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The Marula, *Sclerocarya birrea* (see page 48)

West Australian Nut and Tree Crop Association (Inc.)
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This provides a route for checking current contact details of relevant tree crop organisations at any time.

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For further details of the Association see Inside Back Cover

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THE SAPODILLA IN SOUTHEAST ASIA

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Introduction

The Sapodilla or Chiku is one of the best-known of the big number of fruits in the Sapotaceae family, and the tree on which it grows has many uses, including production of the base of chewing gum.

Although it originated in central America, the plant has become very popular in Southeast Asia, now believed to be the major world production area.

Botany

Botanically the plant is *Manilkara zapota* (L.) P. van Royen. It is a member of the large Sapotaceae family (about 53 genera and 975 species). Its chromosome number is 2n = 26. Its botanical description is to be found in **Blumea**, 7:410 (1953).

Synonyms for the plant include *Achras zapota* L. (1753), p.p., *Pouteria mammosa* (L.) Cronquist (1946), p.p. min., and *Nispero achras* (Miller) Aubreville (1965), nom. inval.

Vernacular names

The common English name Sapodilla is derived from the Spanish diminutive of Sapota, itself a native central American word for a sweet fruit. Other common names such as Chico have similar meaning, being contractions of Chico Sapote, baby sapote. Vernacular names used in Southeast Asia include: Sapotillier (Fr). Indonesia: sawo manila, ciku (Sundanese), sawo londo (Java). Malaysia: ciku. Philippines: chico. Cambodia: lomut. Laos: lamud. Thailand: lamut, lamut-farang. Vietnam: xaboche, hong xiem, tam lu'c.

Origin and geographic distribution

Sapodilla is a native of Central America, Mexico and the West Indies. It is now cultivated to a greater or lesser extent in the tropical lowlands of both hemispheres. It is an important fruit all over South-East Asia.

Uses

Sapodilla is grown mainly for its fruit which is predominantly eaten fresh. The fruits may also be used in sherbets or ice-cream or made into preserve, butter or jam. The juice may be boiled into syrup or fermented into wine or vinegar.

Wild and cultivated trees in America are tapped for their milky latex which coagulates

§ Member, WANATCA

into chicle, the principal constituent of chewing gum before the advent of synthetics. This gum is also used in the manufacture of transmission belts, in dental surgery, and as a substitute for gutta percha, a coagulum of the latex of species of *Palaquium*, also in the Sapotaceae, which had many applications in industry before the advent of plastics.

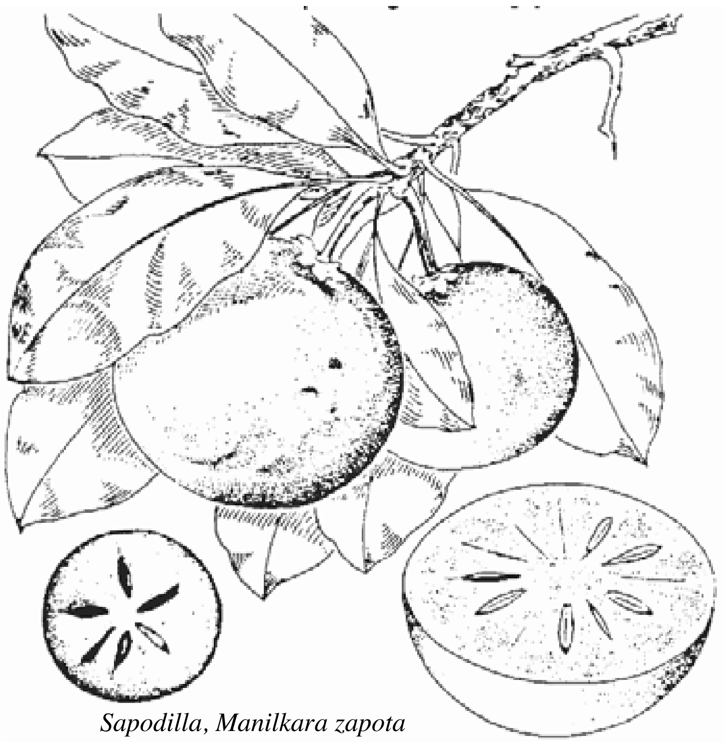
The wood is an excellent material for making cabinets and furniture. The seeds are antipyretic. In Indonesia the flowers are used as one of the ingredients in preparing a powder which is rubbed on the body of a woman after childbirth. The tannin from the bark is used to tan ship sails and fishing tackle; in Cambodia the tannin is used to cure diarrhoea and fever.

