	Value (A$ 000's)	Average Unit Price (A$/tonne)
1970/71	2,256	2,983	1,278
1971/72	2,798	3,589	1,283
1972/73	2,396	2,799	1,168
1973/74	2,804	3,900	1,391
1974/75	3,439	5,460	1,588
1975/76	3,648	6,162	1,689
1976/77	3,170	7,287	2,299
1977/78	3,217	11,232	3,491
1978/79	1,909	5,615	2,941
1979/80	2,422	10,061	4,154
1980/81	2,853	13,120	4,599
1981/82	2,224	11,658	5,243
1982/83	2,618	11,469	4,382
1983/84	2,635	13,132	4,984
1984/85*	3,243	19,970	6,158

* preliminary figures

Table 2. World estimates of cashew raw nut production kilotonnes)
Source: Gill and Duffus Group Ltd. (1984)
Edible Nut Statistics, London.

Country	Year						
	1972/73	1975/71	1978/79	1979/80	1980/81	1981/82	1982/83
Brazil	25	40	65	65	75	75	65
India	60	105	120	115	130	120	120
Kenya	12	20	10	18	15	18	18
Mozambique	117	120	65	70	70	65	40
Tanzania	105	85	65	50	60	45	30
Other	5	5	5	12	12	12	15
TOTAL	374	380	330	330	362	335	270

The Cashew

Originating in north-east Brazil, the cashew (*Anacardium occidentale* L.) grows from coastal sand dunes to over 1000 km inland and in areas up to several hundred metres in altitude. An evergreen, spreading tree with an extensive root system dominated by a vigorous tap root, the cashew thrives in the dry tropics and can tolerate extended periods of drought. Within the gene pool tree height varies from only a few metres to more than 15 m, and tree shape may be erect or spreading with several large, low branches. Trees flower through the dry season and in Australia flowering commences in May to August, with harvest from September to December, before the rainy season. Pest and disease incidence is therefore relatively minor in Australia, with few of the species which affect commercial crops in other countries being present. The botanical structure of the cashew fruit is shown in Fig. 1. The 'apple' is a swollen peduncle, often called a pseudo-fruit. Botanically the raw nut is the fruit containing a seed or kernel which is the nut of commerce.

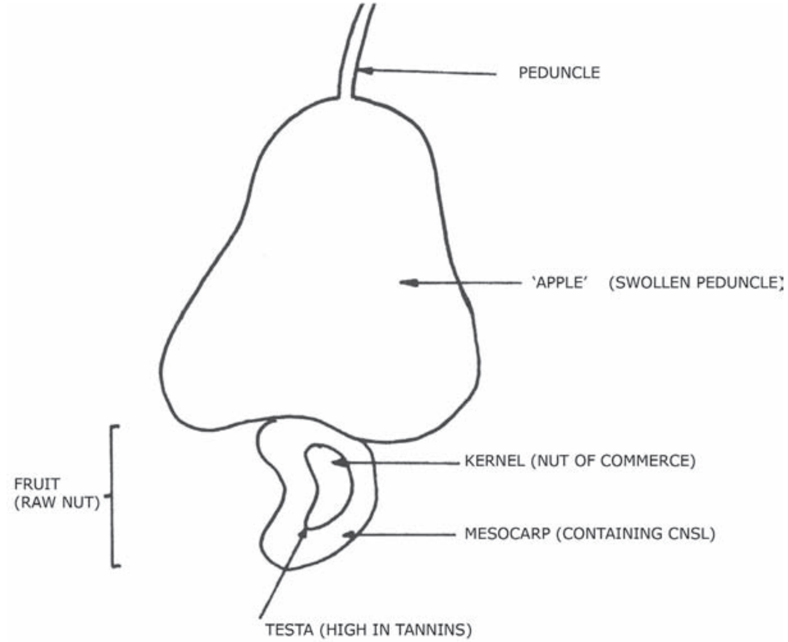

Fig 1. Botanical structure of the cashew fruit.

In Brazil the apple was used traditionally as a food staple. Today juices and carbonated drinks made from the apple are very popular in Brazil and are the main commercial use for the species.

The Portuguese colonists are credited with introducing the cashew to the tropics of India and later Africa and Asia. Introduction to the Caribbean and Central America is thought to considerably pre-date the colonial era. By the 1960's large scale cashew industries had developed in India, Mozambique, Tanzania and, to a lesser extent, Kenya. Together with a small export industry in Brazil these countries supplied the world cashew market.

Cashew relatives

The Anacardiaceae family includes several other species of *Anacardium* of which the largest, *A. giganteum* Hanca, grows in the Amazon rainforests and *A. microcarpum* Ducke, a dwarfing species, occurs on sandy savannahs in Brazil. Other edible tree fruits included in the family are the mango (*Mangifera indica* L. and related species), pistachio (*Pistacia vera* L.), Fiji apple (*Spondias cytherea* Sonn.), hog plum (*Spondias mombin* L.), Spanish plum (*S. purpurea* L.), several *Bouea* species and *Buchanania lanzan* Spreng. Fruits of *Buchanania obovata* Engl. form part of the Aboriginal bush diet in north-west Australia. Yet another genus in the family is *Semecarpus,* in which the 'native cashew' (*S. australiensis*) occurs along the coastal tropics of northern Australia. The 'marketing nut' (*S. cassuvium*) occurs in India. Both these species produce fruits with botanical structures very similar to the commercial cashew.

Products of the cashew

Three major commercial cashew products are the kernel, "apple" and cashew nut shell liquid (CNSL). Used as a dessert nut and in the baking and confectionery industries, the kernel is the most valuable product representing an average 24 percent of the weight of the raw nut. CNSL, corrosive to human flesh, is a caustic, black liquid, which is very heat resistant, it occurs in the mesocarp of the fruit. Immersion of each raw nut in a CNSL bath at 200°C for about two minutes vapourises the water in the shell and fractures its outer layer. Extraction of 35-50% of the total CNSL in each fruit and simultaneous roasting of the kernel is achieved in this process. Shelling of kernels is done manually in India and mechanically in east Africa, Southeast Asia and Brazil. Cashew shells provide the fuel to heat the CNSL baths in Indian factories. CNSL is incorporated into a wide range of polymer based products made to tolerate high temperatures. These include paints and resins, laminates, electrical conductors, brake linings and space vehicle nose cones. It is also used in the manufacture of paper cloth, glass fibres and anti-fouling preparations. The skin colour of the apple may be deep red, bright yellow or a range of colours in between. Apples yield about 10 times the weight of the fruit and may weigh from 25 to nearly 100 g. Each apple is about 60 percent juice which is high in sugars and vitamin C, with a complement of other vitamins and minerals.

Brazil has a large apple juicing and canning industry. In India a small industry manufactures cashew fenni, a liquor, from the apple. In most growing areas the apple is largely wasted. The testa, a layer of tissue surrounding the kernel, is rich in tannins. These are extracted in India for use in the leather industry.

World industry

Today many countries produce commercial quantities of cashew kernels. These include India, Brazil, Mozambique, Tanzania, Kenya, China, Thailand, Indonesia, Philippines, Malaysia, Sri Lanka and to a lesser extent Benin, Malawi, Nigeria, Guinea Bissau, Dahomey, Senegal, Ivory Coast, Uganda, Ethiopia, Zambia, Peru, Taiwan, South Africa and some Caribbean island states.

World trade in cashew kernels increased significantly after 1945. Exports doubled in each of the periods 1949-59 and 1960-69 inclusively, reaching a record of 101,909 tonnes in 1972 (Table 3). A decline in production from east Africa (Table 2) and substantial price rises for kernel in 1973 and 1974 saw world exports fall to around 58-65,000 tonnes in 1978 (Tables 3 & 4). India's share of that trade fell from 99.8 percent before 1950 to 63.3 percent in 1972 and 41.5 percent in 1978. Suppliers of other nuts including almonds and hazelnuts benefited from this market shift at a time when the world nut market was expanding (Table 4).

Table 3. Indian imports of raw nut (R) and exports of kernel for India (KI) and the world (KW) in tonnes.
Sources: Cashew Causerie 3(4):l0-20. 1981
Cashew Causerie 6(3):16-19. 1984
Peirce Leslie India Ltd. 1985

Year	R	KI*	KW
1949	NA	19,277	19,278
1959	NA	38,789	39,302
1960	100,000	43,625	41,578
1965	175,000	51,267	58,830
1968	204,000	63,661	75,742
1972	193,000	66,278	101,909
1974	177,000	65,025	99,722
1975	136,000	53,640	95,542
1976	76,000	51,565	94,388
1977	65,000	40,300	71,287
1978	23,000	26,877	57,435
1979	34,000	37,848	NA
1980	20,600	32,805	NA
1981	31,200	31,000	NA
1982	3,200	30,000	NA
1983	10,231	36,000	NA
1984	NA	32,000	NA

* These data refer to the annual period beginning 1 July of the nominated year.

Table 4. Export estimates of major tree nuts (tonnes).
Source: Anon, 1980

Year	Almonds (in shell & shelled)	Hazelnuts (in shell & shelled)	Cashew kernels	Walnuts (in shell & shelled)	Brazilnuts (in shell & shelled)
1974	67,974	160,764	94,072	41,758	23,655
1975	77,849	141,803	95,961	51,834	40,184
1976	98,035	179,664	94,118	62,945	27,477
1977	112,450	174,466	71,455	48,259	25,294
1978	106,943	199,607	65,000	41,953	20,839

India's processing industry had spawned 400 factories employing over 200,000 workers by 1975 with a capacity to process almost 300,000 tonnes of raw nuts annually. Most of these raw nuts came from east Africa which produced about 75 percent of the world's commercial trade in the early 1970's. Today this region produces less than 25 percent of world trade (Table 2). A record 204,000 tonnes of raw nuts were imported by India from east Africa in 1968, but by the 1980's these nuts were simply not available (Table 3). With lower production and/or increasing demand from their own processing industries, most African and Asian producing countries had fewer surplus raw nuts to export. Improved collection of its domestic crop saw India double its production between 1972/73 and 1982/83 (Table 2). Over the last decade government initiatives have been aimed initially at increasing domestic production to 300,000 tonnes and to 500,000 tonnes by the year 2000. Incentive schemes have seen the industry expand from its traditional base in Goa and Kerala (where 80 percent of India's crop is still grown) to the drier southern and eastern states of Tamil Nadu, Andhra Pradesh, Orissa, Pondicherry, Tripura, West Bengal, Bihar and Karmataka, and north to Maharashtra and Gujarat. Over 500,000 hectares are now under cultivation.

However, more than 50 percent of total processing capacity remains idle and less than 150,000 workers are now employed in the industry. Indian exports in the decade to 1984/85 fell by more than half to 32,000 tonnes (Table 3).

A genetic improvement programme has been conducted for the last 10 years, identifying a number of superior selections. These, together with increased plantings and improved cultural techniques, form the basis of India's attempt to substantially increase domestic production in the medium term. India's competitiveness in the market depends largely on its cheap labour force. With considerable changes taking place in their labour market coupled with increasing production costs, this advantage is not secure. Greater domestic utilisation of the cashew apple and CNSL is recognised as critical to strengthening their industry. A new cashew fenni distillery recently began producing solely for export.

Researchers are refining processing techniques to manufacture a range of foodstuffs from the apple as diverse as pickles, wine, candy, jams, juices and carbonated drinks. Its use as a source of pectin for the food industry is also being investigated. The need to refine CNSL locally using a recently developed Italian process to boost its use in the domestic industrial sector has been highlighted, as well as to increase exports. Even the chips and dust of kernel from the shelling and packaging process find increasing use in stock feed preparations. Brazil, with great scope for genetic improvement due to the breadth of its gene pool, has the capacity to dominate world trade and increased its production three-fold in the decade to 1982, mainly from new plantings (Table 2). An estimated 73-80,000 hectares of cashews were cultivated in 1966. By 1977 a further 65,000 hectares had been planted of a planned 182,000 hectare government financed expansion programme. The balance of this program does not appear to have been planted by early 1984 (pers. comm. A.J. Millington). By 1972 processing capacity equalled 90,000 tonnes of raw nut, which was 50 percent under-utilized. Brazil exported 10,000 tonnes of kernel in 1975 from total production of 51,000 tonnes of raw nut. The current production level could generate about 8000 tonnes of CNSL. The United States of America remains Brazil's biggest single customer. Cashew apple products remain in greatest demand in Brazil's domestic economy.

Kenya's cashew industry is based on small holdings and currently produces about 20,000 tonnes of raw nut (Table 2). Processing is mechanized and government support is aimed at increasing productivity and the area planted to superior selections of cashew. Although small in quantity, Kenya's export product is known for its high quality.

From its maximum annual recorded crop of 143,000 tonnes in 1974, Tanzania's production has declined to less than 50,000 tonnes despite large numbers of trees, an extensive mechanical processing capacity and government programmes to boost production (Table 2). Mozambique's fall in production has been more dramatic. It has an enormous production potential from its estimated tree population of 72-80 million in the early 1970's. With mechanical processing capacity grossly under-utilized, national re-construction must preface any real improvement in Mozambique's industry.

The countries of east and south-east Asia which produce cashews are likely to increase their share of world trade as their industries expand. Statistics are scarce. West Malaysia boasted about 7500 hectares of cashew in 1978 and this is known to have expanded (Table 5). A small industry has also been established in Sabah.

The world market

The USA was the world's largest cashew kernel market, regularly importing 25-30,000 tonnes annually from India between 1955 and 1969 and supplementing that with purchases from Brazil. India still supplied 76 percent of the world market by 1968, and had never sold more than 15,500 tonnes of kernel in a year to the USSR. This changed dramatically in 1968/69. In 1969/70 Russia purchased from India 26,314 tonnes and in 1974/75 a record 39,712 tonnes of kernel. Until 1982 the USSR purchased regularly 60-70 percent of India's exports (Table 6).

Table 5. Area and production of cashew nut in Peninsular Malaysia (ha).
Source: Malaysian Agricultural Research and Development Institute (MARDI)

States	1970	1971	1972	1973	1974	1975	1977	1978
Johore	50	50	2	2	30	13	26	68
Kedah	71	71	69	63	59	54	47	47
Kelantar	366	219	217	266	259	240	190	190
Malacca	1	1	1	1	7	7	9	9
N.Sembilan	0	0	1	1	1	1	1	1
Pahang	384	393	238	271	817	874	1337	1345
Penang	8	3	3	10	8	6	6	6
Perak	76	17	17	27	34	56	42	42
Perlis	27	27	27	24	25	25	27	27
Selangor	0	1	1	1	1	1	1	1
Trengganu	732	814	814	1212	4318	4956	5262	5868
Total	1715	1596	1736	1878	5559	9233	6947	7422
Yield (m. ton)	360	335	355	394	394	629	630	700

As a result of trade agreements negotiated in Indian currency, the USSR purchased cashews together with other Indian goods in rupees. Cashew prices were negotiated upwards and western nations purchased substantially lower quantities. In 1983 the trend was reversed when the USSR purchased only 4 tonnes. The USA again became the major buyer and other nations increased their purchases, at an average price reduction of 19 percent (Table 6).

Table 6. Export statistics for Indian cashew kernels (tonnes).
Source, Cashew Causerie 6(3)l9, 1984.

Country	Year 1972	1975	1978	1980	1981	1982	1983
USSR	23,385	24,797	8,885	22,780	21,183	18,922	4
USA	19,568	18,458	6,015	5,948	3,483	5,206	22,199
Japan	2,001	3,769	3,441	1,798	931	1,658	2,318
Australia/NZ	1,332	2,220	594	1,431	1,096	1,219	1,701
Czechoslovakia	352	90	189	308	501	335	751
Singapore	389	529	286	281	409	592	1,309
Netherlands	1,079	1,402	1,125	1,678	383	570	2,722
UK	1,991	808	490	397	302	548	1,167
Kuwait	131	421	609	331	182	533	413
Hong Kong	1,017	858	293	524	144	888	563
Canada	5,486	2,830	604	307	48	171	1,202
West Germany	892	577	341	220	31	68	323
Others	4,319	2,415	948	853	796	1,110	945
TOTAL	64,542	59,174	23,820	36,856	29,449	31,787	35,697
	665	1,055	752	1,500	1,719	1,507	1,377

Export statistics of other major producing countries are difficult to obtain, and are best viewed in terms of Australia's imports (see next section and Table 7). Domestic consumption in India is estimated at about 10,000 tonnes of kernel annually. All producing countries have a domestic demand for cashew kernels, with their premium quality product being exported. Brazil consumed 7000 tonnes of raw nut in 1975, and is expected to consume 11,000 tonnes of raw nut in 1985 (1979 projection). The member nations of the Association of South East Asian Nations (ASEAN), four of which have cashew industries, together comprise a total population equal to that of the USA and Canada. Collectively their economies are growing at a current rate of 7 percent annually. With increasing living standards, their domestic demand for kernels is likely to rise. Japan and Hong Kong are significant consumers of the product (Table 6). As China's economy grows its cashew industry should find an expanding market within its own borders as well as in east Asia generally. There is likely to be greater participation by these Asian nations in world cashew trade. The world market appears under-supplied. Indian export statistics alone show that Europe can consume 45,000 tonnes of kernel annually. Canada and the USA together can consume more than 30,000 tonnes, West Asia over 1300 tonnes, east and south east Asia over 6400 tonnes and Oceania more than 2500 tonnes annually.

These figures exclude the African and South American markets and exports by other nations. Conservatively then, given competitive produce pricing, the world market should exceed 100,000 tonnes of kernel annually, or over 400,000 tonnes of raw nut. India's CNSL exports peaked at 14,353 tonnes in 1964/65, but are generally about 5000 tones annually. Japan and Korea have replaced the UK and USA as India's major customers for this product (Table 8). Brazil and India together supply most of the world's CNSL requirements today. Brazil's market for cashew apple products seems significant only within its borders.

Australia's market

The cashew is a luxury product in Australia with peak demand coinciding with Christmas and Easter celebrations. Table 1 indicates a steady increase in the quantity and price of imported kernel from 1970/71 to 1975/76 when a record 3648 tonnes were imported. Consumption declined in response to price rises in the late 1970's however importers are now purchasing similar quantities of kernel as they did a decade ago at more than twice the price (Table 1). Substantial variation occurs in purchase price of imported kernels (Table 7). Prices vary according to quality and count (kernels per unit weight). Excluding exporters like Singapore, Hong Kong, USA and West Germany who simply buy and sell kernels, price differences of A$1-3000 per tonne are common.

Table 7a. Cashew kernel import statistics for Australia by country of supply.
Source: A.B.S.

Country	1981/82 Quantity (kg)	1981/82 Value (A$000)	1981/82 Value per tonne (A$)	1982/83 Quantity	1982/83 Value (A$000)	1982/83 Value per tonne (A$)
Brazil	536,729	2,424	4,516	379,142	1,537	4,504
Ethiopia	-	-	-	-	-	-
Hong Kong	-	-	-	-	-	-
India	930,917	5,354	5,751	1,723,679	7,610	4,415
Indonesia	7,170	34	4,742	-	-	-
Kenya	427,504	2,335	5,462	130,411	494	3,788
Malaysia	-	-	-	-	-	-
Mozambique	120,295	691	5,744	162,024	902	5,567
Peru	14,850	18	1,212	-	-	-
P. Rep. of China	21,816	136	6,234	51,784	239	4,615
Philippines	37,446	42	1,122	36,891	31	840
Singapore	12,338	18	1,459	3,402	16	4,703
South Africa	-	-	-	14,772	71	4,806
Sri Lanka	9,118	45	4,935	50,280	242	4,813
Taiwan	-	-	-	13,812	73	5,285
Tanzania	104,775	561	5,354	51,279	254	4,953
USA	-	-	-	-	-	-
West Germany	-	-	-	-	-	-
Other	-	-	-	50	-	NA
TOTAL	2,223,490	11,658	5,243	2,617,526	11,469	4,382

Table 7b. Cashew kernel import statistics for Australia by country of supply.
Source: A.B.S.

Country	1983/84 Quantity (kg)	1983/84 Value (A$000)	1983/84 Value per tonne (A$)	1984/85* Quantity	1984/85* Value (A$000)	1984/85* Value per tonne (A$)
Brazil	457,541	2,131	4,658	480,593	2,564,991	5,337
Ethiopia	15,000	45	3,500	1	20	25,000
Hong Kong	-	-	-	-	-	-
India	1,820,708	9,687	5,321	2,432,35715	419,867	6,339
Indonesia	-	-	-	4,547	4,547	5,060
Kenya	85,260	393	4,609	187,671	1,107,162	5,900
Malaysia	10,851	14	1,286	-	-	-
Mozambique	14,107	70	4,962	-	-	-
Peru	7,485	30	4,008	2,245	6,450	2,873
P. Rep. of China	71,530	327	4,572	77,538	479,900	6,189
Philippines	61,235	75	1,225	-	-	-
Singapore	15,742	74	4,500	-	-	-
South Africa	-	-	-	-	-	-
Sri Lanka	28,346	122	4,304	2	25	12,500
Taiwan	-	-	-	-	-	-
Tanzania	48,010	163	3,395	42,184	272,592	6,462
USA	-	-	-	15,875-	91,455	5,761
West Germany	-	-	-	72	677	9,403
Other	86	1	11,628	-	-	-
TOTAL	2,634,941	13,132	4,984	3,243,085	19,969,785	6,158

* Preliminary figures

† Values in whole dollars.

Table 8. Indian exports of CNSL (tonnes).

Country	1972	1975	1978	1979	1980	1981	1982	1983
Japan	1,350	1,809	1,035	4,172	4,017	2,089	4,512	1,868
Korea	120	90	375	703	718	764	890	1,025
UK	2,941	1,628	1.495	5,787	2.147	710	-	-
USA	183	1,065	1,445	3,108	2,919	380	-	-
Rumania	108	150	120	375	250	260	-	-
Others	311	515	534	1,216	658	597	577	288
TOTAL	5,013	5,207	5,001	11,441	10,699	5,650	5,979	3,176
Value in rupees (millions)	5.9	12.7	34.8	128.3	94.3	27.2	16.5	12.0

This may indicate a lack of discrimination amongst importers, a preference for a range of quality and price for different markets or end uses, or a lack of sufficient quantities of preferred quality kernels being available. The viability of a domestic industry will depend greatly on how price competitive its kernels will be against the imported product and other nuts, and on their quality and consistency. Domestic production should bring stability in price and supply, and allow competitive expansion of what is already a lucrative market.

Implications for an Australian industry

A successful domestic industry will depend largely on the level of productivity which can be attained. Cashews are naturally precocious and bear fruit in their first year. The main genetic factors influencing yield are free vigour and extent of fruit bearing surface area, regularity and degree of flowering, sex ratio of flowers within a panicle, favourable pollen grain germination and pollen tube growth to effect fruit set, size and weight of raw nuts and recovery rate of kernel. Ample evidence of the extreme variability in yield of seedling trees including those grown from the seed of high yielding parents, indicates that vegetative propagation of selected genetic material is critical to orchard development in Australia. Several Indian selections including BLA-139-1 and Vengurla 1 and 4 have exceeded yields of 20 kg per tree annually, with the former averaging 34.7 kg per tree per year over 10 years in Kerala. Nut weight of up to 8 g and commonly 6 g, and 26-28 percent kernel recovery have been achieved.

In Brazil raw nut weights exceeding 10 g and reaching 16 g are commercially produced. Yields of up to 73 kg per tree per year over 10 years have been reported on single, large mature trees in Brazil. Basing large plantings on such yield potential is not always sound but they underscore the importance of good selection procedures for commercial and experimental plantings. Kernel recovery was shown in one study in Brazil to vary from 19 to 32 percent. Evidence indicates that kernel percentage is negatively correlated with raw nut size but this has not yet been corroborated across the gene pool. The need to introduce and evaluate high yielding selections from as wide a range of the gene pool as possible cannot be over-emphasized. Trees producing nuts without CNSL are known to exist in Brazil and India which may offer scope to reduce the complexity of processing. High density orchards using optimum fertilization, irrigation and plant protection practices together with high quality, high yielding clonal selections will form the basis of Australia's industry but still require definition.

Mechanical management, in particular harvesting, is essential within Australia's economic constraints. Modification of the macadamia harvesting system used by CSR Ltd. is expected to provide a suitable system for cashew raw nut harvesting from the ground. If the apple is to be retrieved for processing, harvest from the tree will be required. - Assessment of several prototype fruit harvesters including the Trel-Pikr developed jointly by Crendon Machinery of Donnybrook, W.A. and the W.A. Department of Agriculture is planned at the latter's research facility at the ORIA. Under no irrigation, limited or no fertilization, no pruning and low tree densities, added to poor genetic stock yields of one tonne per hectare are rarely achieved.

In Table 9 a range of productivities is presented as a function of tree yield and tree density. In 1983 a raw nut yield of 2-2.5 tonnes per hectare was suggested as a minimum yield required to generate profit in an Australian context. The aim of plant improvement and cultural experimentation in Australia needs to be a yield approaching 10 tonnes per hectare from mature trees. This could be achieved through higher densities as well as increased tree yield. Selective assessment of management practices and some of the many relatives of the cashew as rootstocks and breeding parents will help in meeting this challenge. Australia's consumption of about 3250 tonnes of kernel in 1984/85 could be supplied at this upper yield, from less than 2000 hectares of trees. At a yield of 2 tonnes per hectare of raw nuts, almost 7000 hectares would be required (Table 9). The medium term intention of the joint venturers in the pilot farms of north-west Australia is to export raw nuts to India for processing. India would welcome this supply, especially from a company with connections with the Indian processing industry as has Twentieth Century Foods. Subject to market circumstances, all, or part, or perhaps even none, of that processed kernel would be re-imported to Australia. Special trade zones exist in India in which companies can import raw products, process them or manufacture other products, and re-export them, whilst benefiting from a substantial reduction in government charges and regulations. Such concessions are aimed at boosting domestic industry, employment and foreign exchange earnings. Any cost benefits are more likely to benefit the joint venturers rather than the final consumers.

Table 9. Raw nut (R) and kernel (K) production of cashew (tonnes per hectare) as a function of tree density and individual tree yield, and corresponding plantation area (A) in hectares required to produce 3,250 tonnes of kernels, imported by Australia in 1984/85.

Tree density (trees per hectare)	Tree yield (kilograms /tree)											
	1			5			10			50		
	R	K	A	R	K	A	R	K	A	R	K	A
100	0.1	0.024	135,417	0.5	0.12	27,083	1.0	0.24	13,542	5.0	1.2	2,708
200	0.2	0.048	67,708	1.0	0.24	13,542	2.0	0.48	6,771	10.0	2.4	1,354
400	0.4	0.096	33,854	2.0	0.48	6,771	4.0	0.96	3,386	20.0	4.8	677

The real benefit to Australia of a domestic cashew industry will flow from its own processing capacity. Current technology is still labour intensive. Preliminary attempts at using the macadamia shelling technology at CSR Ltd. have shown this system to be inappropriate. The kidney shape of the raw nut and kernel and the presence of CNSL will require innovation in design to produce an efficient mechanical shelling plant. A modular design would allow such technology to be used across a range of production capacities. Such developments are likely to follow investment in an Australian cashew industry. Expansion into the export market with kernels and management and processing technology could be a further development of such investment.

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Research Into Pecans

This article summarizes some of the research conducted on pecans and published in the scientific literature during the last 2-3 years. Summaries of individual research reports can be found in the journal, Horticultural Abstracts, volumes 54 (1984) and 55 (1985). The articles mentioned and the addresses of the authors appear at the end of the article.

Propagation

In Texas, USA, Hausen and Lazarte (1984) found that single node cuttings from 2 month old pecan seedlings (cv. Desirable) formed multiple shoots in a liquid culture medium. These shoots produced roots when the nutrient composition was changed and they were successfully transferred to soil and acclimatized in a greenhouse. The composition of potting mixes, shape and size of containers, fertilizer types and rates, the winter culture of pecan seedlings and transplanting experiments with container-grown pecan nursery trees have been reviewed by Overcash et al. (1983).

Growth and its control

Wetzstein and Sparks (1984) have described and illustrated the arrangement of male and female flowers, including the organization of the female flower and the development of the pistillate flower and the whole cluster. The effect of paclobutrazol on the growth of young green-house grown pecan seedlings was investigated by Wood (1984). He found that soil drench applications over the range 0 to 32 mg/pot reduced plant height, plant dry weight, internode length, leaf thickness, leaf area and chlorophyll content. Seedlings treated with high levels of paclobutrazol had a slight tendency for increased rate of photosynthesis.

A review and discussion of pecans in New Mexico, West Texas, Arizona and California has been written by Malstrom (1984). Pests and disease, nutrition, salinity problems, orchard density, pruning, irrigation, harvesting, varieties and pollination are all discussed in a 9-page article. A method of estimating pecan yield was developed by Worley and Smith (1984) in Georgia, U.S.A. They compared their method with measured mechanically harvested yields and it proved quite successful. The method consists of measuring the yield from four 3.6° circle sectors around each tree accounting for 1/25 of the tree yield. This figure is then multiplied by 25 to estimate the total yield.

Irrigation

Water use of irrigated pecans was studied in Texas by Miyamoto (1983). He found that water use was highly dependent on tree size and planting density (60-120 trees/ha) in surface irrigated orchards which were 8-35 years old. Below a depth of 1 m water depletion was minimal. Close- spaced, full-grown trees used 1000 to 1300 mm/season.

A mathematical equation incorporating trunk diameters (range 130-530 mm), planting density and weather can be used to estimate amount of water needed for irrigation.

In a more detailed study Miyamoto (1984) developed a computer program adaptable to micro computers (CPU>48K) to predict soil water storage and irrigation needs. The soil features taken into account are soil water retention properties, evaporation and drainage characteristics, soil salinity and soil variability. The computer program predicted soil water storage with reasonable success on two commercial orchards covering 260 ha.

Harvesting

Machines developed in Israel for harvesting pecans on small farms are reviewed by Sang et al. (1984). The article examines a side-delivery sweeper employing a principle resulting in a continuous windrow with minimum extraneous material. For small plantations, a portable nut harvester utilizing the suction principle was developed. A field pre- cleaner was designed for those growers who still use sheets spread on the ground as the means for collecting nuts shaken from trees. A new pecan harvester was developed utilizing a unique chain-to-soil relationship method that enables the machine to perform well under wet, heavy soil conditions. All the machines are now manufactured commercially.

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Tropical Fruits for the Philippine Highlands

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Introduction

The Philippines is an archipelago of about 7,100 islands and islets in the Pacific about 800 km off the southeast coast of Asia. Located 4°50' (Sibutu Island) to 21°07' (Y'Ami Island) north of the equator, it has a tropical climate characterized by two distinct seasons: the dry (November to April) and the wet (May to October) and with mean temperatures remaining continuously above 20°C. This climatic feature makes the Philippines most suited for the culture of tropical fruit and nut species.

Within the country, however, there are highland areas where the climate approximates that of the mild subtropics and where the temperature may fall below 20°C during some months of the year. Among the populated highlands with agricultural enterprises are three neighbouring provinces in the north (Mountain Province, Benguet and Kalinga-Apayao) and one adjacent city (Baguio City). Other highland areas throughout the country with tremendous agricultural potential still await development.

In terms of fruit cultivation, these tropical highlands can be planted to some temperate species (e.g. apple, pear, chestnut, peach, persimmon, etc.) as being attempted today based on some success obtained in other tropical countries. These areas, however, are probably best suited for the cultivation of fruit species of known subtropical origin (e.g. avocado, citrus, lychee, longan, macadamia, etc.). Finally, fruit species of the tropics whose range of climatic adaptability has been extended to the subtropical areas (e.g. banana, guava, passion fruit, pineapple, etc.) may be grown in the tropical highlands.

There are many other tropical fruit species whose range of climatic adaptability has not been extensively studied. In the Philippines, some species are known to grow well in the highlands. Among them are the bignay, carambola, durian, mango, pili, santol, serali and tamarind.

The following are some brief notes on some subtropical and tropical fruit and nut species that have shown varying degrees of successes in the Philippine highlands.

Avocado *(Persea americana* Mill., Laureaceae). The availability of avocado cultivars belonging to the three major races has extended avocado cultivation in the highlands, although the majority of the crop is still grown in the lowlands.

This situation will probably obtain for as long as Filipinos are able to develop the taste for avocado in general and for subtropical cultivars with high oil content in particular. In most avocado-consuming countries, the fruit is prepared as a salad ingredient. In the Philippines, however, avocado is usually eaten with sugar and milk. For this reason, avocado-flavoured icecream is very popular.

Banana (*Musa* sp., Musaceae). The Philippines grows some 75 banana cultivars mostly in the lowlands. Some Dwarf Cavendish' (AAA) bananas, however, are grown in the backyards in the highlands. There are indications that other cultivars with pure *M. acuminata* Colla genes (e.g. 'Inarnibal', 'Senorita', 'Morado') can be grown commercially in areas with much cooler temperature.

Bignay (*Antidemsa bunius* (L.) Spreng., Euphorbiaceae). This is a dioecious species whose clusters of small red fruits are used in making wine. Being a small tree with attractive foliage, bignay makes a beautiful ornamental plant especially when its fruits start to ripen.

Caimito (*Chrysophyllum cainito* L., Sapotaceae). This tropical American fruit tree has adapted well under local conditions. Its fruits which are either light green or purple when ripe are eaten fresh or made into sherbet. The tree itself is very ornamental-looking owing to its leaves which are dark green above and velvety russet brown beneath. It grows quite tall, however, and necessitates regular heavy pruning for easier management and harvesting.

Calamansi (*Citrus madurensis* Lour., Rutaceae). This native citrus species is extensively grown in the lowlands for its juice and for souring native dishes. Its cultivation has not extended much to the highlands, although in some subtropical countries, it is much grown as an ornamental plant in containers. It is a small, precocious, prolific and almost everbearing tree.

Carambola (*Averrhoa carambola* L., Oxalidaceae). Known locally as balimbing and in other countries as starfruit. Carambola is becoming a popular fruit in the Philippines owing to the recent introduction of improved cultivars with large and subacid fruits. This small tree is quite precocious and very prolific. With proper pruning, the tree stays low with much of its fruits produced on bare trunk and branches.

Durian (*Durio zibethinus* Mum, Bombacaceae). Probably the most popular fruit tree of Southeast Asia, durian has always been cultivated in lowland areas and its range of climatic adaptability has not been studied. Limited experiences in the Philippines seem to indicate that durian can be successfully grown at higher elevations. In the southern provinces, for example, durian is found at a wider range of elevations with trees grown at higher elevations maturing their fruits about two to three months later.

Guava (*Psidium guajava* L., Myrtaceae). Traditionally a lowland fruit crop, guava is now known to grow in much cooler environments in subtropical parts of California and Florida. While its top is susceptible to frost damage, its root system is able to produce suckers which can resume fruit production in one to two years. In the Philippines, little attempt is made to cultivate guava in the highlands.

Lemon (*Citrus limon* (L.) Burm.f., Rutaceae). Being a subtropical fruit crop, its successful cultivation in the Philippines is in the highlands. Even in these areas, total production is still limited, probably because of the presence of leaf mottling (a mycoplasma-like disorder transmitted by jumping lice) and because lemon fruits have to compete with the native calamansi.

Lime (*Citrus aurantifolia* Chrism. & Panz., Swingle, Rutaceae). The present situation with lime is similar to that of lemon. There are "native" limes, however, that are well adapted in lowland areas. Although they are not grown commercially, these native limes are quite important as a flavouring ingredient in the making of custard pies known locally as leche flan.

Lychee (*Litchi sinensis* Sonn., Sapindaceae). This subtropical fruit crop from south China was introduced into the Philippines about 80 years ago. The first introductions were from seeds and while they grew into large trees, they had not fruited. Recent introductions, particularly from other tropical countries (e.g. Thailand), were more promising. A more concerted effort at lychee varietal introduction and performance evaluation is needed to develop this very promising fruit in the Philippine highlands.

Longan *(Euphoria longana* Lam., Sapindaceae). While other Euphorias are presently grown in the Philippines (e.g. *E. didyma* Blanco), longan is of more recent interest. In fact, only isolated cases of longan trees fruiting have been reported. Other interested fruit growers have propagated these fruiting trees. As with lychee, a more systematic varietal introduction and evaluation is needed.

Macadamia (*Macadamia integrifolia* Maid. & Betche, Proteaceae). This Australian nut tree was first introduced into the Philippines in the early 1900's but is still of rare occurrence. Introductions were mainly of seeds from Hawaii. Fruiting trees have been reported and these are being propagated by air layering. What is presently needed is to grow seedling rootstocks and introduce scions of the recommended cultivars from Hawaii and Australia for grafting.

Mandarin Orange (*Citrus reticulata* Blanco, Rutaceae). This loose-skin orange is grown extensively in low and medium elevations in the country. Its cultivation in the highlands offers a lot of potential for fruit crop diversification. The availability of subtropical cultivars in other countries augers well for the expansion of the Philippine citrus industry.

Mango (*Mangifera indica* L., Anacardiaceae). The local mango cultivars (e.g. 'Carabao', 'Pico') are well adapted to lowland areas with a distinct dry season. Other cultivars grown in some subtropical countries (e.g. Florida, Taiwan) have been introduced into the Philippines, but adaptability tests have been conducted mainly in the lowlands. It is well to study their performance in the highlands.

Passionfruit (*Passiflora* spp., Passifloraceae). The culture of passionfruit in the Philippines has not progressed very much mainly because its main processed product, the passionfruit juice, has not been well introduced to the people. Both species (*P. edulis* Sims and P. *quadrangularis* L.) perform well in both lowlands and highlands. In Baguio in the north, the fruits are bought mainly by tourists.

Pineapple (*Ananas comosus* (L.) Merr., Bromeliaceae). This second most important fruit of the Philippines is grown commercially in places of low to medium elevations. Limited plantings are found in the highlands where fruits produced are decidedly of much inferior eating quality.

Pummelo (*Citrus grandis* (L.) Osb., Rutaceae). This much demanded citrus fruit is grown both in the lowlands and highlands. Outstanding cultivars from China and Thailand dominate the present plantings. It is an important fruit during the Christmas season when price is at its peak.

Santol (*Sandoricum koetjape* (Burm.f.) Men., Meliaceae). This native fruit of India and Malaysia is now well distributed in the Philippines. Outstanding cultivars from Thailand with large, subacid fruits have been introduced and now constitute the greater bulk of the commercial plantings in the lowlands. These introduced cultivars, unfortunately, are quite susceptible to gall-forming mites.

Serali (*Flacourtia indica* (Burm.f.) Merr., Flacourtiaceae). Known locally as bitungol, this very minor fruit is cultivated only in backyards. It is a spiny shrub or small tree bearing small globose, purple or reddish-purple fruits which are very popular among children. Selection of outstanding cultivars may lead to the commercial development of this prolific tree.

Sweet Orange (*Citrus sinensis* (L.) Osb., Rutaceae). This subtropical citrus species has adapted well in low and medium elevations in the Philippines. Cultivation in the highlands is being pushed through by some growers to produce better quality citrus fruits.

Tamarind (*Tamarindus indica* L., Leguminosae). This native fruit of Tropical Asia and Africa is now of widespread distribution in the Philippines where its fruit is extensively used for making juice and for souring native dishes. Grown mainly in the lowlands, its cultivation in the highlands is still rarely done. Availability of outstanding cultivars bearing sweet and large pods should encourage commercial cultivation of this fruit crop.

The Mango - an Industry for Western Australia

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Summary

There is a trend to greater commercial plantings of, and research programmes into, the mango in many tropical and subtropical countries including northern Australia. Increasing plantings are occurring from Kununurra in the far north to Perth, in Western Australia. Significant production is now beginning to influence the Perth Metropolitan market. In order to create a sound base for growth in this fledgling industry, and to avoid over-supply for a short period, growers should consider planting new varieties to lengthen the fruiting season which can be increased to as long as 8 months of the year. Recent successful experimental exports of our Kensington Pride variety to Singapore indicate that advantage should be taken of this Asian market and attempts made to increase mango exports from WA to other northern hemisphere markets.

Introduction

The mango tree (*Mangifera indica* L.) is believed to have originated in the Indo-Burma region. Over 1000 varieties are thought to exist in India where this fruit, cultivated for over 4000 years, occurs in diverse environments from the far south to the foothills of the Himalayas. Both the Hindu religion and the Indian people venerate the mango in literature, art, music, religious and other ceremonies, and it is widely used in amenity plantings. Mangoes tolerate a wide range of climates and soil types, are deep rooting, drought tolerant and hardy, once they are established (Singh, 1960). Through colonial and pre-colonial introductions the mango now occurs throughout the tropics and sub-tropics (Purseglove, 1968). In more recent times it has been planted in warm temperate areas on both coasts of Australia and at one inland site (Alexander, 1981), as well as in California Thompson, 1982), South Africa and Israel.