Production and international trade

Sapodilla is popular in South-East Asia because the fruit is very sweet. Statistics indicate that the region is the major producer of the fruit: in 1987 Thailand produced 53650 t with a total area of 18950 ha; the Philippines 11900 t with 4780 ha; Peninsular Malaysia 15000 t with 1000 ha; in Indonesia production during 1986 was estimated at 54800 t. The fruit is consumed almost entirely in the country of production and international trade is negligible. In many areas it is available when few other fruits are in season.

Properties

The sapodilla fruit is rather dry and some cultivars have a gritty texture. About 84% of the fruit is edible and contains, per 100 g: water 74 g, protein 0.5 g, fat 0.9 g, carbohydrates 24 g, fibre 3.0 g, ash 0.4 g, phosphorus 32 g, calcium 9 mg, iron 1 mg, sodium 5 mg, potassium 198 mg, vitaminA,85 IU, thiamine and riboflavin 0.01 mg, niacin 0.3 mg and vitamin C 26 mg. The energy value is 400 kJ/100g. The predominant organic acid in the fruit is malic acid.



Sapodilla, Manilkara zapota

Description Evergreen, upright to spreading tree, 5-20(-30) m tall, all parts rich in white gummy latex; trunk low-branched, bark rough, dark-brown, crown globose or pyramidal, conforming to Aubreville's architectural model.

Leaves alternate, ovate-elliptic to oblong-lanceolate, 3.5-15 cm x 1.5-7 cm, cuneate or obtusely acuminate at both ends, frequently emarginate, entire, glabrescent, glossy dark green, midrib prominent below, lateral nerves numerous, parallel; petiole I 3.5 cm long. Flowers solitary in upper leaf axils, usually pendulous, up to 1.5 cm in diameter, brown-hairy outside; pedicel 1-2 cm long; calyx deeply 6-parted, usually in two whorls, densely grey or brown tomentose outside; corolla white, campanulate, 6 lobes about half as long as the tube; staminodes 6, petaloid; stamens 6; ovary 10 12-celled, villous; style subulate, exserted from the flower.

The fruit is a pendulous berry, globose, ovoid or ellipsoid, 3-8 cm x 3-6 cm, rounded or impressed at base, apex rounded and crowned by the remnants of the style; skin thin, dull reddish to yellow-brown, covered with a sandy brown scurf; flesh juicy, soft, yellow to red-brown, sweet. Seeds 0-6(-12), oblong, 2 cm long, brown or black, compressed laterally, hilum distinct.

Growth and development

The seeds germinate about 30 days after sowing without any treatment and exhibit an epigeal type of germination. The seedlings grow very slowly, producing a central stem which dominates the whorls of laterals in trees with an upright habit; the spreading habit is achieved by more prominent sympodial extension of the laterals. In an equable climate some extending shoots can be found at any time, but trees relieved from stress may seem to produce a general flush. Seedling trees start to flower 6-10 or more years after planting; grafted trees in 4-6 years and marcotted trees in 3-4 years. Flowers are produced in the leaf axils near the tip of young immature shoots. These shoot tips have greatly shortened internodes, so that the flowers appear to be borne in clusters. Flowering may take place throughout the year but the peak of flowering in the Philippines is April to June, that is early in the rainy season.

Observation of two cultivars in the Philippines showed that flower buds reach anthesis 45- 60 days after emergence. The stigma is receptive between one day before and three days after flower opening; on the day of opening it is sticky with stigmatic fluid. Self-fertile cultivars produce much pollen, which is viable. Cross-pollination by insects, e.g. bees, is recommended and is necessary for low-yield cultivars, most of which produce little pollen, which is defective. Fruit growth as observed in India proceeds in 3 distinct stages: in the first 16 weeks diameter exceeds length; after a transitory period of 4 weeks the fruit assumes its characteristic oblong-ovoid shape and takes another 9 weeks to ripen. The fruits take about 6-8.5 months to mature so that in the Philippines the main harvest season is from December to February. In Thailand the fruit is more seasonal and abundant from September to December.

Other botanical information

For a discussion of the correct scientific name of the sapodilla see reference [7], *Pouteria sapota* (Jacq.) H.E. Moore & Stearn. Numerous cultivars exist, often bearing local names; in many cases names in different localities are presumably synonyms.

In Indonesia two groups of cultivars are distinguished: Sawo manila with ovoid fruit, including 'Sawo Betawi' and 'Sawo Kulan', and Sawo apel with globose fruits, e.g. 'Sawo Apel Benar' and 'Sawo Apel Lilin'.