Research Priorities

A number of physiological and agronomic problems are associated with the growing of mangoes. These include the tendency to a biennial bearing habit, the need for both a ‘dwarfing’ growth habit and to lengthen the fruiting season with early and late bearing varieties, and the as yet poorly understood cultural aspects of nutrition, water relations and the desirability of tree pruning. It is widely held that the mango requires a stress period to trigger flower initiation. Much experimentation in manipulating drought, assessing temperature effects and other stress factors has been undertaken to attempt to correct the biennial habit which characterises a number of mango varieties.

At the Indian Institute of Horticultural Research (IIHR), Bangalore, S. India, the research emphasis is now on physiological studies to explain biennial bearing and hybridisation to overcome it. Dr. Elias K. Chacko. a Research Fellow at the Institute, suggests that two types of mango occur naturally. The first is able to replenish the nutrients lost in the reproductive process efficiently, in time to support a normal flowering the following season. The second type cannot regain its nutrient balance as quickly, resulting in either a light flowering the next (off) season followed by a normal (on) season, or more rarely no flowering for one or more seasons.

At Kununurra in a commercial cropping orchard, 12-year-old Kensington Pride seedling trees on Levee soil yielded very poorly during 4 consecutive years, which had warmer than average dry season temperatures.

Dwarf rootstock studies undertaken in India have indicated that the dwarf habit is inherent in the scion, and not passed to a non-dwarf scion from a dwarf rootstock (pers. comm. C. Chacko). Dwarf rootsiock studies continue in Australia and South Africa. Dr. C.P.A. Iyer, a geneticist also at IIHR is screening open pollinated seedlings in an attempt to find superior quality material. He is also crossing under controlled conditions regular bearing varieties with others showing high yields and superior fruit quality, many of which exhibit biennial bearing (Iyer, 1972). The resultant hybrid seedlings are then screened for the same qualities, and their progeny also screened.

Australian mango research programmes include floral studies (Scholefield, 1952) and variety evaluation in the Northern Territory and Western Australia (Burt, 1977; Toohill, 1982), Queensland (Meurant, 1981) and Victoria (Alexander et al, 1981). The CSIRO Division of Horticultural Research is also undertaking a seedling screening programme using open pollinated seed of a number of mono-embryonic varieties at Darwin, in an attempt to find new varietal material. A number of tropical and sub-tropical countries continue to research the mango in order to improve their respective industries, many of which are expanding. Cultural experimentation is in its infancy in Australia.

World Production

India is currently the largest producer arid exporter of mangoes. The Philippines, where the mango is the second most important fruit crop, is increasing its exports to Singapore and Japan in particular. through increased plantings, better management techniques and including out of season flowering Astudillo et al, l978; Bondad, 1980). Most other Asian production is consumed domestically although India traditionally supplies some Middle Eastern and Persian Gulf countries. Thailand and the Java highlands have traditionally supplied the Singapore market, where the Thai ‘Elephant Husk’, ‘Nam Tok Mai’ and ‘Aokrong’ varieties still enjoy popularity (pers. comm., C. Yong, Manager Demonstration Farm, Singapore). South Africa’s export thrust is mainly to Europe whilst Central and northern South Americas’ current programme to increase mango exports is aimed at the lucrative North American market (Bondad, 1980).

The mango is not traditionally found in the Japanese market, with the result that few if any varietal preferences exist there. With appropriate product promotion the Japanese market has the potential to accept large quantities of a wide range of varieties year round (pers. comm., C. Yong).

Mango production in Asia begins as early as April in north-east India and progresses through to September/October as one travels eastward and southward through the Malay archipelago to eastern Indonesia. The Philippine production normally peaks in April - June but with off season flower induction they are able to supply fruit to the Asian market over January - April without competition.

According to external trade statistics for imports of mango fruit, the Philippines can supply mangoes in every calendar month, but quantities are low in the September - February period, fluctuating between 29 and 140 tonnes over 1982-1983. This period coincides with Australia's production peak. However in April 1982, Singapore imported 1265 tonnes of mangoes, which indicates that their market is poorly supplied during the September - February period.

With the exception of the Philippine variety 'Carabao, almost all varieties consumed in the Asian market are of the Indian type, characterised by high terpene levels permeating the entire flesh. Australia's main variety 'Kensington Pride' is believed to be of Indian origin, but is considered by the Indians (pers. comm., E. Chacko) to be of inferior quality, without that 'bite' associated with the Indian types. Even in Singapore the 'Carabao' is less preferred than the Thai and Indonesian (Indian types) varieties, but sells well when free of competition (pers. comm., C. Yong).

Hence with marketing promotion and lengthening the supply period with new early and late varieties, the out of season production of the southern hemisphere should be well received in the Asian and Middle-Eastern market place.

Western Australian Production

Substantial plantings of mango have been, and continue to be, established in a number of Kimberley centres and at Carnarvon (Table 1). Further Crown Land releases in the Kimberley will increase that region's area of mangoes, resulting in Carnarvon no longer being the sole, nor even the major, supplier of mangoes to the Perth market (Burt, 1977) in the future. The extent to which Carnarvon's mango industry may expand is limited by a restricted water supply and by competition (with other cropping systems) for the available irrigable land. Currently Carnarvon plantings are older, with half to two-thirds of the tree population (Table 1) bearing (pers. comm., T. Mueller, Gascoyne Research Station, Carnarvon). By contrast approximately one quarter of the Kimberley tree population is at bearing age, and only recently so.

Table 1. Estimates of mango tree populations in various centres of Western Australia as at March, 1983 (from Ellis 1980, Toohill 1982).

Centre	Area (ha)	No. of Trees Bearing & non-bearing	Type of Planting: Back yard	<50 trees	>50 trees
Broome	20-30	2,500 - 3,000	300	35	20
Carnarvon	-	5,000 - 5,500*	NA	NA**	NA
Derby	3	300	150	5	-
Kununurra	12	1,200	150	20	5
La Grange	1	100	-	-	1
Pandanus Park	15	1,400	-	-	1
Wyndham	2	200	100	4	-

NA = Information not available.
* Carnarvon had 2,200 trees in 1977 (Ellis 1980).
** Majority of orchards at Carnarvon fall into this category.

In 1982/83 Carnarvon supplied 83.5% of Western Australia's recorded total yield of Kensington Pride variety (Fig. 1). Kununurra supplied some 12% and Broome 4% of the total of 100.1 tonnes which passed through the Perth Metropolitan Market (Table 2).

Table 2. Approximate quantities of mangoes sent to the Perth Metropolitan Markets (or elsewhere, as indicated) from various centres in the 1982/83 season.

Fruit originating from	Total Weight (kg): Kensington Pride	Common	No. of 6 kg trays of Kensington Pride
Broome	4,800	10,000	700
Carnarvon	83,500	-	13,900
Kununurra	12,500	NA	2,020
La Grange	NA	$3,000**	NA
Pandanus Park*	NONE	3,000	NONE
TOTAL	100,800		16,620

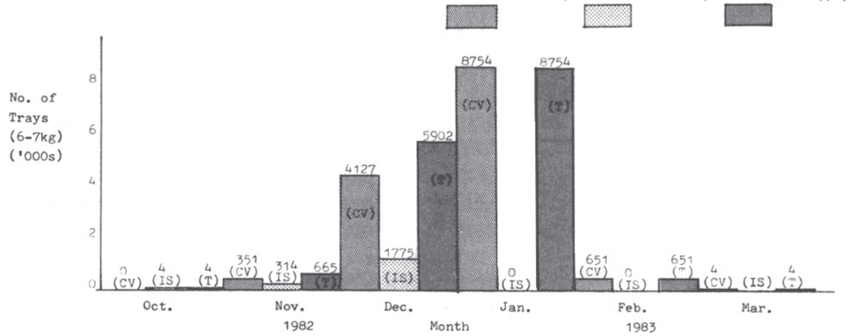
NA = Information not available
* Mangoes from this Centre, an Aboriginal Lands Trust property, were sold almost entirely to the West Kimberley and Pilbara Aboriginal community. None went to Perth. (pers. comm., I. Watson, Manager, Pandanus Park)

** Only information available. The great majority were common mangoes, sold to Perth and Port Hedland (pers. comm., Fr. McKelson, La Grange Mission).

During October to December, 1982, a total of 2,093 trays, or approximately 13.6 tonnes of Kensington Pride mangoes were supplied from interstate sources to the Perth Metropolitan

Fig. 1 Monthly Quantities from Carnarvon[1] and Interstate[2] in 1982/83 of Kensington Pride Mango Variety, Marketed at Perth Metropolitan Markets.

(CV = Carnarvon, IS = Interstate, T = Total Supply)

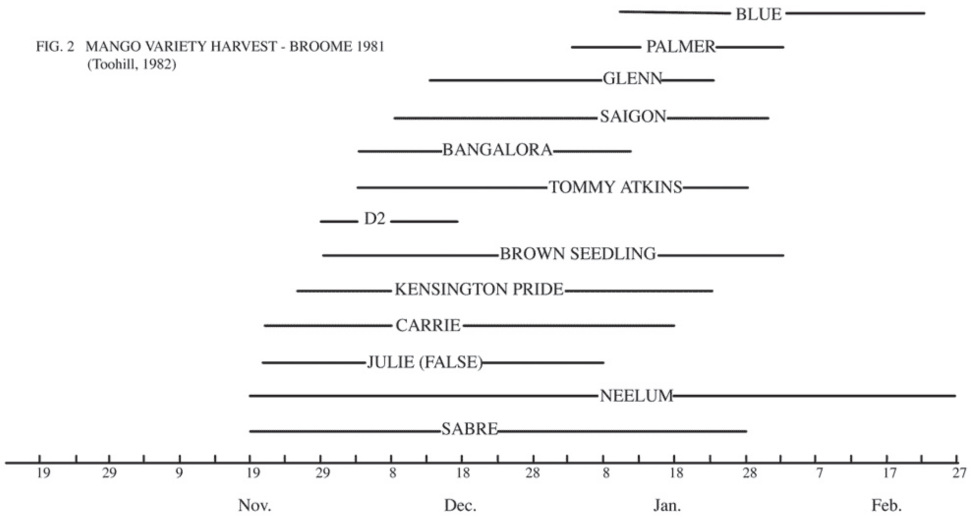


1. Pers. comm. T. Muller, Gascoyne Research Station, Carnarvon.
2. Pers. comm. G. Ward, Fruit Preservation Section, Hort. Division W.A. Dept. of Agric., Perth. (Figures do not differentiate between interstate sources.)

market (Fig. 1). No figures were available for January - March 1983.

An introduction programme of mango varieties from around the world is currently under way in several Australian locations (Toohill, 1982). As well as variation in appearance, quality and other fruit characteristics of these varieties, they also vary in their time of harvest. Fig. 2 gives the harvest period for a number of these varieties (Toohill, 1982) and shows that at Broome, it is possible to produce mangoes from mid October till late January. This effectively extends the season from the 6-7 weeks for the single Kensington Pride variety, up to a period of 16-20 weeks. A similar extension of season can apply to other WA centres, where

FIG. 2 MANGO VARIETY HARVEST - BROOME 1981 (Toohill, 1982)



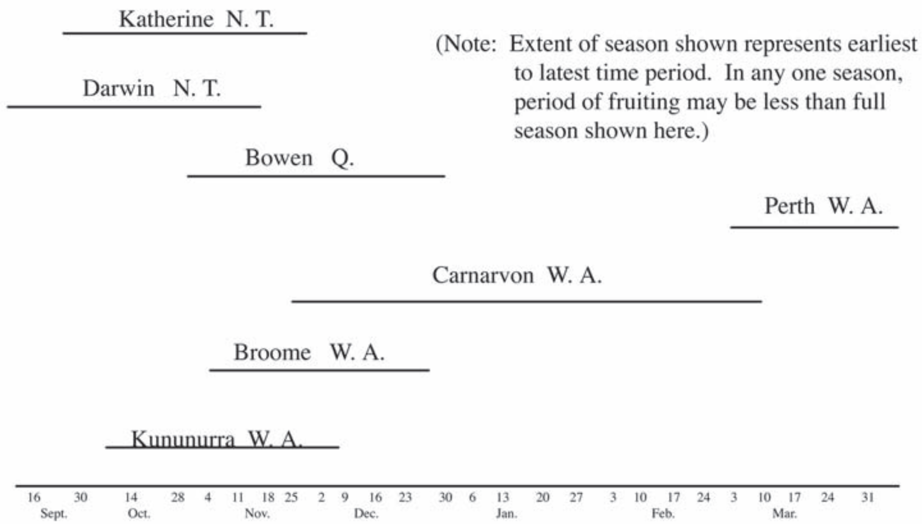
varietal testing is under way or just beginning.

The need to test new varieties in each region cannot be over-emphasised, as local environmental constraints vary significantly (Thompson, 1982). These may include tolerance to disease (e.g. Anthracnose), frost, humidity or long dry/hot periods.

In order to land a fruit on the Perth market with minimal competition to gain maximum prices, gaps must be found in the seasonal supply pattern, and appropriate varieties grown to mature and start ripening during those periods.

Figs. 1 and 3 indicate three main periods characterised by low supply, viz: August - early October, late November - early December and February - March. The first period is when the harvest in Kununurra has just begun, and before Northern Territory production has peaked. The second falls towards the end of the production period of the northern centres (i.e. Kimberley, WA, Top End, NT and North Queensland), and before Carnarvon has peaked. The third period is marked by low production in south Queensland, northern NSW and the Perth area.

Fig. 3. Harvest period for Kensington Pride Mango variety in various Australian centres.



In the Northern Territory, a 50,000 tree mango plantation of Kensington Pride is presently being established (Toohill, 1982). When this project reaches production (as early as 1986/87), it will have an increasingly significant effect on the Australian mango market and present stiff competition to some Kimberley and North Queensland production areas.

Price Fluctuations

In the 1982/83 season, gross prices for Kensington Pride variety on the Perth Metropolitan Market fluctuated from a high of $26.00 per tray for early produce from Kununurra, to $10 to $12.00 in late November, December and January when Broome and early Carnarvon produce had to compete with imported fruit from interstate, and later as Carnarvon produce approached its peak. The lowest price for Carnarvon produce was $6.17 per tray on January 12, 1983, when production peaked.

By late January prices had risen to $15.69 as Carnarvon production declined (pers. comm., T. Mueller, Gascoyne Research Station, Carnarvon).

During the same season, the Gascoyne Research Station was marketing fruit of a number of its new varieties on the Perth Metropolitan Markets.

Table 3 shows that experimental consignments of new mango varieties to the Perth market received good prices, often equalling those received for Kensington Pride. High prices for late season Kensington Pride were maintained by the even later bearing varieties Kent (a Florida USA type) Cairn's Late and Neelum (both Indian types).

Table 3 Gross prices ($A) received for Ke□
and some Carnarvon growers. (Source: T. Mueller, Gascoyne Research Station, Carnarvon W.A.)

	Variety												
Date	Kensington Pride	Haden	Glenn	Banana	Carrie	Sabre	Manzano	Blue	Golds-worthy	Kent	Cairn's Late	Allen	Neelum
Dec. 15, 1982	15.00	12.00	-	-	-	-	-	-	-	-	-	-	-
Dec. 22	10.80	10.80	10.80	10.80	-	-	-	-	-	-	-	-	-
Dec. 29	12.00/13.15	12.00/13.15	10.00/13.15	-	13.15	9/13.15	-	-	-	-	-	-	-
Jan. 5, 1983	11.50/12.20	11.50/12.20	-	-	-	11.50/12.20	-	-	-	-	-	-	-
Jan. 7	12.20	14.00	-	-	10/00	-	10.00	-	-	-	-	-	-
Jan. 12	6.17/8.50	-	-	-	-	-	-	-	-	-	-	-	-
Jan. 17	10.00	-	-	-	-	-	8.00	7.50	-	-	-	-	-
Jan. 19	9.50/9.68	-	-	-	-	-	-	-	-	-	-	-	-
Jan. 26	13.19/15.69	-	-	-	-	-	-	-	14.00	-	-	-	-
Feb. 2	-	-	-	-	-	-	-	-	-	-	-	-	-
Feb. 16	-	-	-	-	-	-	-	-	-	20/00/22.00	20.00	-	-
Feb. 23	-	-	-	-	-	-	-	-	-	17.00/20.00	-	20.00	15.00

* Where two figures occur, they represent prices received from two different market agents.

The Gascoyne Research Station of the Western Australian Department of Agriculture at Carnarvon tested market response of a number of consignments of Kensington Pride mangoes (some 900 trays) in Singapore during the 1982/83 season. Consignments were road freighted to Peru and air freighted to Singapore. When Perth market prices were low, during the peak of the Carnarvon season (Table 3) gross price returns from Singapore were favourable, despite some bruising of produce in transit. In terms of net return to growers (excluding carton costs) the Australian dollar price differential per tray in favour of export over domestic (Perth) sales was $0.15 on January 5, $7.57 on January 12 and $5.40 on January 19, 1983, respectively. Two consignments were held in cold storage in Perth and air freighted to Singapore 2 weeks after harvest. The net price differential was - $0.42 on January 26. On February 2, a Singapore net price return per tray of A$7.77 was received but no domestic sales were available to provide a comparison. Two weeks later however, Kent and Cairn's Late varieties received gross returns at Perth of $20.00 to $22.00 per tray respectively.

Perth presently imports mangoes from South Africa (late February - March), the Philippines (March - April) and Mexico (June - July). The South African product is likely to compete with the Perth metropolitan production if the latter becomes significant.

The Singapore market appears to offer better profits to growers in Western Australia during the peak production times when the Perth domestic price is reduced by over-supply. At other periods, present indications are that domestic prices provide better returns to growers.

The average gross price per tray received by a Northern Territory grower in 1982 for Kensington Pride mangoes marketed in the Eastern States was $35.00 ($175,000 gross income from approximately 300 12-year-old trees) (pers. comm., B. Cull, DPI, Nambour, Queensland). The profits to be made from early fruit production are obvious. A further potential market for Western Australian mangoes is the expanding Pilbara population which is projected to reach 60,000 by the year 1990, and the growing Kimberley population (Ellis, 1980).

Conclusion

The mango is likely to become a major tree crop in Western Australia. In order to support this industry research and development agencies must assess new varieties in each potential production region, in order to advise growers on how best to time their production cycles.

North Queensland and Carnarvon both have established industries based on Australia's own Kensington Pride variety. Present production is still small enough to allow continued good profits to be made from this variety especially from the earlier producing northern areas. New areas must however look at new varieties to 'fill the gaps' in the supply cycle to maintain profits in the medium term.

Continued research into cultural aspects and screening of seedlings (from both open and controlled pollination) is necessary. Further testing of the Asian and other overseas markets for Australian mangoes is desirable. The export option is essential for the longer term future of a Western Australian industry where the approximately one million consumers are dwarfed by the potential market to over 14 million persons in Australia's eastern states and that of east Asia.

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Physiology and Productivity of Tropical and Subtropical Fruit Trees

In May 1985 the International Society for Horticultural Science held a Symposium on the Physiology of Productivity of Tropical and Subtropical Tree Fruit at the University of Queensland, Brisbane. The full proceedings will be published in the Society's Technical Communication Series: Acta Horticulturae.

Physiology is the scientific study of the functions of plants and their parts. Productivity is the efficiency of production. Bringing these two themes together assumes that an understanding of the function of plants, in this case trees, will lead to ways of improving the efficiency of production.

Physiological understanding of temperate tree species has improved dramatically during this century but our understanding of tropical and subtropical species is much more limited. Balanced against this is the large amount of traditional knowledge which has accumulated over long time periods as people have learnt to manage these species.

Here we present the abstracts of the keynote address and the review papers presented at the Symposium hoping to stimulate your appetite for an increased understanding of the function of tropical and subtropical tree crops.

The topics covered were:

Impact of physiological research on the productivity of tropical and subtropical fruit trees

Tree growth and productivity - the role of the root

Reproductive physiology

Plant carbon balance

Integrating physiological information about fruit trees to evaluate productivity

Tree mineral nutrition

Research and progress in cultural systems and management in temperate fruit orchards

Chemical regulation of plants and plant processes

Stress physiology in trees

Tree water relations

Symposium concluding remarks

D.W. Turner
Editor

Impact of Physiological Research on the Productivity of Tropical and Subtropical Fruit Trees

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Less information is available about the physiology of subtropical and tropical fruiting trees than about temperate, deciduous species such as apple, pear, peach, etc. which have been extensively researched in both Europe and the USA. Despite this, subtropical and tropical fruiting trees are known to have a number of physiological characteristics that separate them from temperate and arid species. This paper aims to list some of these differences and to suggest research areas in physiology that will have an impact on their productivity. Virtually all are evergreen trees with leaves that remain functional for long periods, e.g. up to 3 yrs in the case of citrus. They have no physiological dormant period and leaf fall occurs throughout the year. Many have the flushing habit of growth in which shoots and leaves expand simultaneously in spring and autumn or in response to favourable environmental conditions. Most originated in tropical rainforests, are large in size and have many of the characteristics of shade plants. A number of them have restricted centres of origin and have a degree of genetic uniformity, e.g. the separate races of avocado. Many have the capacity to form apomictic seeds which tends to suppress genetic diversity, although these seeds form a convenient method of clonal propagation, e.g. mango, citrus rootstocks.

Generally, subtropical and tropical trees flower profusely, set relatively low numbers of fruits and are biennial or irregular producers. Many have complex self incompatibility systems while others have developed simple outcrossing mechanisms involving temporal differences between pollen shed and stigma receptivity. The initiation of flowers in these trees occurs under conditions of variable and often low light intensity and of limited variation in day length and temperature. In some cases, water stress or conversely the alleviation of stress is thought to provide the trigger to flowering. There is an urgent need for more information on the physiology of the floral process covering aspects of flower initiation, pollination, fruit set and development. The fruits of most tropical trees are soft, difficult to store, susceptible to transport damage and to cold injury even at temperatures well above 0°C. Many are non-climacteric fruits and do not ripen off the tree.

It is difficult to assess the impact of academic physiological research on the productivity of tropical and subtropical fruit trees. They have been cultivated for many thousands of years and a considerable body of traditional knowledge has been assembled about how to manage and manipulate them. Physiological research commonly commences from a desire to document the basic features of a particular crop plant and to relate these features to the available physiological knowledge about plants in general.

It also attempts to provide explanations for traditional and empirically derived management processes on the assumption that once they are better understood it might be possible to further improve these processes.

Current and future physiological research that should influence the productivity of tropical and subtropical tree crops includes work in the following areas. Studies of their reproductive biology, including a knowledge of cultivar combinations and the nature of the pollinating insects required to achieve fertilization is currently making a major impact on planting and management programs. This information is also essential for crop improvement by breeding as cultivars with improved fruit quality, regular set and reduced tree size are required.

Studies of the photosynthetic characteristics of tropical trees is another area of research that should enable us to optimise overall growth and to develop appropriate orchard management systems. While studies on the partitioning of photosynthetic products may lead to ways to overcome problems such as the competition that occurs between developing fruits and flushing leaves. A knowledge of the endogenous hormones of tropical trees and fruits and of their responses to exogenously supplied hormones is an area of physiological research that should pay dividends similar to those that have been achieved with table grapes. For example, it may be possible to develop hormone setting sprays. Most tropical trees are large and techniques to dwarf them using rootstocks or chemicals are required. Finally, nutrition is an area where considerable progress has already been made with the development of critical leaf values for a range of macro and micronutrient elements. Studies of the importance of mycorrhizas in the nutrition of tropical trees and the possible development of more effective strains is seen as important.

Tree Growth and Productivity - The Role of the Root

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In many studies on fruit tree growth and productivity only the growth of the above-ground parts has been of concern, the role of roots often being largely ignored or overlooked. However, it is obvious that roots and shoots interact in their growth and function. These interactions undoubtedly reflect the inter-dependence of each organ for their carbohydrate and mineral nutrient contributions and requirements. Moreover, recent developments indicate that plant hormones, particularly cytokinins and possibly gibberellins, supplied by the roots play an important role in the balance and apportionment of the plants resources. The growing root apex appears to be the site of synthesis of these hormones and thus points to the importance of root number, as well as root surface area, in adequately describing the root system.

The identification and understanding of this close coordination between roots and shoots opens up the possibility that above-ground growth can be altered by below-ground manipulation. One novel treatment, root restriction - where the root system is confined to a small volume, appears to have merit as a means of controlling plant size. The necessity to control shoot vigour and plant size is of particular importance in the fruit crop industry especially for large-growing and low-yielding tree crops. Limiting root development can be a very effective means of reducing vegetative vigour without adversely affecting fruit production. Alteration of the reproductive and vegetative balance by root manipulation appears similar to effects produced by the use of dwarfing rootstocks. In fruiting plants the growth of fruit places an added demand on the root and shoot systems for both mineral nutrients and for photosynthates. As fruit grow this demand would be expected to become increasingly competitive with vegetative growth. Indirect evidence indicates that both root restriction and rootstocks may influence the hormonal output of the root system thereby limiting shoot vigour. In these circumstances flower and fruit development can proceed without excessive competition from growing shoots.

The inclusion of the root in studies on the dynamics of shoot and fruit interactions has so far received little attention. A better understanding of the whole plant can only come from more thorough investigations of root: shoot: fruit interactions.

Reproductive Physiology

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Reproductive physiology is important to crop productivity as the economic product of a fruit tree is generally a reproductive structure. Microscopy techniques have been widely used to investigate reproductive physiology. Light microscopy of sectioned or cleared material can give information on all aspects of the reproductive cycle. Fluorescence microscopy is particularly useful for studies of pollen tube growth and scanning electron microscopy is an excellent tool for studying flora initiation and development.

The major stages of the reproductive cycle which affect tree crop productivity are floral initiation and development, flowering, pollination, fruit set and fruit development. The evergreen tropical and subtropical tree fruit species have a relatively short period between floral initiation and anthesis with no dormant period as occurs in deciduous temperate fruit trees. Many species have outcrossing mechanisms such as dioecy (date palm), monoecy (lychee), andromonoecy (mango), dichogamy (avocado) or self incompatibility (macadamia). Fluorescence microscopy has confirmed that in macadamia the incompatible pollen tubes are inhibited in the upper style. Cultivars should be interplanted in the orchard for maximum yields.

Insect pollinators are required for species with outcrossing mechanisms. This can be achieved by introducing honeybee hives into the orchard or by encouraging local insects which may be efficient pollinators. Flowering and pollen tube growth can be very temperature sensitive. In the avocado the temperature threshold varies between cultivars and is one of the reasons why Fuerte and Sharwil yield poorly in cool areas. Fuerte also has a high proportion of disorganised embryo sacs, as detected by light microscopy, and this may further reduce yield. Some species, such as mangosteen and some citrus, show parthenocarpic fruit development, and pollination and pollen transfer are not important considerations. In citrus overcropping and excessive seediness may be detrimental to yield and fruit quality. Premature fruit drop is a problem in a number of tropical and subtropical tree fruit species. Fruits shed within a month of flowering are generally unfertilised and reflect poor pollination. Fruits shed later than a month after flowering are fertilised and physiological factors such as competition or stress may be responsible. Fruit growth is generally sigmoidal and development of the characteristic fruit attributes does not occur until the final maturation stage.

Plant Carbon Balance

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Photosynthesis

Physiological information on the process of photosynthesis is abundant. We have the option of collecting a similar data set for tropical and subtropical tree fruits or of applying the principles already established to estimating the productivity of new crops. To assess potential productivity we need photosynthesis-light response curves and a description of the canopy in terms of leaf area density, leaf angles (?), extinction coefficient, total leaf area and the approximate geometrical shape of the tree.

Estimates can then be made of the light environment in relation to flowering (?), fruit growth and development and colouring. Theoretical arrangements of the canopy can be examined in relation to radiation interception and potential photosynthesis. These descriptions need to take account of where the fruit is borne on the tree - on the outside of the canopy (lychee, longan), within the canopy (jackfruit), or on the larger limbs (durian).

After considering the calculations treatments can be designed for field experiments to test whether calculated differences are real. The merits of genetic (varietal) and/or mechanical (pruning and training) control of tree form can then be assessed.

Assimilate partitioning

The harvest index is useful in agronomic work, but concepts of root/shoot functional equilibria and source-pathway-sink relations provide a framework for a physiological approach. Studies of movement from one organ to another throughout ontogeny provide useful qualitative assessments of whether material is moving and in what direction. This is a good technique for exploratory studies.

Quantitative analysis includes the measurement of dry matter distribution between organs and allometric relationships. A more detailed physiological understanding comes from studying the carbon balance of whole plants or plant parts, especially fruit. Effort put into understanding the processes involved in the source-pathway-sink complex and their control could be rewarding and amongst the newer crops we may discover a species worthy of in-depth study because of its ability to shed light on the more fundamental processes.

In simulation studies a variety of approaches are used to describe the partitioning of carbon - perhaps reflecting our lack of understanding. Partitioning coefficients are simplest while sucrose concentration gradients, relative growth rates or root/shoot equilibria are also used.

Partitioning can be manipulated by pruning, fruit thinning, fertilizing and irrigation. We want to maximize the proportion of assimilate allocated to marketable product.

Carbohydrate storage

In deciduous trees or when a catastrophe has caused defoliation, reserves are used to re-establish the leaf system. Reserves may also be used for new growth on a leafy shoot. Only about one third of the reserves seem to be useable' and new growth is not proportional to the amount of reserves present.

The hope that reserves may be manipulated to improve the efficiency of crop production has not been realized. There is a need to critically assess the importance of reserves, especially in evergreen species. Reserves can be manipulated by environmental factors such as light and temperature and by cultural practices such as pruning and fertilizing. A better understanding of the factors controlling carbohydrate utilization may increase the effectiveness of manipulations.

Integrating Physiological Information about Fruit Trees to Evaluate Productivity

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Investigations of the suitability of a particular fruit tree species or cultivar for a particular region, or attempts to improve their productivity or the reliability of fruit production, must be based on understanding of the physiological processes contributing to fruit production, and their responses to environmental conditions. Studies on particular processes are important, but may provide little insight into the factors limiting productivity unless the results are evaluated in the framework of a model of the production cycle of the tree. In this paper a generalized model of the production cycle of fruit trees is presented and the physiological processes considered to be important for fruit production examined within the framework it provides.

Models may be conceptual, simply describing qualitatively how we think a system (or part of it) works, or quantitative. Quantitative models may be stochastic or deterministic. They may be empirical - simply based on data - or mechanistic, where the behaviour of a system is defined in terms of its underlying processes (mechanisms). This necessarily involves (sub-)models of those processes. Models of fruit tree productivity are most usefully written at this level, when they serve to integrate available knowledge, serve as a means of exploring the consequences of variation or change in responses of different processes, and provide a basis for evaluating the performance - or potential - of the trees.

The yield of fruit trees depends on the number of fruits formed (set') and carried to maturity. The first steps in the process (on a mature tree) are floral initiation, growth and development to maturity, and pollination. Each of these processes may be affected by both endogenous and exogenous factors; observations on phenology in relation to weather, and detailed studies on phenological processes, are basic to understanding the production cycle of fruit trees. The number of fruits set depends on the number of flowers successfully pollinated; final fruit number is, in most species, greatly affected by fruitlet losses (fruit drop), which may be extremely high in some species. Pollination may be dependent on outside agencies, ovule fertilization may be affected by temperature and fruit drop may depend on factors like fruit number and the 'vigour' of the trees, as well as on environmental factors. The growth of the fruits held on the tree depends on the allocation of carbohydrates to the fruits (i.e. on the carbon balance of the tree) and in most cases, on satisfactory water relations.

The amount of detail included in a model of fruit tree productivity depends quite strongly on the purpose for which the model is being developed.

Tree Mineral Nutrition

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This review will consider the principles involved in developing an understanding of the nutrition of woody perennial crops. The subject will be discussed under the following headings.

Properties of woody perennials: These species live for long periods, have extensive root systems and can accumulate and draw on nutrient reserves within the plant. Tree crops are difficult to study in nutrient culture when mature and data obtained with immature plants are not easy to extrapolate particularly where effects on fruitfulness and fruit quality are concerned.

Nutrient uptake, translocation and redistribution: Between and within species there are considerable differences in ability to take up nutrients or exclude toxicants which have been exploited to enhance productivity in some crops. Some elements are mobile within the plant and redistributed. Others are variably mobile or immobile.

Role of nutrients: Nutrient elements can be divided into those which form part of the structural materials of the plant, those involved in metabolism and those involved in osmo-electric roles. Changes in concentration within the plant will lead to effects on growth and yield. Shortage of a nutrient may reduce growth or production and lead ultimately to characteristic deficiency symptoms. Excessive accumulation of some nutrients leads to toxic responses while excesses of others may lead to "luxury" concentrations within the plant. Subtle effects on the quality of fruit may be brought about by changes in nutrient concentration within the plant even though growth is not affected.

Diagnosis of nutrient status: Three approaches are possible.

(a) Visual symptoms of deficiency or excess can be used to identify acute nutritional problems but symptoms vary from crop to crop, so preliminary work is needed to characterise specific deficiency symptoms for a range of nutrients. Where more than one element is deficient visual diagnosis may not work.

(b) Soil analysis can help to point out possible problem areas (e.g. related to pH, salinity, excess lime or aluminium) but it is not easy to use predictively in woody perennials.

(c) Tissue analysis is the most useful technique both for diagnosis of specific nutritional problems and monitoring of the success of fertilizer programs. Standards are normally developed empirically (e.g. by survey of highly productive orchards). Careful work to define the most useful sample unit and size is important. Standard ranges to define adequacy are usually used but nutrient ratios have also been used for some tropical crops.

Fertilizer programs: Some tropical and sub-tropical soils present problems not encountered in temperate zones (e.g. pH, mineralogy). Fertilizer programs must suit particular crop/soil/climate combinations.

Research and Progress in Cultural Systems and Management in Temperate Fruit Orchards

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Early bearing and high yields per hectare, have the most effect on profitability of orchards and, consequently, has been the aim of most tree management research. It is now possible to obtain commercial crops as little as 18 months after planting and to have fully developed orchards, capable of maximizing yield, within 3-4 years of planting. The three main research avenues that have led to this situation are tree density, tree size and tree shape.

Early commercial bearing is not possible at low tree density. High density planting (HDP), however, may also facilitate efficient light interception and high yields in mature orchards. On the other hand, when trees in a HDP have filled their allotted space, management becomes a challenge because most fruit trees are planted at higher densities or allocated less area than the tree normally occupies when fully grown. The resulting overcrowding leads to declining productivity. Research workers have developed a number of methods to control tree size. Most temperate tree species now have dwarfing rootstocks but with the exception of apples and perhaps pears, as many problems have been created by dwarfing rootstocks as have been solved. Growth retardants, and lately especially paclobutrazole (PP333) have been used successfully. Summer pruning can control tree size and if severe enough will limit the tree to any desired size. When very high densities are required (>1500 trees ha^{-1}) summer pruning must be too severe and results in compensatory growth, which suppresses fruit growth and yield. Tree shape has more recently been also used to fit trees into a limited space. Cordon systems such as spindle, axe and Tatura trellis allow trees to grow to their limit within a confined space. Regulated water deficits are proving a very effective means for controlling tree size.

The simple view still prevails that yield per hectare will be maximized if all the light falling on each hectare is intercepted by the foliage canopy. This assumption, however, does not apply for fruit crops.

When the canopy closes the light quality deteriorates within the canopy where fruit and developing buds are located. In addition photosynthesis is stimulated in leaves supporting nearby fruit. The most fruitful orchard canopies must therefore transmit sufficient light for fruit bud initiation and fruit set within the canopy as well as allowing leaves near growing fruit to be well illuminated.

Although one invariably finds that rate of economic return is better for HDP than conventional systems the establishment cost per hectare remains a disincentive for commercial orchardists. Further, for tree crops, the nursery stage adds to the time required to bring a new orchard into production. Consequently systems for rapid or cheap propagation have been extensively studied in recent years.

Chemical Regulation of Plants and Plant Processes

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Use of chemicals to regulate plant growth is growing at a rate faster than that of any other sector of the agricultural chemical industry. This growth is occurring because of an increase in the range of chemicals available for particular purposes, a wider awareness of potential use, and development of a wider range of uses for particular chemicals.

Particular chemicals, either naturally occurring or synthetic, have been shown to influence most if not all aspects of plant development, from seed germination to senescence and death. Exploration of the potential benefits that may be gained from the application of biologically active chemicals to tropical and sub-tropical fruit crops and fruits requires definition of management goals. Secondarily, it requires judgements concerning whether these goals are attainable in the short or long term, and are economically and socially desirable.

Three aspects of the use of chemical regulators explored are:

1. Management of existing material;

2. Breeding of improved material; and

3. Breeding of improved material which responds in a specific way to applied chemical cues.

Objectives which are of primary importance in the first area relate to ripening and storage of fruits, control of flowering, and control of vegetative growth and assimilate distribution. The degree to which these objectives are achievable probably runs in reverse order to their presentation here. Objectives in the second area are taken here to relate particularly to regulation of breeding cycles and manipulation of floral biology.

Chemical regulators are also widely used in novel procedures of asexual plant genetic manipulation. The third area is one which is only now being implemented and is likely to rise dramatically in importance in the near future. The objective here is to create plants which are modified genetically either to tolerate particular biologically active chemicals or to require the application of particular chemicals to proceed through their normal lifecycle. Examples of each of these are herbicide resistance and the creation of fruits which require an external chemical cue to ripen.

Stress Physiology in Trees

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Environmental stresses (high salinity, water deficit, heat, cold) may all have dramatic effects on physiological performance, hence productivity of fruit trees. A review of papers published on the effects of salt stress in tropical and subtropical fruit trees reveals a heavily biased concentration on just 2 crops (citrus and avocado). Responses of other tropical and subtropical trees are poorly documented. Tolerance to salinity, response to excesses of specific ions and long term responses of trees to salinity are all areas requiring research attention.

Water deficits may have severe effects on physiological function and productivity particularly when they occur at critical stages of development. However, strategically applied water deficits may also be used to advantage to change the balance between vegetative and reproductive growth and to increase productivity.

Other environmental stresses which have severe effects on physiological processes and performance, but which may be of lesser practical importance due to limited occurrence also require research attention.

Tree Water Relations

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Evergreen perennial trees such as citrus and avocado retain many general characteristics of ancestral shade plants from which they evolved viz. luxuriant foliage with high stomatal density and quantum efficiency, but limited photosynthetic capacity and low hydraulic conductivity.

Moreover, horticultural plantings of these species make extensive use of semiarid regions which are subject to strong insolation, so that orchard trees are frequently subjected to environmental stresses where radiant load plus evaporative demand result in physiological strain. Short term responses include turgor loss and partial stomatal closure accompanied by reduction in photosynthesis and photoinhibitory damage. Longer term, and sometimes irreversible consequences of such cumulative strain then become manifest as impaired leaf expansion, lower productivity and disturbed patterns of growth arid development. Alleviation of such stresses commonly depends upon supplementary watering where amount and timing becomes crucial for orchard viability in the long term. Leaf criteria which may contribute towards such irrigation scheduling are clearly relevant for advanced management, and form a basis for this present paper. Examples of tree response to moisture status which involve adjustments in leaf physiology will be reviewed, and a brief outline of useable indications will be attempted for both citrus and avocado. (Data which follows refer exclusively to citrus.)

Leaf gas exchange virtually ceases at leaf stomatal closure can be instigated at or below - 1.0 MPa. Conductance varies widely within that range according to tissue solute status. leaf turgor, incident radiation, leaf-air vapour pressure gradients, crop load and recent microclimate condition. Stomatal behaviour in citrus is characterized by spatial heterogeneity, but one stable feature pertains; maximum conductance (600 m mole $m^{-2}s^{-1}$) is achieved under warm conditions (30°C) attenuated radiation (10 - 20 W m^{-2}) and shallow vapour pressure gradient from leaf to air (7 mbar). Continuity of moisture supply from root-zone to transpiring leaf is crucial for maintenance of such fast gas exchange and leaf water potential commonly falls with strengthening evaporative demand; photosynthesis and stomatal conductance show attendant reduction. Citrus trees are thus prone to partial stomatal closure and hence midday depression in gas exchange rate.