In the Philippines the small-fruited, prolific ‘Pineras’ is most common. ‘Ponderosa’ has large fruit of excellent quality but it does not soften uniformly after harvest and trees require cross-pollination for good yield. Other cultivars are ‘Sao Manila’ and ‘Gonzalez’

Well-known Thai cultivars are the small-fruited ‘Krasuey’, the fairly large-fruited ‘Kai Hahn’ and the medium sized, globose ‘Makok’. Popular cultivars in Malaysia are ‘Santong’, ‘C 54’ and ‘C 58’. In Queensland, Australia, cultivars from various countries have been evaluated; the most promising cultivars are ‘Kai Hahn’, ‘Makok’, ‘C 58’, ‘Tropical’, ‘BKD 110’ and ‘Sao Manila’

Ecology

Sapodilla is a very adaptable species. It thrives in the tropics, but is found in large numbers at elevations up to 2500 m in Ecuador and also in the subtropics (Israel); mature trees are not greatly damaged by a few degrees of frost. Sapodilla is very drought-resistant, doing well in the taxing monsoon climates of India. With its tough branches the tree tolerates strong winds and salt sprays close to the seashore. However, growth and fruit quality are impaired in extreme environments; the tree thrives in warm, moist tropical lowlands, usually below 600 m in Southeast Asia. The best soil for sapodilla is a rich, well drained, sandy loam, but few soils are unsuitable and sapodilla comes second after the date palm in the category of fruit trees with high tolerance of saline soils.

Propagation and planting

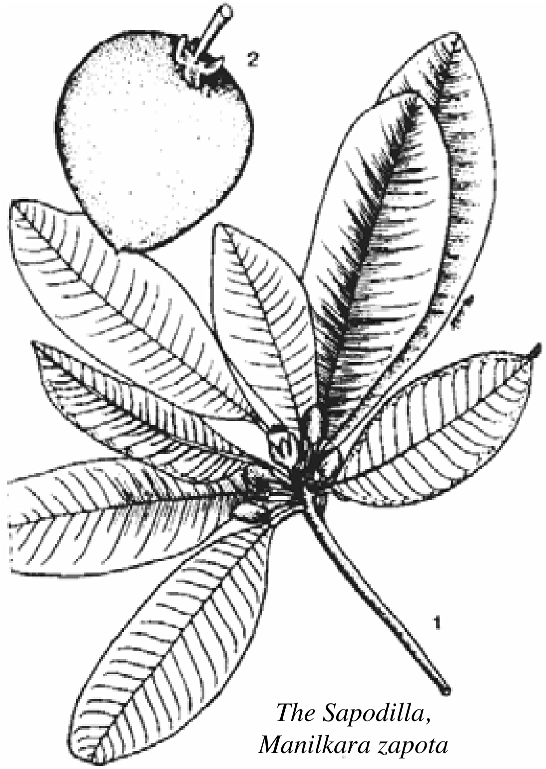
Cultivars are propagated either by grafting or marcotting. The seeds for rootstocks are sown in a sandy seed-bed, about 2 cm apart and at a depth of about 1 cm. The seeds germinate in about 30 days, fresh seed giving up to about 80% germination. Seeds can be kept for several months but it is best to sow them immediately after collection. After a few months the seedlings are transplanted into polybags. They grow very slowly; even if spurred on by nitrogen applications, it takes 2-3 years before the rootstocks are ready for grafting.

Other species of *Manilkara* Adans, have been tried as rootstocks, partly to find faster growing seedlings. *M. kauki* (L.) Dubard did well in Indonesia and India and is being tried in the Philippines. However, in India *M. hexandra* (Roxh.) Dubard proved to be the best rootstock, even after 40 years, provided only the more vigorous seedlings were grafted, there being much variation in vigour. Some species of *Madhuca* J.F. Gmelin, *Palaquium* Blanco and *Sideroxylon* L. are also graft-compatible with sapodilla. Inarching is the traditional grafting method, giving as much as 95- 100 % success. However it is a rather laborious method. In the Philippines it has been replaced by cleft or wedge grafting. Sapodilla can be grafted any month of the year, but best results are obtained during the cooler and drier months (November-February in the Philippines). Scions are cut from quiescent terminal shoots with buds ready to sprout. Fruiting twigs are better than non-fruiting twigs. Cleft grafting gives 80-90 % success.