Photosynthetic capacity is inherently low with CO_2 and light saturated laboratory rates of around 20 fmole CO_2 $m^{-2}s^{-1}$. Under humid orchard conditions (e.g. Florida) maximum values range from 6 to 11 (same units) depending upon leaf age, temperature, water vapour pressure deficit and rootstock. Notwithstanding low photosynthetic capacity, quantum efficiency of light energy conversion into biochemically useful forms remains high (shade plant characteristic) but such foliage is also more vulnerable to photoinhihitory damage in strong sunlight. Leaves so affected change their chlorophyll a fluorescence properties (esp. variable fluorescence Fv); such change can then serve as an index of photosynthetic dysfunction and hence the extent of cumulative stress. Photo inhibitory damage appears heightened in the presence of NaCI salinity and especially at reduced leaf water potential so that progressive shift in Fv should provide an in vivo ‘integrator’ of foliar response to environmental stress.

Symposium Concluding Remarks

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The aim of these concluding remarks is to speculate about some of the research areas in physiology that might lead to productivity gains in tropical fruit crops in the foreseeable future. The exercise is essentially one of looking into a physiological crystal ball. Promising areas include aspects of vegetative and reproductive growth and the requirement of physiology to more closely define the selection criteria required for plant improvement programs.

Vegetative growth

Optimisation of photosynthesis and growth. The recent development of miniaturised, portable instruments for measuring carbon dioxide fixation rates in the field enables the effect on photosynthesis of environmental factors and stresses, such as those due to light, temperature, humidity, water and salt levels., to be easily monitored. Using such devices it is relatively easy to assemble data about the environmental factors that limit vegetative growth in particular situations. As well, the influence on photosynthesis and growth of crop species and variety, different canopy configurations, and the effects of altered spacing and pruning treatments can be readily assessed. It is possible that in a few years relatively simple devices to monitor photosynthesis he available for use at the individual farm level and could be used for irrigation scheduling etc.

Much more information is required about the nutritional requirements of tropical evergreen trees and particularly about how to monitor them. Critical values for the essential macro and micronutrient elements at defined stages of development are available for crops such as citrus, macadamia and mango. However, critical values have not been determined for a number of tropical fruit crops.

Another area requiring some attention concerns the role of mycorrhiza, as in the case of citrus strain differences are known to be important. A number of tropical fruit trees have restricted centres of origin and have been introduced to this country under quarantine conditions which excludes soil. It would seem worthwhile to test the influence of appropriate mycorrhizal strains on their growth and productivity.

Tree size control

A major problem with many tropical fruit trees is that vegetative growth far exceeds reproductive growth, leading to excessive tree size, internal tree shading and poor fruit productivity. The quest for dwarfing rootstocks should be continued and as well, the use of dwarfing chemicals such as PP333. The approach advocated by Chalmers at his Symposium of controlling tree size by reducing water supply should also be tried in dry tropical areas.

Reproductive growth

Studies of fruit bud initiation. A potentially rewarding research area in physiology concerning tropical fruit trees is the control of flower bud initiation, as irregular cropping occurs in many species. Considerable traditional knowledge is available which suggests growth checks caused by water and heat stress, low temperature, girdling, hormones and other chemicals, etc., can stimulate flower bud initiation. Much work is required to more closely define these effects and make them reproducible in a range of environments. It is probable that greater control over flowering will be achieved using both hormones and other chemicals and the precision of this approach will be increased by a knowledge of the endogenous levels of plant hormones present in different species at specific stages of development.

Pollination. Major productivity gains will almost certainly come from an increased understanding of the environmental and genetic constraints to pollination. There are many steps in the chain of events that commences with flowering and culminates in fruit formation. Many of these events are temperature and humidity dependent, so that data assembled in one particular situation often does not apply in other closely related environments.

Not only are plant factors involved, but as well the nature and size of insect populations can vary in time and from place to place. Many tropical fruit trees have out crossing mechanisms but not a lot is known about the insect species which effect pollination. Productivity gains may come from breeding specific pollinating insects and also from techniques to improve the transfer of pollen between species with monoecious flowers.

Selection for cultivars with some degree of self fertility would seem desirable. Research aimed at inducing parthenocarpic fruit formation with plant hormones would form another way to approach this problem. In this connection it may eventually be possible to alter the sink strength of developing fruitlets with hormone treatments to improve fruit set which is poor in many tropical fruit trees.

Requirement for physiological research to provide selection criteria for plant improvement programs.

It is possible to overcome many of the physiological shortcomings of tropical fruit trees by variety improvement. A number of approaches are now available to bring about the genetic improvement of plants and increasingly these techniques will be applied to complex perennial fruit trees.

Current techniques for cultivar improvement include the introduction of a broad genetic range of material from the centre of origin of the crop, selection for differing local environments and by hybridisation to combine characters which exist in different genetic lines. Increasingly breeding using both ionising radiation and chemicals is being used with fruit trees to bring about small genetic changes in otherwise acceptable cultivars.

The newer methods of genetic improvement all involve the use of sterile or in vitro techniques. These can be used to eliminate virus and viroid infections, to rescue the embryos of prematurely shed fruit and to expose the somoclonal variation that arises when single or small groups of cells are cultured and regenerated into plantlets. In time genetic transformation systems involving the use of vectors based on *Agrobacterium tumefaciens* will be applied to single cells and leaf discs of perennial fruit crops. These systems offer the eventual prospect of bringing about defined sequences of genetic change. Accordingly, it is necessary for tree physiologists to begin to define the characteristics that are regarded as desirable in fruiting trees to improve yield, disease resistance and fruit quality.

Australian Proteaceae as Food Plants

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Introduction

There are probably 1600 species in the family Proteaceae with 900 of these occurring in Australia. In a family that has yielded the Macadamia nut, native to New South Wales and Queensland and commercialized as the world's most prestigious, and arguably best, nut, we look expectantly for other examples of food plants. We are not disappointed with the wide range of consumable parts we find - flowers, nectar, pollen, water-yielding roots, gums, seeds and fruits. However, we soon become less impressed by their palatability and yield, though analyses indicate that we should not underestimate their high nutritional value. Superimposed on these impressions, is the fact that the larger of the more attractive parts can be poisonous, without pretreatment. In the absence of commercial development, the rest of the Proteaceae offer no threat to the reign supreme of the Macadamia nut. I explore these observations further here, with examples from the literature and my own preliminary attempts to unearth the potential of the Australian Proteaceae as food plants. An appendix of scientific and common names is located at the end of the article.

Flowers, nectar and pollen

Banksias and Lambertias have sometimes been referred to as 'native honeysuckles' in recognition of their large nectar output, and Maiden (1889) declared that "Proteaceae seem to be the most abundant yielders of honey among Australian plants". *Grevillea robusta* (Silky oak) is regarded as "one of the richest sources of nectar" by Cribb and Cribb (1976), though it would need to be, to compensate for the energy lost in climbing the tree to get at the flowers! The flowers of *Grevillea eriostachya, G. juncifolia, Hakea chordophylla, H. eyreana, H. suberea* and *H. macrocarpa* are sipped or steeped in water for drinking by aborigines in Central Australia (Latz 1982). The preparation from *H. eyreana* is described as "a sweetish, blackish drink sometimes with a slightly alcoholic effect". Maiden (1889) states the flowers of *Grevillea kennedyana* (NSW) are "exceedingly rich in a clear, sweet, honey-like liquid, which can be easily shaken out ... and collected".

On a warm day after rain my children and I enjoy sucking the sweet nectar from *Grevillea banksii* (up to 250 µl per flower). Beware however if you are susceptible to hay fever - leave the flowers alone. Of course, it is much easier just to eat the flowers! I have tried the following so far: *G. banksii, G. leucopteris* and *Hakea petiolaris*. These belong to the 'soft-flowered' genera, which contrast with the 'hard-flowered' genera (*Banksia, Dryandra*) that are more suited for the export market (Lamont 1983).

My taste impressions were: the styles are soft, moist, insipid and represent the most edible part of the flower; the knobs (pollen presenters) on the ends of the styles are slightly bitter and are best removed; the rest of the flower including the stalk is chewy (soft in *H. petiolaris*) and slightly bitter - cancelled by nectar. Do we have here a possible garnish for salads? The bracts of *G. leucopteris* are rather chewy and insipid and may sometimes have tiny insects caught on them (Lamont 1982) - also tasteless! In contrast, the young leaves and main flower stems are stringy and very bitter (stems of *G. leucopteris* and *H. petiolaris* are tasteless).

Despite reservations by Maiden (1889), it is true that the nectar production of some night-secreting Banksias, e.g. *B. ericfolia, B. telmatiaea*, is so great that it may flow down the stem onto the ground (Carpenter 1978, Lamont 1980). The musky smell of the nectar of these night-active flowers does not enhance their human appeal, despite the fact that their sugar (energy) content is up to five times that of strictly day-active flowers, e.g. B. spinulosa, *B. attenuata* (Carpenter 1978, Lewis & Bell 1981). The quantity and quality (sugars, amino acids) of nectar produced by another night-secretor, *Grevillea leucopteris*, can only be considered moderate by world standards (Lamont 1982).

When looking for honey-plants for the domestic bee, good choices exist among the Banksias and Dryandras (most species), Grevilleas, Hakeas (e.g. *H. petiolaris)*, Lambertias, Lomatias, Xylomelums and Telopeas "all of which are important nectar sources" (Smith 1969, Cribb & Cribb 1976). Beware however that some species and genera produce no nectar (e.g. *Grevillea endlicherana*, *Petrophile*) while in others, the nectar cannot be reached by bees (e.g. *Adenanthos*). It is doubtful that day-secreting Proteaceae are a superior source of honey than a number of other Australian plants on a flower or total plant basis (Ford et a!. 1979), but some species may have the benefit of producing flowers over summer, autumn or winter when preferred sources may be restricted to spring. On the basis of quantity and quality, there is little doubt that Eucalypts provide the best source of honey (Smith 1969). Of course, if you were dying of thirst or hunger in the desert, the point would be fairly academic!

However, even on sighting a proteaceous species your problems may not yet be over. There have been complaints of feelings of nausea and headache after drinking quantities of the nectar of certain Banksias and Lambertias (Maiden 1889). Cribb and Cribb (1976) warn against sipping *Lomatia salicifolia* "as there are reports that flies visiting the flowers are killed"! Emus feasting on the flowers of *Hakea eyreana* (recall a favourite drink of Central Australians) were considered to become somewhat stupefied and easy to kill by the aborigines (Latz 1982). Most of these claims can probably be traced to the presence of the one poison - cyanide - for this substance is present at low levels in the flowers of *Grevillea robusta*, *G. banksii* and *H. suberea* (Everist 1974, Aplin 1975, Lamont unpub.) - all extolled for their virtues earlier! In case you think this cancels everything I have already said, I could not detect cyanide in the nectar of *G. banksii* (the only nectar I tested), the reports of ill-effects are rare, and small quantities of cyanide are inactivated by digestion, washing, cooking or exposure to air. I have never heard complaints about ill-effects of heath' honey, a large component of which must come from the Proteaceae. As a general guide, cyanide is usually accompanied by a bitter taste, which makes the parts unpalatable anyway.

Pollen for making 'bee-bread' is abundant in all Proteaceae, whether they yield nectar or not, with a number of Dryandras in particular bearing large amounts of pollen and nectar (P. Briffa and Lamont unpub.). While pollen may be high in protein and energy, it cannot be digested by most birds that eat it (including that from Grevilleas and Banksias, Paton 1981) and I have yet to see evidence of the ability of humans to digest it.

Roots and stems

Many members of the Proteaceae have bumps (protuberances) on their lateral roots (*Banksia, Dryandra, Stirlingia, Adenanthos* and *Conospermum*) which store much starch (Lamont, unpub., Purnell 1960, Pate and Dixon 1981). However they are rather 'woody' and bitter and attempts to get rid of these are not worth the trouble. The stems are also rich stores of starch (Purnell 1960) which is difficult to extract. That the long lateral roots of *Hakea leucoptera* are a source of "excellent water' (again, when you are dying of thirst!) recurs in literature (Maiden 1889, Latz 1982) but there must be other equally good examples, especially in sand. Gum exuding from insect wounds in the trunk of *Grevillea wickhamii* is eaten by aborigines (Latz 1982).

Seeds and Fruits

With current evidence that Western man eats too much sugar and meat (among other things) and not enough fibre, we can turn to (unsalted) seeds and fruits as a partial remedy. Apart from that, they can be very satisfying to eat, especially when you have the opportunity to remove them from their 'shell' or skins first. For our purposes, the fruits of Proteaceae can be divided into four types:

a. husk succulent at maturity, with a hard shell surrounding one or two seeds e.g. *Persoonia, Helicia*;

b. husk leathery at maturity, with a hard shell surrounding one seed e.g. *Macadamia, Hicksbeachia*;

c. husk and shell combined into a leathery coat surrounding one seed e.g. *Petrophile, Isopogon, Adenanthos, Conospermum*;

d. husk and shell combined into a leathery or woody coat which splits at maturity to release usually two winged seeds e.g. *Lomatia, Grevillea, Hakea, Xylomelum*, *Banksia, Dryandra, Strangea*.

A fuller treatment of the structure of the fruits of various genera is given by Johnson and Briggs (1975). It will be found that all the above categories possess edible seeds, but rarely edible flesh. *Persoonia falcata* and other eastern Australian members of *Persoonia* do have edible flesh (Flecker *et al*. 1948), which Maiden (1889) describes as "mucilaginous, insipid and slightly astringent" and Cribb and Cribb (1976) as "like nibbling sweet cotton wool"! The Western Australian species I have tried (Table 1) were bitter unless completely ripe e.g. fallen off plant, but were otherwise similar to the above description.

Table 1. Palatability and harvest qualities of a selection of seeds and kernels of Australian Proteaceae.

Tests for cyanide were negative for all species given here. (Lamont, unpub.)

Species	Seed size (in relation to almond)	Need to remove seed coat	Texture (relative to almond)	Taste (relative to almond)	Ease of a) picking b) opening	Yield per plant	Overall rating
Banksia attenuata	much smaller	wing only	harder	insipid	inconvenient	low	low
B. baxteri	much smaller	wing only	harder	insipid	fair, flame best	moderate	low
B. grandis	smaller	wing only	harder	insipid	inconvenient/ ground, sun	moderate	fairly low
Grevillea annulifera	smaller	yes (thick, corky)	similar	similar - 'waxy'	on ground, knife	low	moderately low
G. leucopteris	much smaller	coat crunchy (wing edible)	similar	similar	from ground, already open	moderate	low
Hakea platysperma	smaller	yes	more leathery	almost insipid	easy, sun	very low	low
Persoonia saccata	much smaller	yes (hard)	soft (flesh soft)	insipid (flesh bitter or sweet)	easy, secatures	very low	very low
Xylomelum augustifolium	similar	yes	firmer	very bitter - inedible	inconvenient, oven	low	inedible
X. occidentale	similar	wing only	firmer	may be slightly bitter	inconvenient, oven	low	fairly low
X. salicifolium	similar	yes (easy)	firmer	may be slightly bitter	inconvenient, oven	low	fairly low

If starving, I would be tempted to remove the skin (which is astringent) and swallow the rest of the fruit whole, as they are so much trouble to chew! Unfortunately, this would bypass the kernel which is quite palatable, though insipid.

Latz (1982) reports that the seeds of *Grevillea stenobotrya* ("shaken into the hand and eaten like almonds"), *G. striata, Hakea eyreana* and *H. suberea* were used by two Central Australian tribes. The kernel of *G. annulfera* has been compared to the almond (Maiden 1889) and classified "very nutritious for human consumption" by Hocking (1981), though Menninger (1977) sees no future for it as a commercial crop, a species and topic to which we will return at the end. I found four of five *Grevillea* species, and six of seven *Hakea* species I tried, edible but insipid (except *G. annulifera* which I agree is comparable to almond, especially when roasted, though with a slightly waxy aftertaste, Table 1).

There is a vast literature on *Macadamia integrifolia* and its lesser-ranked cousin, *M. tetraphylla*. It is not my purpose to review their horticulture here, other than to note that they are the only Australian species grown commercially as food plants, that orchards were begun as long ago as 1892 (in Hawaii) and that plantings are currently escalating, especially in their home range, in response to increasing world demand. The other Macadamias include *M. whelanii* and *M. praealta*, both with nuts up to 5 cm wide, and *M. ternifolia*, with smaller nuts than the commercial species. All these are extremely bitter (cyanide) and inedible unless ground, soaked and baked to make a porridge or damper (Flecker et al. 1948, Cribb and Cribb 1976, Menninger 1977). In commenting on the untreated kernels of *M. praealta* Thies (1977) says he found them "worse than liquid quinine ... and it took me about half an hour to get rid of the taste ...” Since *M. integrifolia* crosses readily with *M. tetraphylla* and *M. ternifolia*, I could envisage a breeding programme aimed at combining the size of the large-nutted species with the yield and taste qualities of *M. integrifolia* (and in the spirit of G.B. Shaw, ending up with *M. integrifolia* tasting like *M. praealta* !).

Other (sub)tropical species with considerable food potential include *Hicksbeachia diversifolia*, with a white kernel of “good flavour” (Flecker et al. 1948, Thies 1976) and *H. pinnatifolia*, which is simply described as “edible” by Menninger (1977) and “fairly hard and of ‘rather agreeable flavour” by Thies (1976), both hard-shelled like the Macadamia but larger. *Helicia ferruginea* and *H. glabriflora* have dark blue fleshy husks (Anon. 1978) - I do not know if the flesh or kernels are edible but Menninger (1977) comments that *Helicia youngiana* is “unpalatable, as with the other species”. This could probably be overcome by the pretreatment required for the non-commercial Macadamias, and also species of *Kermadecia* (Menninger 1977). *Bleasdalea* has 2 cm wide nuts but their palatability has not been tested (Irvine 1980).

The largest (though not heaviest) propagules among Proteaceae are the attractive winged seeds of *Xylomelum*. Cribb and Cribb (1976) state that *X. pyriforme* is reported to be edible, and I found this to be true for *X. occidentale* and *X. salicinum*, though odd kernels were sufficiently bitter for members of my family to spit them out!

In contrast, *X. angustifolium*, especially when fresh rather than roasted, was extremely bitter - and my reaction was similar to Thies’s (1977) on eating *M. praealta*. My tests however showed none of these three Xylomelums contained cyanide, although the leaves of *X. angustifolium* did (confirming Aplin 1975). While on the subject of poisons, the fruits of *Grevillea robusta* and *G. banksii* (especially when young) may contain cyanide (Everist 1974). I found the bitter seeds of *G. banksii* and *G. pteridfo1ia* both contained cyanide and were inedible, although neither young (slightly bitter) nor mature seed of *G. leucopteris* and mature seed of *G. annulifera* contained cyanide - neither for that matter did any of the five Banksias, three Hakeas, the *Dryandra, Lomatia* or *Persoonia* I tested (Table 1).

Nutritional data are available for a number of the Australian Proteaceae. When compared with the almond, only M. integrifolia has larger kernels, of the 14 species examined (Table 2, Grundon 1972, Hocking 1982). All but *M. integrifolia* and *G. leucopteris* have a higher protein content than almond (Table 3), and all, but two Grevilleas and *M. integrifolia*, have a higher protein content than soybeans, recognized as one of the best sources of protein in the world, though whether their amino-acid composition is as suitable for human nutrition is unknown. All but *M. integrifolia* have a higher phosphorous content than almond (up to 4.4 times in *H. platysperma*) and a higher calcium content (up to 12.5 times in *G. leucopteris*). Most of the 14 species analysed have a slightly lower potassium content than almond, except *H. platysperma* and *X. angustifolium*, while all, except the Banksias and *Dryandra formosa*, have a higher magnesium content (up to 2.7 times in *H. platysperma*). All, but *G. wilsonii* and *G. annulifera* of the 11 species for which data are available, have a much higher iron content than almond (up to 13.2 times in *H. victoriae*). The important micronutrients for humans, zinc and copper, are well represented in proteaceous seeds, but comparable data are not available for almond.

Table 2. Inorganic nutrient content of seeds of some Western Australian (Sandplain) members of the Proteaceae. Adapted from Kuo et al (1982) and Thomas and Corden (1977).

Species	Seed dry wt (mg)	P (%)	Ca (%)	K (%)	Mg (%)	Fe (pg/g)
Almond (control)*	1530	0.5	0.2	0.8	0.3	43
Banksia coccinea	14	1.0	0.9	0.4	0.2	190
B. hookerana	38	1.2	1.6	0.6	0.2	241
Dryandra formosa	10	1.0	1.3	0.7	0.2	206
*Grevillea annulifera**	120	1.0	0.7	0.8	0.6	25
G. leucopteris	46	1.0	2.5	0.6	0.5	96
*Hakea platysperma**	298	2.2	0.3	1.0	0.8	300
*H. victoriae**	28	1.4	2.4	0.6	0.6	620
*Xylomelum angustifolium**	756	2.0	0.4	1.3	0.7	122

* Kernels only

The Macadamia nut is recognized as one of the best sources of (polyunsaturated) fats in the world (Thomas and Corden 1977, Table 3). In contrast the other 9 species studied (including *Hicksbeachia pinnatifolia,* J. Brand, pers. comm.) have much lower concentrations than other commercial nuts, but about the same as commercial beans. Carbohydrate concentrations are much lower than nuts or beans (Thomas and Corden 1977, Table 3), but nutritionally this is no disadvantage and similar low concentrations prevent ‘caramelizing’ of Macadamia nuts during roasting (Halliwell 1979). Fats and sugars are largely responsible for flavour, and their low concentrations in most Proteaceae could explain their fairly tasteless properties (Table 1). I found roasting gave a more ‘scorched peanut’ flavour, but made the seeds harder to chew.

The following conclusions can be drawn from my preliminary testing of 25 species of which all, but three of the Grevilleas, are from southwestern Australia (Table 1): The seeds are much smaller than those of almond, except *Hakea platysperma* and *Xylomelum* species.

Table 3. Organic nutrient content of dried seeds of some Australian Proteaceae. Adapted from Kuo of al. (1982), and Thomas and Corden (1977)

Species	Protein (%)	Fat (%)	Carbohydrate (%)	'Fibre' (%)
Almond (control)*	20.5	56.5	19.8	1.5
Soybean (control)	38.7	18.9	38.0	1.6
Banksia coccinea	63.1	20.0	<5	8.3
B. hookerana	59.3	19.5	<5	12.6
Dryandra formosa	63.7	20.1	<5	8.0
*Grevillea annulifera**	34.1	29.9	<5	27.9
G. leucopteris	15.5	31.0	<5	43.9
*Hakea platysperma**	43.1	25.3	<5	22.3
*H. victoriae**	63.6	16.1	<5	10.3
*Xylomelum angustifolium**	61.2	13.8	<5	15.6
*Macadamia integrifolia**	8.6	75.0†	<6.5†	8.9

* Kernels only
† best quality for roasting (Halliwell 1979)

The wings of Banksias, Hakeas and Dryandras and seed coats of *Grevillea annulifera* and Xylomelums should be removed before eating; the seed coats of other Grevilleas in particular are crunchy and resist complete mastication but are almost impossible to remove. The texture of proteaceous kernels is similar to that of almond but they are usually insipid or slightly bitter by comparison. Most are easy to pick from the plant, except those high on trees (classified here as 'inconvenient). Unless the ripening fruits are bagged, the seeds of Grevilleas and a number of other species drop to the ground on ripening where they are often hard to find (some are taken away by ants and buried, or eaten by birds, Lamont 1982). *Hakea* fruits usually shed on drying (especially if left in the sun) while *Banksia* fruits are best opened by burning the heads - periodic dunking in water will force out the stubborn seeds (Cowling and Lamont 1985). Make sure you can distinguish the central plate of *Banksia* and *Dryandra* fruits from the two membranous-winged seeds - I was once asked my opinion of the germination potential of over 2 kilos of central plates carefully collected from beneath a *Banksia* tree!

The yield of seeds is low by commercial standards. The problem is not that there are too few flowers - on the contrary Proteaceae are among the most prolific of native plants (Lamont 1983). The problem is largely one of low seed set: for 15 species studied, this varies from 0.1% of flowers produced by *Banksia menziesii* up to 16.3% for *Hakea erinacea*, with an average of 3.7% (Whelan and Burbidge 1980, Hopper 1980, Pyke 1982, Lamont 1982, P. Briffa and Lamont unpub.). Whelan and Burbidge (1980) found up to 63% of the heads of *Banksia grandis* do not produce any seeds; Pyke (1982) found this to be nearly 90% for *Lambertia formosa*. My own studies on *Banksia hookerana* show seed set may also vary greatly from year to year under natural conditions: from 0 to almost 10 fruits per head on average per year

and 0 to 1% seed set per year over 9 years. My other work on *Hakea undulata*, which also has a nutritious, though small, seed, shows great variation between years, although as with *B. hookerana*, there is an overall trend of gradual build up in numbers with succeeding years. Of interest is the wide variation between as well as within plants of *H. undulata* in the same patch - both in numbers of seeds and in their size. Seed loss through failure to develop within the fruit and fungal decay was minor in all plants, although destruction by borers reached up to 47% of three-year old fruits. Scott (1979) found up to 70% of the seeds of six *Banksia* species may be eaten by larvae.

Of course much of this yearly variation in yield can be reduced by cultivation - and % seed set can also be expected to rise. I found that seed set in *Grevillea leucopteris* can be raised from 0.5% to 8.3% by summer irrigation (Lamont 1982). Variation between plants provides some scope for selection of the higher yielding forms. Along with Hicksbeachias and some of the Banksias (Table 1), *G. annulifera* has most potential as a food plant. Like most Proteaceae, its greatest virtues are tolerance of extremely poor sandy soils and long summer droughts. Its yield in nature is extremely low, some plants bearing nothing in a given year (Hocking 1981).

However its kernels are highly nutritious, if somewhat small by commercial standards, and there is great variation in seed size and nutrient content within and between isolated patches (e.g. a range of 24.5 to 33.3% protein between three populations studied by Hocking 1981) which indicates considerable scope for plant improvement. As agriculture moves into marginal lands and resource availability (fertilizer, water) throughout the world decreases, the logical choice is for perennials rather than annual crops - and perhaps this survey of one of the logical candidates, the Australian Proteaceae, is timely. But much preliminary testing and assessment remains to be done. Meanwhile, closer to the coast and in richer soils, the Macadamia nut reigns supreme among the Australian Proteaceae.

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APPENDIX: Scientific and common names of Proteaceae species.

Adenanthos		Stick-in-jug Flower
Banksia	*attenuata*	Slender Banksia
	baxteri	Baxter's Bariksia
	coccinea	Scarlet Banksia
	ericifolia	Heath-leaved Banksia
	grandis	Bull Banksia
	hookeriana	Hooker's Banksia
	menziesii	Firewood Banksia
	spinulosa	Hairpin Banksia
	telmatiaea	Swamp Fox Banksia
Bleasdalea		-
Conospermum		Smoke Bush
Dryandra	*formosa*	Showy Dryandra
Grevillea	*annulfera*	Prickly Plume Grevillea
	banksii	Bank's Grevillea
	endlicherana	Spindly Grevillea
	eriostachya	Flame Grevillea
	juncifolia	-
	kennedyana	-
	leucopteris	White Plume Grevillea
	robusta	Silky Oak
	stenobotrya	-
	striata	Western Beefwood
	wickhamii	Wickham's Grevillea
	wilsonii	Wilson's Grevillea
Hakea	*chordophylla*	-
	erinacea	Hedge-Hog Hakea
	eyreana	-
	leucoptera	Needlewood
	macrocarpa	-
	petiolaris	Sea Urchin Hakea
	platysperma	Cricket Ball Hakea
	suberea	Cork Tree
	undulata	Wavy-leaved Hakea
	victoriae	Royal Hakea

Helicia	*ferruginea*	-
	glabriflora	-
	youngiana	-
Hicksbeachia	*diversfolia*	-
	pinnatifolia	Money Nut, Rose Nut
Isopogon		Drumstick, Coneflowers
Kermadecia		-
Lambertia		Native Honeysuckles
Lomatia	*salicifolia*	Wild Parsley
Macadamia	*integrifolia*	Smooth-shelled Macadamia
	praealta	Ball Nut, Possum Nut
	ternifolia	Maroochy Nut
	tetraphylla	Rough-shelled Macadamia
	whelanii	Whelan's Nut Oak
Persoonia	*falcata*	Geebung
	saccata	Snottygobble
Petrophile		-
Stirlingia		Blue Boy
Strangea		-
Xylomelum	*angustifolium*	Sandy Plain Woody Pear
	occidentale	Forest Pear
	pyriforme	Woody Pear
	salicinum	Hooked Woody Pear

Using Nature and Logic in Tree Crop Introduction and Breeding

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First off let me say that this is a paper for everyone; everyone who is concerned in any way with the planting of tree crops. Every time any of you puts another crop tree in the ground, or even puts in an order to have some more trees planted, you are contributing to the introduction and breeding of these trees. The logic of this statement will become apparent later.

That comment over, I will start on the paper proper. I have organized it a bit different to most papers, because I have the acknowledgements first. The work on which the paper is based owes a strong debt to two people in particular (Table 1).

Table 1

PRINCIPLES OF INTEGRATED TREE CROP DEVELOPMENT

1. (Thomson) : Local selections will always triumph.
2. (Laszlo) : Select from sources with similar climatic conditions.
3. (Noel) : Recognize the great variability and mutability of plants.

The first debt is owed to Paul Thomson of California, who has made the point, on a number of occasions (e.g. Thomson 1982) that to produce a successful tree crop, you almost invariably end up with a selection made locally. This paraphrases what Paul has said, and if it seems a bit sweeping in its implications, I will expand upon its truth a little later.

The second debt is owed to Ivan Laszlo of Canberra. In his article 'Lateral Thinking about Tree Crops' (Laszlo 1982), Ivan brings out the importance of selecting the tree crop material which you intend to grow from areas with similar climatic conditions to those of your chosen site.

To these two principles, I want to add a third, of my own: that it is most important to recognize that plants contain a great deal of internal variability, and also a great deal of internal mutability, that is, liability to change. These three principles form the basis of integrated tree crop development.! will be illustrating the application of these principles with a few examples. First off I will list the examples (Table 2) with a few brief comments only. Now these sample factors are not particularly controversial, they are part of the accepted wisdom of our area of endeavour. I am not seeking to contradict any of them here, though I hope to present them again with a different slant.

Table 2

SOME SAMPLE TREE CROP FACTS

1. Avocados are sensitive to salt levels.
2. Sirora is the best pistachio selection for Australia.
3. Cherimoyas do not pollinate well in a dry climate.
4. Cashews need a complex shelling factory for commercial production.
5. Coffee is a tropical crop.
6. Walnuts do not like hot, dry summers.

To return now to some of the background behind the three principles which I mentioned earlier. The first thing I want to show you is a map (Figure 1).The almond and the walnut both originated in an area of central Asia. Of course, the exact spot cannot be stated, but for both it appears to have been around what is now Afghanistan, northern Iran and the Turkestan republic of the Soviet Union.

From this region of origin, the almond is believed to have spread through the northern part of the Mediterranean, probably mostly due to the Romans, and to have found especially good homes in Italy, France, and Spain during ancient times. With the discovery of the New World and its subsequent settlement, the almond went along too, and became acclimatized in California. Australian plantings of almonds probably came mostly from California, though it is almost certain that some would have come in direct from Europe; we in Western Australia would have borrowed our plants from South Australian sources.

The walnut is believed to have followed a somewhat similar route, though, as a more cold-hardy tree, it moved a bit further from the Equator. In particular, it appears to have spent some time in Poland, to have been common in England (where it is still called the English walnut), and to have found a home in western USA, in Oregon and Washington as well as northern California. On its way to Western Australia it seems to have passed through New Zealand and Victoria rather than South Australia.

FIGURE 1. ROUTES OF THE ALMOND AND WALNUT TO WESTERN AUSTRALIA

THE ALMOND

THE WALNUT

Now the point about this piece of history is this. We talk about the walnut and the almond as though these words meant something definite and specific, as we might talk about copper or granite. This is far from the case. On their travels to Western Australia, these two nut plants have undergone innumerable changes and alterations. In its wild state, the almond, for example, can fairly be described as a small, poisonous seed in a thick shell, growing on a scruffy sort of tall bush. To become a nut crop, first it had to become domesticated and selected in its area of origin. The trees with sweet kernels had to be found, the individuals which grew well under local climatic conditions had to be unearthed.

Then came propagation. Everyone who has grafted trees knows that certain varieties, of rootstock and of scion, will bud or graft better than other varieties. It is only logical that varieties which propagate well will be perpetuated and spread around the place, while ones which do not will die out. The almond has a long history, it is one of the oldest of nut trees in cultivation, and that is why it is one of the easiest nut trees to propagate.

Much the same sort of things can be said about the walnut. While wild walnuts are usually trees rather than bushes, their nuts tend to be thick-shelled, small, and a long way from a commercial crop. However, the trees are very tough.The travels of these two species illustrates their mutability, their ability to undergo change. The end result of their travels, is that the plants which we are growing in Western Australia are nothing like their wild ancestors; only the name is the same. You can see that this must be so, for example, if you compare the conditions in Poland with those in Perth.

Suppose I illustrate this with a parallel. Those of you who read any science fiction will have come across stories where, say, the starship Juglans has a failure in its warp drive, and is forced to stop off at the planet Avocado for repairs. Avocado is inhabited by an alien but civilised race. Fortunately, one of the crew has an Avocadean friend, and can speak Avocadese fluently.

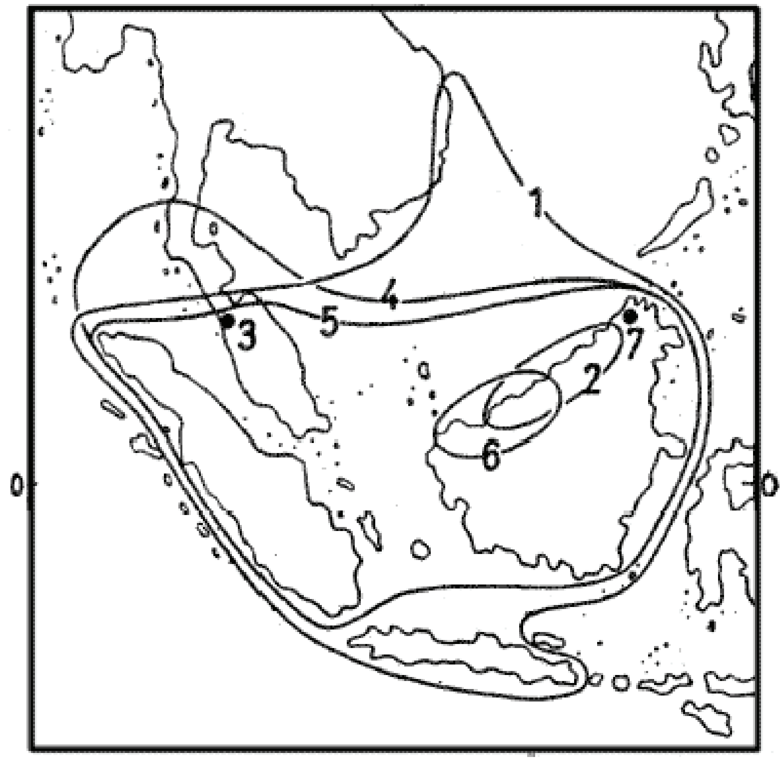
Now suppose that they write science fiction on the planet Avocado; in their story, their ship will be forced down on the planet Earth. Fortunately, one of their crew can speak fluent Earthese. Now you will all know that there is no language called Earthese; instead there are perhaps 1000 languages and perhaps 10,000 dialects scattered across the globe. In fact, when you take differences in upbringing, education, and hence vocabulary into account, you could claim that every individual speaks a slightly different language.

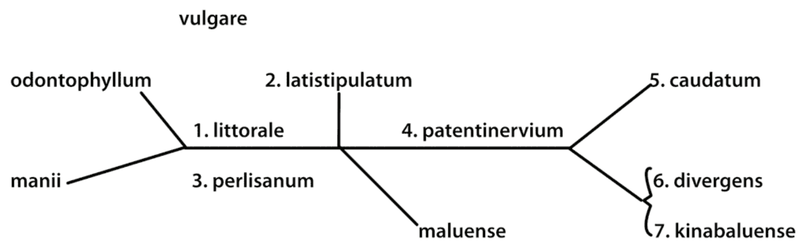
The case with plants is similar. Every plant is likely to have a unique individual genetic basis, due to continuing and continually varying natural and artificial selection and to natural mutation.

I will go on now to another example, the distribution of the genus *Canarium* (Fig. 2). This is a largely tropical family of trees, which includes the Pili nut and the Kenari nut or Java almond. Now you will notice that while some of the species are quite widespread, others are small in range.Plants, especially nut and fruit trees with quite large fruits, do not spread naturally at a very quick rate. When they do spread, they do so most readily into adjacent areas

where the growing conditions are most similar. We could draw lines through areas of similar growing conditions, like the pressure lines or isobars which you see on a weather map, and we could call these isophyte lines. Plants spread more rapidly along the isophytes.

FIGURE 2. DISTRIBUTION OF SOME ***CANARIUM*** SPECIES





Plants may also spread across the isophytes, but they do this much more slowly, because in so doing they have to undergo natural selection and change to meet the altered growing conditions. Logically, then, you will find greater genetic diversity in a plant where it is growing across steep isophyte gradients. Because altitude is one of the strongest influences on climate and other growing conditions, the isophytes will often parallel the contour lines on a map.

Now notice on the map, the black dot marked 7. That dot is the total range of the species *Canarium kinabaluense*, and it coincides exactly with the site of Mount Kinabalu, the highest mountain in southeast Asia. The isophyte gradients are so close there, that Canarium has had to undergo enough changes to be classed as a separate species where it crosses the isophytes.

Other examples of steep isophyte gradients are found along the Andes, a very rich source of tree crop species, and around the Himalayas. Tropical jungles also contain steep isophyte gradients, for other reasons than altitude changes, and when you have jungles abutting against steep mountain gradients you can expect to hit the jackpot in plant diversity. For this reason, I believe that New Guinea will prove one of the richest sources of tree crop species in the future. In crops which are already cultivated, it is worth looking at high isophyte gradient areas outside the original source; the Philippines may thus be a good source of varieties of fruits introduced from South America in earlier centuries.

I want to return now to the three principles of tree crop development which I mentioned at the beginning, and flesh out the initial comments.

First, Thomson's principle that local selections are of vital importance in establishing a commercial tree crop industry. You will be familiar with many examples of this - the selection of the Granny Smith apple in Australia, the Chellaston almond in South Australia, and the HAES series of macadamias in Hawaii. Now here you might say, "Wait on, what about the Navel orange, or the Fuerte avocado? Things like these are clearly very widely grown - don't they contradict this principle?"

Well, I am not claiming that there are no possible exceptions to the rule, but I will try and show that it applies very much more widely than you might at first think. I suggest that the reason why the conventional picture has been accepted more or less as a basic fact is because of the assumption that a plant species, or even a plant clone, like a Fuerte avocado, is a single entity.

If you apply a little logic, you will see that this assumption may not be on as solid ground as it appears. First, there is the question of the rootstock. Even if you have a 'genuine' scion on your tree, the rootstock is likely to be a local selection of some sort, and of course rootstocks can have a very strong influence on the growth patterns and likelihood of success of a tree crop.

Second, and this is a very important point, you cannot always assume that a piece of named clonal material is just what you expect. Leaving aside the question of errors in plant labels and so on, the point that is normally neglected is the mutability of plant material, its liability to change its fundamental genetic nature while you are looking at it.

Everyone who has dealt with trees in large numbers will have come across the occasional 'bud sport', a mutation occurring on just one part of a tree. Some time ago I noticed that the leaves on one branch of one of my chestnuts were variegated with gold patches among the

green. In some plants, for example the sweet potato, mutations are so frequent that a conventional breeding programme is virtually pointless. Workers in tissue culture propagation have come across so many instances of mutation in the tiny cell clumps which they are growing on into complete plants, that they use this feature as a direct breeding and selection method. They are actually selecting from the mutations that arise, for a given characteristic, say salt tolerance, within the cell cultures themselves. This technique is called somacloning.