Marcotting is best done during the rainy season. The branches to be used should be more or less upright and have a diameter of about 1 cm. Coconut coir is one of the common rooting materials used. Treating the girdled stem with a root hormone is beneficial. Complete rooting is achieved in 4-12 months depending on the size of the branch and on the cultivar used. Success in marcotting is 60 % or more, the smaller branches generally showing the highest percentage take. Mist propagation using leafy stem cuttings treated with a root-promoting substance has been successful. The suggested tree spacing in the orchard is 6-10 m. Planting is best done at the onset of the rainy season.

Husbandry

Newly planted trees need to be watered during dry periods to improve establishment. Moreover, the trees respond by extra growth and come into bearing more quickly. Although the trees are very drought-resistant, flowers and fruitlets are shed under moisture stress; hence in dry climates bearing trees also benefit from irrigation. The tree architecture, with a central leader and whorls of laterals extending sympodially, calls for little pruning, the more so since the flowers are borne near the shoot tip.



The Sapodilla, Manilkara zapota

However, in clonally propagated trees the architecture is not so clearly expressed. In cultivars with upright growth the central leader may be headed back in the formative years to promote lateral growth. In cultivars with a cluttered habit pseudo-central leaders should be removed and some thinning of weak and interlacing branches is recommended as the trees grow older. Also the lower whorl of branches is removed as it sags towards the ground.

In experiments in India the response of both growth and fruiting to nitrogen was quite convincing. Mature trees need 1.5 kg N or more per year, recommended doses of P_2O_5 and K_2O are about 0.5 kg per tree. Fertilizer or manure is applied at the onset of the rainy season, in time to support the increased extension growth and flowering brought on by the rains, and well before the end of the rainy season to sustain fruit growth. In this way fertilizing may further concentrate the crop in a certain period. Fertilizer is applied in a ring under the dripline of the tree canopy.

Diseases and pests

There are no serious diseases of the sapodilla. The pink disease (*Corticium salmonicolor*) is a canker which kills affected branches. In India, a leaf-spot disease (*Phaeophleospora indica*) has been reported.

Some insect pests may inflict serious damage to the sapodilla trees. The maggots of the oriental fruit fly (*Dacus dorsalis*) feed on the flesh of ripe fruit making it unfit for consumption. The larvae of the phycitid fruit borer (*Alophia* sp.) attack the fruits at all stages of development. The larvae of the gelechiid moth (*Eustalodes anthivora*) feed on the flowers causing them to drop. The twig-borer (*Niponoclea albata* and *N. capito*) larvae tunnel into the twigs and pupate inside, whereas the adult beetles girdle the branches. Mealy bugs and aphids feed on the leaves, young shoots, flowers and young fruits. Scale insects cluster around the twigs and branches and along the leaf midribs, causing leaf drop and twig dieback.

Harvesting

Some fruit may be ripening on the tree throughout the year, but generally there are one or two major harvest peaks because of concentrated blossoming, or because viable pollen is produced during certain periods.

The fruit is climacteric and is picked when mature but still firm; it needs a few days to soften and become edible. The fruits are considered mature when the skin colour turns from green to yellowish-brown, the scurfy bloom on the skin comes off easily and the latex flow is minimal when the fruit is detached. This change is not easily seen, however, because the fruit surface is covered with a brown powdery material. Therefore the surface of a few fruits is rubbed with the thumb to remove the bloom and to observe the skin colour; as a final test these fruits may be detached.

Mature fruits are picked without the stalk. A white latex exudes from the stalk, and the practice in the Philippines is to put the fruits in a container with water and allow them to 'bleed'. Bleeding is stimulated by scraping the stalk end with the thumb nail or with a sharp object. If this is not done the latex remains inside the fruit and coagulates there. The fruits are scrubbed with a piece of cloth to remove the bloom and allowed to dry by placing them with their stalk ends down.

Yield

There are few records of actual yields. In India, a norm for annual fruit number for trees of 7 years and older is to multiply tree age by 100, 2500 fruits being considered the maximum. Although the average yields calculated on the basis of area and production are low (except for Peninsular Malaysia), sapodilla is certainly not a reluctant bearer. Annual yields per ha of 20- 30 t have been reported in Florida, 20-25 t in the Philippines and 20-80 t in India.

Handling after harvest

The fruits are usually graded and marketed immediately after harvest. They ripen in 3-7 days. The fruits can be stored at low temperature to prolong their shelf life. Unripe fruits stored at 15° C can be kept in good condition for about 11 days; at lower temperatures unripe fruits stored for more than 10 days do not ripen normally. Ripe fruits stored at 0°C remain in good condition for 12-13 days.