The point is this: if you can recall instances of bud sports, such as my variegated chestnut branch, which is obvious, how many other mutations are occurring which go completely unnoticed because the mutation does not physically change the plant? If the mutation leads to improved salt tolerance, will you ever realize it?

Another point about crop trees, which is obvious if you think about it. In the higher mammals such as man, the female of the species is supposed to have formed all the egg cells which represent her potential children, before she is even born. Contrast this with a fruit tree; not only are the egg cells formed from scratch each year, the whole of the sexual apparatus of the tree is also formed from scratch.

So, if any changes do occur in the tree during the course of a year, they can show up in the very next harvest.

If you have ever been taught about propagating fruits, you will remember a basic piece of advice: "select your scion wood from a good healthy bearing tree". Sensible advice, and advice which will tend to pass on the effects of any mutations in the bearing tree which improve bearing capacity. Be warned, however, that the budsticks you use, even if correctly labelled and supplied in good faith, may not contain all the desirable genes which you expect. A member of our Association once told me that she had been to see the original Sharwil avocado tree. "Why", she said, "it was nothing like the Sharwil trees we are growing; it was a vigorous, dense tree, loaded with fruit."

Perhaps by now one of the implications of what I have put before you will be apparent. If there is any truth in what I have told you, it means that all the years of work and millions of dollars which have been put into variety trials, all over the world, have led to published results which may be, to some degree, of doubtful validity.

To turn now to making use of what we have developed here so far. Traditional fruit crops, such as apples, have been developed without any conscious thought of underlying principles, until recent times at least. With newer crops, some of the things I have been talking about have been taken into account. In kiwi fruit, for example, the most important variety in New Zealand is called 'Hayward'. This variety has performed exceptionally well in the Bay of Plenty area. When moved elsewhere, however, it has not always done as well. In California, for example, a strain of Hayward called 'Mar Vista Hayward' suits some local factors better (Whittaker, 1983). It will be obvious to you that this strain must be different to the original Hayward, if there is such an entity any more.

The macadamia, although an Australian native nut, was first developed commercially in Hawaii. There, around the beginning of the century, a small number of seeds of the species now called *Macadamia integrifolia* were planted. These led to fruiting trees, and in a long series of trials some 30 or 40 years later, the Hawaii Agricultural Experiment Station (HAES) selected a few trees, out of hundreds, which they thought worth propagating.

In recent years, a great deal of work has been done here in Australia on creating a commercial crop from the macadamia. Naturally enough, among the things which they have done is to import the HAES selections for trial here. They found that the varieties which perform exceptionally well in Hawaii just do not yield the same good results in Australia (Stephenson & Gallagher, 1983), and what is more, they have come to the conclusion that they never will. Eventually, we must select or evolve our own varieties for our own local conditions.

People who have consciously tried to develop a local tree crop industry, based on non-local experience, tend to adopt what may be called a “Top Down’ approach.

That is, identify a variety growing elsewhere which has good characteristics such as heavy bearing, attractive and flavoursome fruit, and so on; import the variety, through quarantine if necessary: and then provide it with the conditions which it needs to produce well.

There is nothing wrong with this procedure, as an interim stage in getting a tree crop industry underway, but it should not be regarded as anything more than an interim stage. The commercial reality of the situation usually turns out to be that it is too expensive to alter local conditions enough for the plant to attain the same yields and returns as it did in its original environment.

A better long-term method is what might be called the Bottom Up approach. That is, bring in seed from a wide variety of sources, concentrating particularly on sources with similar climate and growing conditions to your target area; grow these on, continually selecting plants which make vigorous growth under unmodified local conditions; and only then start selecting for the fruiting characteristics desired. At this stage it is quite reasonable to import a large variety of good scionwood, but with the expectation that this will contribute some useful genes to your final selection, rather than in itself form the basis for a viable local industry.

I would like to return now to the list of Sample Tree Crop Factors (Table 1), and mention a few ways of looking at these factors in a different light. First the sensitivity of avocados to salt levels, a widely accepted limitation which is well documented (Downton et al., 1982). Now avocados are in the genus *Persea*, which has a number of species mostly native to Central America. To look at the salt problem in a new way, I suggest using the three principles. From Laszlo’s principle, the idea comes of looking for species which are naturally salt tolerant. And when you look into it, you find that there is a species, *Persea borbonia*, called the Red Bay, which grows in southern Florida. Most of southern Florida is only a few metres above sea level, so it is quite likely that Red Bay trees can be found which have a high degree of salt tolerance, and may be suitable for avocado rootstocks.

Number 2, the ‘Sirora’ pistachio, accepted as the best Australian selection to date. Let us look a little more closely at the background to this variety. The selection work was done by Don Maggs at CSIRO Division of Horticultural Research, Merbein, in Victoria. According to Don (Maggs, 1984), the selection trials were done on around 100 seedling trees, of which more than half turned out to be males. So what the trials really showed, was that Sirora was the best performer out of about 45 trees, at Merbein. From Thomson’s principle, we can clearly expect that other selections will turn out to be better, in other areas, particularly if a much wider range of sources is used.

The pistachio example interestingly illustrates the incredibly small genetic base from which the creation of a major tree crop may be attempted. I have already mentioned the fact that the Hawaiian macadamia industry developed from a few introduced seeds only.

The same is true of kiwi fruit; all the modern kiwi fruit varieties have been developed from a handful of seeds taken to New Zealand sometime after 1900 (Sale, 1983). These points illustrate the third principle; wait long enough, and you will be able to get the characters you want from even a limited genetic base. But how much more sensible to introduce them in a year, instead of working for fifty!

The pistachio also illustrates another point. One of the ‘good points’ of Sirora is that it has a high percentage of naturally split nuts, which, like paper shells in almonds, make them convenient for the in-shell trade. I believe that the real future of pistachio nuts lies in the processed kernel trade, and for this, split shells are a disadvantage for cracking, rather than a good feature.

Example 3 is the poor pollination of cherimoyas in a dry climate. A new approach to overcoming this problem may be found in Annona species which grow in dry climates. According to Meninger (1967), one relative grows in almost desert conditions.

Number 4 is the complex shelling plant needed for cashews. Cashew nuts grow within a shell which contains liquid, which has a considerable industrial value, but is quite tricky to handle. Biting a cashew nut shell can lead to painful blistering of the lips. This feature takes the cashew out of the farm-door trade and into the industrial arena, like the tung nut. The processing plant costs around a million dollars. However, occasionally plants are found (Ohler, 1979) which produce nuts without the shell liquid. Clearly if these were developed, the whole face of the cashew industry could change.

Coffee, the fifth example, is well known as a tropical crop. The earliest species cultivated, *Coffea arabica*, is native to the highlands of East Africa, and the *robusta* species comes from lower areas towards the west. Between them, these two tropical species dominate world trade. However, the real focus of *Coffea* species is probably in Madagascar, which has at least nine natives, some of which grow naturally de-caffeinated beans. Selection from the highland Madagascar species could yield a very valuable warm-temperate coffee industry.

The last example is of the difficulties of growing walnuts where you have very hot, dry summers, as in Perth. If you consider the path the walnut has taken to get to Perth, you can see that the genes which might make it perform well under these conditions have all been driven out during its travels. If we want to grow good walnuts in Perth, we should go back to its origins, in Central Asia; there we may find the genetic basis we need.

In closing I will give you a quotation. A famous scientist, I think it was Lord Kelvin, once said that the sciences were made up of physics and stamp collecting. What he meant by this, of course, was that in the sciences, only the physicists were working on the basis of fundamental laws which described their universe, the others were just collecting books of facts; things like certain fossils appear in certain rocks, certain substances react together, and so on. As you might guess, Lord Kelvin was himself a physicist, but still he had a point.

What I have tried to do in this paper is to move the topic of tree crop development a bit of the way along from stamp collecting to physics.

Based on a talk presented at ACOTANC 2 Conference. Melbourne, September 1984.

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Blame it on Henry Ford: The Story Behind Home-acre Farming

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Introduction

If you look at one of those stunningly beautiful photographs of the earth taken from deep space, you may notice great differences in depth of colour of different areas The deserts stand out brightly, usually white or pale yellow; the arid scrub and mountain areas are yellow-brown. The cultivated lands and grassy plains are a bit darker, coloured a light green, the great northern pine forests are a darker green, and the tropical jungles are almost black. This simple fact is the basis of one of the three efficiencies which underlie home-acre farming; that of light efficiency.

Light efficiency

The darker areas of the earth are darker, simply because they are absorbing more of the sun's light. All life on earth depends ultimately on sunlight for the energy it needs to survive, and the areas which are dark are those in which plants are making the best use of this light. If you go into a dense jungle or pine forest at midday, it will be dark at the forest floor even though the sunlight is brilliant above the treetops; forest plant life is very efficient at absorbing light, over 99 percent may be used before it has the chance to reach the soil. Sometimes so much is absorbed that not enough is left to allow ground-level plants to survive.

If you had a light-meter, and lowered yourself from a balloon through the forest canopy, you would see a gradual reduction in the light reaching the meter as you went lower into the forest. In a jungle, there is a multitude of plant forms with all sorts of leaf patterns, each designed to trap light at a particular level below the canopy; leaves able to pass or deflect excess light at the top, leaves able to soak up weak light efficiently at the bottom.

When you compare this situation with that in a field crop or pasture, you can see immediately that neither can possibly be as efficient at light absorption as a forest. They have neither the height of absorbing leaves, nor the complex community of leaf shapes needed for this.

In fact, actual yield figures for different land uses in food production show a really dramatic scale of yields. Raising beef cattle under open range conditions yields only about 4 kg of meat from each hectare per year; under better pasture conditions, lamb yields will average around 100 kg/yr.

Going to a standard field crop, such as wheat, a good average yield is twenty times better, at 2000 kg (2 tonnes) per hectare. This is with regular fertilizer application; without this, yields drop progressively to well under half.

The next step is for an orchard crop, which can yield as much as 50 tonnes to the hectare, even without fertilizer applied. This is an astounding 10,000 times better than the range-cattle situation, and even this yield can be at least doubled with an integrated home-acre situation.

The vital point is this; tree-based food production systems are so intrinsically efficient that they produce an energy surplus. Anything else, from a tall field crop on down, is only efficient enough to continue if its energy deficiency is recognized and compensated for with the addition of fertilizers. From a forest, you can take fruits, nuts, timber for building and for fuel, year after year, without diminishing it, in fact it continues to put its energy surplus into building up a rich soil, a true energy bank. All this is a measure of its light efficiency, which, incidentally, continues all through the year, and not just through a short growing season.

So if light efficiency is the first base on which home- acre farming is built, its inference is that the system is heavily dependent on tree crops.

Land efficiency

To look at the next of the three efficiencies of home-acre farming, land efficiency, we will zero in on a small part of the earth - New Guinea. Now it is fashionable to think of agriculture in such places as New Guinea as being primitive and undeveloped, but this is quite untrue; in fact, they have a very highly developed system. What throws people off, is that their system is so very different at its roots, when compared to Western agriculture. And, unlike ours, it is not a new system, but one which has been running for many centuries.

In New Guinea, the traditional smallholder system is based on the slash and burn technique applied to create clearings in the forest, which are then cultivated for a few years and abandoned when their fertility declines. It is another reflection of the energy surplus created by tree-based ecologies. However, the clearings are not farmed as isolated units, but are run together with surrounding forest, and especially desirable wild trees are left during clearing.

An important feature of the smallholder gardens created in the clearings is the great number of varieties of particular plants grown, in stark contrast to Western monocultural practices. A single garden may contain 50 different varieties of banana, and each is chosen with a purpose and to suit its own special position in the garden. There will be softer bananas for baby food, varieties for breakfast eating, for soups, as part of a main meal, for snacks while working; and for dessert. There will be special varieties for use in parties and ceremonies; drought-resistant bananas for rapid-draining soils, drought-susceptible varieties for planting on moisture-holding soils, and shade-tolerant varieties for planting under coconuts.

Everything is taken into account. Bananas susceptible to an insect pest, the rhinoceros beetle, are planted in clear places away from the rotting tree stumps where the beetles breed. Varieties which persist for only a short time are used as temporary shade for cocoa. The same pattern of great diversity is repeated with other garden crops, such as sweet potatoes. And all the different plant species are intermingled in a wild but purposeful pattern.

This, of course, is nothing like the Western approach, of vast plantations or orchards of one species with only one or two varieties within it, monoculture with absolutely no regard for variations in soil, in exposure, in slope, and in proximity of other plants. If you think about it, you can see that the Western system is markedly inferior in efficiency of land use, as it cannot match the great interlocking diversity of the New Guinea one, which, like a good employer, uses and puts together all the best features of the diverse people or plants which make up the system, giving a whole which is greater than the parts.

So the result for home-acre farming, in applying the second factor of land efficiency, is to call for complex, multi-variety, multi-species use of land resource in small, localized areas. To look at the third efficiency, which is people efficiency, and to see why the current Western approach has grown up, we can zero in on another spot on the planet, in the Eastern United States.

People efficiency

Earlier this century, Henry Ford achieved a brilliant advance in the technique of car manufacture; he applied the methods of mass production, assembly-line control, and tight standardization. With the Model T, he offered a choice of any colour you liked, as long as it was black.

Henry Ford's success was admired and copied by manufacturers of all sorts of goods, and, although it was not their intention, these manufacturers brought about a basic change in what would now be called consumer psychology. People came to want and expect great uniformity and consistency in the products they bought. This was achieved, but with an accompanying loss, the loss of diversity or wide choice.

In the prosperous Britain of Victorian times, an astounding variety of fruits and nuts was available, some taken for granted, others sought after as novelties. The same picture was echoed in other fields. But with the rise of mass production in the early 20th century, all this was swept away. We are now seeing a revival of interest in diversity of choice, but it still has a long way to go. Here in Western Australia, we have a choice from just one variety of potato; the Victorians could pick from twenty.

Also with the rise of standardization and marketing techniques, came the urge towards uniformity of presentation, achieved in fruit through concentration on one or two varieties which produced regular uniform crops at a given time, and through ever more rigid grading and packaging. In this state, for example, the Government prevents, by law, the sale of apples below a certain diameter.

Now all this law, regulation, and consumer psychology has grown up quite insidiously by ignoring a basic truth. One car may be identical to another car produced later on the production line, but no apple is identical to any other apple. The fact is, that the production of apples is not suited to the production-line techniques which work well for cars.

A good example to bring out the underlying factors is to look at what the New Zealanders have done with kiwi fruit. Here is a fruit which they developed from scratch, in a classic model of the Western approach. Kiwi fruit grow on vines which are sensitive to wind and sun, and the New Zealanders have put tremendous amounts of effort and money into research and development, to come up with vast fields of row after row of very expensive trellises, covered with shadecloth and surrounded by windbreaks. Fertilization and irrigation are carefully controlled to produce large numbers of uniform fruit from a single commercial variety. The fruit was renamed (it used to be called Chinese gooseberry) and skillfully packed, promoted, and sold all over the world.

There is nothing wrong at all with the New Zealand approach, it is widely regarded as a model for the development of a 'new fruit, one well worth copying here and elsewhere. But, and this is the essential point, there can be a place for other approaches, which may be equally valid, even though quite different. One of these alternative approaches is home-acre farming.

If you go back in history to the 16th century, or even, to some extent, to the 19th century, you will find many similarities in both social and agricultural systems with the smallholder garden system which still reigns in New Guinea today. These are systems in which the concepts of employment, and of unemployment, which are so uppermost in our minds today, had very much less meaning; a large proportion of the population grew much of what they ate themselves.

You can see that in terms of people efficiency, these older systems had a lot going for them. At a recent conference, an economist who had studied the mixed-crop smallholder system in New Guinea pointed out how much better off these people were, compared to the large expatriate plantation owners. When the world price of coffee or coconut fell abruptly, the plantation owners could be ruined; the smallholders just paid more attention to their yams or bananas for market sales for their cash needs, and continued to feed themselves happily from what they enjoyed growing.

So far as people efficiency is concerned, the important point for home-acre farming is a high degree of local consumption of food produced in a diverse, essentially non-mechanized approach. Now we have all three essential bases of home-acre farming, and can compare this approach with the one which we inherited from our European ancestors.

Putting it all together

The three efficiencies of use of light, land, and people which underlie home-acre farming are expressed by the predominant application of tree crops, diverse and interlocking growing ecologies, and low-mechanization, localized food production and consumption patterns. A little thought will show that this approach can be more productive, more efficient, more economical, and more satisfying than one which we inherited from other lands with other climates.

Go back now to the kiwi fruit example. All those rows of uniform, expensive trellising are to enable the maximum use of machines and maximum control of uniform cultural practices. Take the kiwi fruit out of the trellises, and put it back in its natural place as a vine growing up other trees in a forest-type ecology, and you immediately get rid, of most of your worries. No need for trellises, windbreaks, shadecloth, or watering. Sell the produce to your local community, and you cut out transport, packing, and promotion costs, and much of the wastage involved in fruit going bad before sale, and fruit rejected because of grading standards.

Pick the fruit by hand, grow enough for yourself and some over for sale, and live indifferent to world prices. You can be sure that those New Zealanders who are paying an army of pickers, truck drivers, airline pilots, oilmen, salesmen, advertising men and others to get their fruit to you will be worse off. And if they get a disease which sweeps through their closely-packed plantings, they will certainly be more worried than you will, with your small number of isolated vines forming just one of many strings to your bow.

As I said before, the home-acre farming approach has much in common with the farming systems of Europe in the 16th century. I should make it clear that I am not advocating a return to the 16th, or even the 19th century; I am just pointing out that the 21st century may have more in common with these earlier times than it will with the 20th century.

A social system which does not include the concept of employment cannot have unemployment. We are unlikely to go completely back to such a system, but we are certainly moving part of the way. Ever-shorter working weeks, more acceptance of part-time jobs, people getting by on unemployment benefit and growing their own vegies, are all moves in that direction. Consumer goods like computers and video recorders will still need to be made in factories, but these are getting more and more to be run by robots instead of people. Sure, most of us will still need to put in a few hours each week to keep civilization rolling, but the opportunities look bright for those of us who would like to grow more of what we eat, to have the chance to do so.

On a practical point, this is not just a theoretical idea put up for consideration. Our Association, the West Australian Nut & Tree Crop Association, has links with a Cooperative company which is just now setting up a scheme to make small acreages available, at nominal cost, to people interested in setting up tree-cropping situations to experiment with a host of possible initiatives.

Finally, I would re-iterate that home-acre farming is a concept developed on efficiency, efficiency of use of light, land, and people. Nevertheless, you can see that the system is a natural organic system; tree-cropping systems can function very well without fertilizer because of their energy surplus, and without chemical sprays through diversity of genetic material used. It is also a first-class permaculture system, and one in which plant variety rights are quite irrelevant. And there is no doubt that it is a system which has very great regard for the environment. So, if you are one of those people who have strong views on these matters, and if you have felt in your bones that the ideas you believed in had to prove right in the end, here is the proof which you needed, based on cool economic fact.

Based on a talk presented at ACOTANC-2 Conference, Melbourne, September, 1984.

Collecting Information About Fruit and Nut Crops for Western Australia

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AUSTRALIA

The largest fruit industry in Western Australia (WA) is the apple industry. It constitutes about 60% of the value of production of tree fruit crops. Much further down the list come stonefruit (14%) and citrus (10%) with pears (7%) and bananas (7%) close behind. The remainder (or ‘other fruits’) make up a small 2% of the value of production.

Amongst the ‘other fruits’ are crops which have been present in WA for a long time but which haven’t become significant industries. These include persimmon, papaya, guava, passionfruit, figs, walnuts and chestnuts.

There are some fruit and nut crops which have been introduced more recently and the question arises as to whether some of them will become significant fruit industries. For example, the avocado was first planted in home gardens. There are now about 15,000 trees planted in orchards in WA. Other interesting crops include macadamia, mango, custard apple, tamarillo, kiwifruit, pistachio, lychee, longan and white sapote. Some of these crops are in commercial production while others are unknown quantities. Indeed many possibilities for new crops exist: acerola, blueberry, choko, citrus species, feijoa, jujube, jackfruit, loquat, sapodilla, surinam cherry and others.

It is impossible and inappropriate to put a large amount of public resources into developing new crops. But a good deal of information can be collected by people who have a few plants in their garden. In the December 1983 issue of the Journal of Agriculture, (Western Australian Department of Agriculture) alternative fruit and nut crops for the South- West were discussed. In several articles the importance of observations on trees growing in gardens is mentioned. Information gathered on these trees complemented that collected in experimental plots on research stations and pointed to the potential of some species.

The type of observations needed fall into three categories: the environment, the plant and management practices.

The environment can be described in terms of rainfall, temperature and humidity. These data can be obtained from a nearby meteorological station or can be recorded on site, giving due consideration to the location of the instruments. A record of disasters: cyclones, storms, strong winds, heatwaves, frosts, floods and droughts, needs to be kept including comments on their effect on the trees. The soil can be described in terms of its texture (sand, loam, clay), depth and organic matter. The site description should include the altitude, aspect and slope as well as a comment on previous site history (natural bush, cultivated, pasture).

The behaviour of the plant can be recorded by observing changes in size (height, diameter and trunk girth 15 cm above the ground) and the number of flushes which occur and how long they last. Some measurements on the growth of leaves and fruit can also be helpful. The time of occurrence of particular events can be important. Record the date of bud swell, bud burst, flower initiation (buds can be dissected and examined with a 10x hand lens), flowering, fruit set, fruit drop and maturity. Observations on the fruit or nuts should include their size, weight, number, the number of seeds and the proportion of edible parts (by weight). Some records of taste and flavour are worth noting as well as the reactions of your friends. The cultivar or variety is important (or is it a seedling?) as well as the root stock. A record of any pests and diseases, especially attacks by native insects can be helpful in assessing potential pests.

If you carry out any spraying, fertilizing, pruning, girdling or irrigation it is helpful to record how much was applied, when it was done and what chemicals were used. It is especially important to record details of manipulative treatments with which you may have experimented. Armed with these data you will be in a good position to objectively inform the severest critic of the performance of your crop. Such data are especially useful when combined with matching sets for the same species in other localities or even for different varieties. If the data can be bulked in a formal way it is even better.

An example of how crop and environment data can be combined to study the potential of new crops has been published by Moncur (1983) who studied new and established crops in northern New South Wales and south-east Queensland, Australia.

References
Anon (1983). Alternative fruit and nut crops-prospects for the South West Journal of Agriculture-Western Australia 24,110-137.
Moncur, M. (1983). Tropical and sub-tropical fruit production in the north-east of New South Wales and the North Moreton region of Queensland. CSIRO Division of Water and Land Resources, Technical Memorandum 83/3.

Based on a tall presented at the August 1984 meeting of the WANATCA, Nedlands WA.

Book Reviews

Ecology of Tropical Plants
by Margaret L. Vickery, with a chapter by John Hall
John Wiley & Sons, Chichester (1984).

Adapted from 'Plants and Environment' by R.F. Daubenmire this book of 170 pages illustrates the relationships between tropical plants and their environment. The book contains much new and updated material.

Margaret Vickery is a botanist with a special interest in ecology and plant chemistry. She has ten years of research and teaching experience in Tropical Africa and is co-author of two other books. In this book the relationships between habitat, ecosystem and plant communities and the adaptation of plants to their habitats are emphasized.

The chapters look at the relationships between plants and soil, water, radiation (light), atmosphere, between one another, animals and man. There is also a chapter devoted to tropical vegetation. Dr. John Hall of the University of Dar es Salaam, Tanzania has contributed a chapter on investigating the new environment. This chapter contains useful information on assessing soil texture and the amount of water available to plants, soil organic matter content, soil reaction and measurements of the components of the water cycle.

This is a good book which is easy to read and worth having if you want to understand more about how plants relate to their environment. For those who want to go deeper there is a list of suggested reading at the end of each chapter.

Tropical Tree Fruits for Australia
compiled by P.E. Page, Horticulture Branch
Department of Primary Industries, Queensland (1984).

The first Australian Tropical Tree Fruits Workshop was held in Queensland in 1980. Review papers were prepared for the workshop on tropical tree fruit thought to have some potential in Northern Australia. This book contains these review papers and includes additional chapters on macadamia, avocado and pummelo which were not discussed at the workshop.

Seventeen authors from the CSIRO Division of Horticultural Research; the Department of Agriculture, NSW; the Department of Primary Production, Northern Territory; and the Department of Primary Industries, Queensland have reviewed more than 70 species in 26 plant families. Included are 68 coloured plates of more than 50 fruits. Each fruit has been treated under headings of botany; climatic and soil requirements; genetic diversity; production season and time of cropping; yield, market (local) and export potential; cultural details; harvesting methods; marketing and processing characteristics; and storage and transport.

The amount of coverage given to each fruit varies, perhaps reflecting Australian experience or lack of it with many species. For example, the treatment of lychee covers 13 pages while other fruit are covered in as little as one page. A list of references is given after each chapter, some have one or two listed while others have up to 20.

The book is unique for Australia because it brings together material which was widely scattered. It will be of interest to fruit growers, extension workers and advisers. Research workers may challenge some of the general statements made and may be encouraged to provide some data to expand our knowledge of tropical tree fruits. Horticulturists may be encouraged to ‘try it and see!

Altogether, a worthwhile publication and good value at the price: $33.85 hard cover, $26.15 paperback.

Promising Fruits of the Philippines
by Roberto E. Coronel (1983).

There are many fruit and nuts which are not widely grown in the Philippines but which have potential for development in local and export markets. These same fruits and nuts are thought to have potential in other countries as well and this gives this book wide appeal.

The book attempts to bring together all available information on the most promising fruit. In this regard it is up to date and thorough.

The author, Dr. Roberto E. Coronel, is one of the leading tropical fruit and nut experts in the Philippines. He has studied at the University of the Philippines at Los Banos (UPLB), the University of Hawaii and the University of California at Riverside. He now works as researcher at the UPLB Institute of Plant Breeding and his main work has been the establishment and conservation of tropical fruit germplasm. This experience becomes evident in this book.

The book is intended for

- students of tropical horticulture as a reference material
- extension workers
- fruit growers who need information on propagation and culture
- researchers who want to know the state of the art
- homeowners and nutritionists who need information on processing.

The 508 pages and 22 chapters cover sugarapple, avocado, bilimbi, carambola, caimito, cashew, sapodilla, duhat, durian, grape, guava, soursop, jak, langsat, mangosteen, pili, rambutan, seedless and seeded breadfruit, santol, ciruela, strawberry, tamarind and tiessa.

$37.15 hardcover, $27.85 paperback.

Principles and Practices for Harvesting and Handling Fruits and Nuts
Edited by M. O’Brien, G.F. Cargill & R.B. Fridley
AVI Publishing Company Inc. Westport, Conneticut (1983).

This book is intended as a reference for those familiar with the production of fruits and nuts. An engineering approach has been used extensively but the non-engineer will be able to get a good understanding of the principles involved because of the style and language. There are plenty of pictures.

The four sections cover

- broad aspects of fruit harvesting (cultural, social and economic)
- engineering principles which have been used to make harvesting less laborious (both manual and mechanical harvesting)
- postharvest transport, preprocessing, sampling and containerisation
- total harvest systems which integrate engineering principles with the biological and economic constraints of the crop.

Each of the 20 chapters have different authors all of whom come from the United States. Chapters include: Manual harvesting of fruits and nuts and use of mechanical aids; Fruit and nut collection by pickup; and Collection by catching.

The section on systems for harvesting various crops includes chapters on berry harvesting, grape harvesting and harvesting from individual trees as well as intensive orchard systems.

The chapter on harvesting nuts covers almonds, walnuts, filberts, macadamias and pistachios. The last chapter discusses the harvesting of citrus, tropical and subtropical fruit, especially avocado, dates, coffee, fig, olive and pineapple.

D.W. Turner
Editor

Addresses of Nurseries and Commercial Sources

Please notify the Editor of any omissions or errors, especially where WANATCA members are involved. (+ indicates WANATCA Member)

WESTERN AUSTRALIA

BLOSSOMS GARDEN CENTRE, 2311 Albany Hwy, Gosnells 6110. Retail and wholesale, large range of tropical, exotic and temperate fruit and nut trees.
+ DAWSONS NURSERY, Hale Rd, Forrestfield 6058. General garden centre with range of traditional fruits and nuts.
+ KELMSCOTT AZALEA GARDENS, 41 Roberts Rd, Kelmscott 6111. Retail garden centre with large range of tropical and exotic fruits.
+ MICROCULTURE, Lot 60, Russell Rd, Landsdale 6065. Tissue culture propagators.
+ NUTLAND NURSERY, 97 Carabooda Rd, Wanneroo 6065. Plant production, specializing in avocados, pecans, chestnuts, macadamia, pistachios and others. Contract growing. (09) 407 5467
+ NUT TREE AND CONIFER NURSERY, 52 Croydon Rd, Roleystone 6111. Advance order system.
+ OLEA NURSERIES, RMB 44, West Manjimup 6258. W.A.'s largest producer of temperate fruit and nut trees. Wholesale only.
PACKSADDLE PRODUCE CO., PO Box 249, Kununurra 6743. Wholesale producer of tropical fruit seedlings.
+ PECAN INDUSTRIES, PO Box 69, West Perth 6005. Wholesale producers of pecans, jojobas, pistachios, chestnuts. Planting and management services.
RICHARDS, A., 1439 Albany Hwy, Cannington 6107. Propagation and nursery needs.
+ SPREADING CHESTNUT, PO Box 27, Subiaco 6008. Retail outlet, has wide range of nut trees and unusual fruits.
+ WALDECK NURSERIES, Russell Rd, Wanneroo 6065. Large Perth chain of garden centres, stock more popular fruits and nuts.
+ ZAMIA NURSERY, 1 Coppin Road, Mundaring, 6073. Propagators of stone and pome fruit, grapes and other temperate fruits. Rootstocks and contract growing.

VICTORIA
AUSTRALIAN BLUEBERRY NURSERIES, Boundary Rd West, Narre Warren East 3804.
+ BLOMS SEEDS. P.O. Box 335 Dandenong 3175. Extensive listings of trees, shrubs, palms, flowers and vegetables.
BLUEBERRY HILL NURSERY, R.S.D E655, Ballarat. Blueberries, feijoa.
BOTANIC ARK NURSERY, Copelands Rd, Warragul 3820. Wide range of unusual and useful plants.
FLEMINGS MONBULK NURSERIES, Macclesfield Rd, Monbulk 3793. Temperate fruit tree wholesaler.
C.J. GOODMAN, Box 47, Bairnsdale 3875. Temperate deciduous fruit and flowering fruit trees. Wholesale and retail.
HIGH GROVE NURSERY, Mt. Stanley Rd., Stanley 3747. Propagators of grafted chestnuts, walnuts, and layered hazelnuts.
JOHN BRUNNING & SONS, Somerville 3912. Fruit tree wholesaler with large traditional range.
LUCAS LINERS, PO Box 81, Olinda 3788. Mass producers of 1-year seedling trees, including some nuts.
MABUHAY GARDENS, PO Box 3, Monbulk 3793. Seed of exotic fruit trees, wholesale only.
W A SHEPHERD & SONS, Mooroodue, 3933. Good range of temperate fruits and berries.nuts,

walnuts, and layered hazelnuts.
JOHN BRUNNING & SONS, Somerville 3912. Fruit tree wholesaler with large traditional range.
LUCAS LINERS, PO Box 81, Olinda 3788. Mass producers of 1-year seedling trees, including nuts.
MABUHAY GARDENS, PO Box 3, Monbulk 3793. Seed of exotic fruit trees, wholesale only.
W A SHEPHERD & SONS, Mooroodue, 3933. Good range of temperate fruits and berries.

SOUTH AUSTRALIA
BALHANNAH NURSERIES, Balhannah, 5242. Traditional fruits.
+ FRESHFORD NURSERY. Highbury, 5089. Grafted walnuts, persimmons, and pecans.
PERRY NURSERIES, Kangarilla Rd, McLaren Flat 5171. Avocado, pistachio, quandong, carob, guava tamarillo, chestnut.
STOECKEL NURSERIES, P.O. Box 113, Paringa 5340. Stonefruit and citrus. Wholesale/retail.
TOLLEYS NURSERIES, PO Box 2, Renmark 5341. Citrus specialists, supply trees, seeds, and budwood.

TASMANIA
HAZELBROOK FARM NURSERIES, R.S.D. 1600 Pine Rd, Penguin 7316. All stone fruit, hazelnut, chestnut, deciduous ornamentals. (004) 37 2072

NEW SOUTH WALES
BLUE HILLS BLUEBERRY FARM AND NURSERY, Tilba Tilba 2546. Chestnuts and N.S.W, waratahs.
EAST COAST BLUEBERRIES-SECTOR (NURSERIES) PTY LTD. P.O.Box 7, Gosford East.
FRUIT SPIRIT, Research Nursery and Gardens, Dorroughby 2480. Paul Recher, (066) 89 5129
+HUNTER PECANS, P.O. Box 217, Muswellbrook 2333.
H.G. KERSHAW, PO Box 84, Terry Hills 2084. Wide range of tree, shrub, and palm seeds.
MOUNTAIN BLUE NURSERY, Walton Rd, Federal via Lismore 2480. Blueberry specialists.
PREMIER NURSERIES, PO Box 400, Griffith 2680. Wholesale and retail supplier of fruit trees.
RIVERINA NURSERIES, Farm 645, Griffith 2680. Range of fruit trees.
SUNRAYSIA NURSERIES, Sturt Highway, Gol Gol 2739. Grapes, olives, citrus and avocados.
+ YARRAHAPINNI FRUIT TREES, A. & K. Seccombe, c/-P.O. Stuarts Point 2441. Large range grafted fruit and nut trees, vines, blueberries.

QUEENSLAND
+ BIRDWOOD NURSERY, Blackall Range Rd, Woombye 4559. Avocado, custard apple, lychee, mango, kiwifruit.
B W WHOLESALE & EXOTIC NURSERIES, PO Box 125, Childers 4660. Avocados, lychees, custard apples, pecans.
FITZROY NURSERIES, PO Box 859, Rockhampton 4700. Very good range of tropical fruits and nuts, pecans, macadamias.
+ FLOWER'S TROPICAL NURSERY, Rosemount Rd, Nambour 4560. Specialists in carambola, sapote, abiu and over 100 varieties of tropical fruit trees.
LANGBECKER NURSERIES, PO Box 381, Bundaberg, 4670, Avocadoes, pecans, custard apples.
LIMBERLOST NURSERIES, Freshwater, Cairns 4870. Range of tropical trees, including some fruits and nuts.
PIONEER VALLEY NURSERY, P.O.Box 43, Marian 4741. Tropical fruit tree nursery.
+ SIPPY FARM LYCHEE NURSERY, Euclo 4554. Wholesale growers of all lychee varieties, including No Mai Chee.
+ TURNER HORTICULTURAL, PO Box 109, Spring Hill 4000. Grafted macadamias, grapes, tropical fruits.

Addresses of Useful Organisations

This list of addresses will be printed each year. Please notify the Editor of any errors or omissions.

Australia

Australian Capital Territory
Forestry Branch, Department of Primary Industry, Banks St., Yarralumla, ACT 2600,

New South Wales
Department of Agriculture, PO Box K220, Haymarket, NSW, 2000.
Australia: Society for Growing Australian Plants, 860 Henry Lawson Drive, Picnic Point, NSW 2213

Northern Territory
Department of Primary Production, PO Box 4160, Darwin, NT, 5794.

Queensland
Australian Macadamia Society, PO Box 445, Caboolture, QLD 4510.
Department of Primary Industries, PO Box 46, Brisbane, Q. 4001.
Rare Fruit Council of Australia, PO Box 707, Cairns, Q. 4870.

South Australia
CSIRO Division of Horticultural Research, GPO Box 350, Adelaide SA 5001.
Department of Agriculture and Fisheries, 25 Grenfell Street, Adelaide, SA, 5001.
Woods and Forests Department, 135 Waymouth Street, Adelaide, SA, 5000.

Tasmania
Department of Agriculture, GPO Box 192B, Hobart, Tas. 7001.

Victoria
CSIRO, Horticultural Research Station, Merbein, Vic. 3505
Department of Agriculture, Scoresby Horticultural Research Station, PO Box 174, Ferntree Gully, Vic. 3156.

Western Australia
CSIRO, Division of Tropical Crops, Kimberley Research Station, Kununurra, WA 6743.
Department of Agriculture, 3 Jarrah Road (West), South Perth, WA, 6151.
Permaculture Association of WA, PO Box 430, Subiaco, WA, 6008.
Western Australian Nut and Tree Crop Association (Inc.), PO Box 565, Subiaco, WA, 6008.

Canada
Society of Ontario Nut Growers, RR1, Niagara-on-the-Lake, Ontario. L0S1J.

Costa Rica
Institute Interamericano de Ciencias Agricolas de la OEA, Turrialba, Costa Rica.

Israel
Department of Subtropical Horticulture, Volcani Centre, PO Box 6, Bet Dagan, Israel.

Korea
Institute of Forest Genetics, Seung Kul Park, Swon, Kyunggi-Do, Korea.

New Zealand
Crop Research Division, Department of Scientific and Industrial Research, Private Bag, Christchurch, New Zealand.
New Zealand: Lincoln Agricultural College, Lincoln College, Canterbury, New Zealand.
New Zealand Tree Crops Association, PO Box 1542, Hamilton, New Zealand.

Spain
Spain: Centro De Experimentia Agraria, Apartado 415, REUS, Tarragona, Spain.

United States of America
USA: Agri-Silviculture Institute, PO Box 4166, Palm Springs, California 2263, USA.
California Macadamia Society, PO Box 666, Fallbrook, California 92028.
California Rare Fruit Growers, Fullerton Arboretum, California State University, Fullerton, California 92634.
Connecticut Nut Growers Association, 27 Baldwin Rd, Manchester, Connecticut 06040.
Friends of the Trees Association, PO Box 567, Moyie Springs, Idaho 83845, USA.
Illinois Nut Tree Association, 1498 Urbandale Dr, Florisant, Missouri 63031.
Indiana Nut Growers Association (Merna Dicoff), 9805 E.100 St., Zionsville, Indiana 46077.
International Association for Education, Development, and Distribution of Lesser Known Food Plants and Trees, PO Box 599, Lynwood, California 90262.
International Tree Crops Institute USA Inc., Route 1 Gravel Switch, Kentucky 40328, USA.
International Tree Crops Institute USA Inc., PO Box 1272, Winters, California 96594, USA.
Iowa Nut Growers Association, Stewart Road, RR 6, Iowa City, Iowa 52240, USA.
Kansas Nut Growers Association, PO Box 247, Chetopa, Kansas. 67336
Michigan Nut Growers Association, 199 Strongwood, Battle Creek, Michigan 49017.
Nebraska Nut Growers Association, 207B Miller Hall 8N, University of Nebraska, Lincoln, NE 68583.
North American Fruit Explorers, PO Box 711, St Louis, Mo. 63188.
Northern Nut Growers Association, RR3, Bloomington, Illinois, 61701.
Nut Growers Association of Oregon, Washington, and British Columbia, PO Box 23126, Tigard, Oregon 97223,
Ohio Nut Growers Association, 1807 Lindbergh NE, Massillon, Ohio 44646.
Pennsylvania Nut Growers Association, RR 3: Box 78, Duncannon, PA 17020.
People of the Trees, 1102 Snyder, Davis, California 95616. USA.
Rare Fruit Council International, 3280 South Miami Avenue, Miami, Florida 33129,
Tree Crops Research Project, 230 East Roberts, Cornell University, Ithaca, New York 14853.
United States Pecan & Field Station, USDA-ARS, PO Box 579, Brownwood, Texas 76801.

Venezuela
Foundation para el Desarrollo de la Region Centro Occidental de Venezuela, Apartado 523, Borquisimeto, Venezuela.

MEMBERSHIP LIST 1985

Adams (P) 3 Elizabeth Cres Bunbury 6230
Aitken (Mr W J) 6 Wroxton St Midland 6056
Albuquerque (Mr A A) 334 The Boulevard City Beach 6015
Alcoa Tree Coordinator [D Readhead] PO Box 172 Pinjarra 6208
Allen (J) 102 Carnarvon St East Victoria Park 6101
Anthoine (Mr T D)'Tanridge' RSM 239 Busselton 6280
APACE Western Australia Winter House Johanna St North Fremantle 6159
Archers Fruit Trees [L A Nielsen] Main Rd Grandchester QLD 4305
Arid Zone Res Inst (Librarian) Divn of Agric & Stock DPP PO Box 2134 Alice Springs, NT 5750
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