Genetic resources

Seedling trees exhibit much variation in plant and fruit characters. In the Philippines, for example, the introduction of new cultivars and the planting of their seedlings has led to wide variability in the sapodilla population. Moreover, many seedlings never bear fruit, pollen

sterility being quite common in seedling populations. In recent years germplasm has been collected by the Institute of Plant Breeding in Los Baños, the Philippines; Australia (Queensland), India, Cuba, Brazil, Costa Rica, the United States (Florida, Puerto Rico, Hawaii) and some other countries also maintain sapodilla germplasm collections.

Breeding

Cultivars result from clonal propagation of selected seedling trees. The major objectives in varietal improvement are large fruit size, good eating quality and seedless fruits. Controlled hybridization started in India in the 1950s, but this has not yet resulted in the introduction of new cultivars. Only a few parents (e.g. 'Prolific' from Florida) produce seedling offspring with viable pollen, bearing regularly.

Prospects

The sapodilla is a very popular fruit in South-East Asia and other tropical countries. It would seem that supplies do not fully meet domestic demand. Trees are sufficiently fruitful and manageable to be grown in orchards. The factors that largely determine the scope for expansion of commercial production are shortening of the nursery period, better insight into pollen viability and the compatibility of cultivars, as well as development of growing techniques to shift the main flowering and harvesting seasons.

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Based on an article in *Edible Fruits and Nuts: Plant Resources of South-East Asia* (PROSEA Foundation, Indonesia, 1992).

National Plant Genetic Resources Laboratory: <A 1925>

STONEPINES AS NUT PRODUCERS:
CURRENT SITUATION AND PROSPECTS

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Introduction

Most fruits and nuts are harvested from cultivated trees. However, stonepine (*Pinus pinea* L.) from which cones are harvested are trees growing still as forest stands. These stands have been planted for a mixed yield of wood and cones, and thus trained for tall and clean trunks, which make harvesting of cones very difficult. Although currently pine nut production can be considered more important than wood profit, as it generates higher and more steady incomes, stonepines thriving on mountains probably will not lose their main forestry aspect in the future.

With this background it seems clear that pinenut ('pinion') production has to find other supply sources soon, apart from the current forestry stands, as the difficulty and high cost of harvesting will make this crop totally uneconomic. Currently, in the developed countries, the income from the sale of pinenuts goes 80-90% for pickers and 10-20% for owners.

Mechanization of stonepine harvesting using shakers, although perhaps possible in some flat areas with low tree densities, is not feasible in most cases. The only possible alternatives to maintain this market alive and rising in the future, would be either improving yield of future stands, using selected seed and applying woodland management focussed solely on cone production, giving cheaper harvesting, or planting very productive orchards, using clonal rootstocks of selected stonepines as pinenut producers. In these plantings agronomic technical approaches would be applied for their optimum development, as is done with other tree crops like almond, orange, apple, etc.

Genetic improvement

Stonepine genetic improvement programmes in Spain have been based on two activity lines - selection and delimitation of selected forests and stands to get seeds, and selection of high producing pinenut individuals for vegetative propagation.

Selection of forests and stands

The main aim of this line would be to determine areas where selected seeds of an acceptable genetic quality could be harvested, at a reasonably low price, for reforesting programmes. A forest or stand can be classified as select when most individuals present phenotypic characteristics where the character for which the selection is made is clearly superior to the surrounding populations, and located sufficiently isolated from other populations showing poorer characteristics.

An isolation of about 500 m can be sufficient distance to ensure that pollen coming from undesired populations does not reach individuals of the selected area. As criterion for selection of these stands the ecological evaluation of the species, as well as productive and phenotypic differentiation (evaluated by cone harvest) of the stands has to be considered (Gordo and Gil; 1995).

Due to the absence of data on the genetic structure of this species, we can only make an approach to their genetic variability, assuming its correlation with the environmental variability. The natural presence of a species in a broad range of climatic and edaphic conditions, would mean the existence of different populations adapted to specific environments (Prada and Gil; 1997).

As more precise data is lacking on the genetic structure of this species, geographic structure (isolation) and phytoclimatic, edaphic and altitude factors can be considered as the most differentiating aspects. Using as a base the geographical distribution and these ecological aspects, the DGCONA and the ETSIM have established, for the whole Spanish stonepine growing area, seven source regions and four restricted zones.

Stone pine cone harvesting in Valladolid, Spain

In evaluating regional sources for this species, subspecies, or a particular variety, all the territory or all the districts having the same ecological conditions in which populations thrive and present similar phenotypical or genotypical characteristics are considered. In each of these source regions, or at least in those which are interesting from the point of view of fruit production, selected forests or stands are determined as basic material to get selected reproduction material, using cone production as selection parameter.

In the Castile and Leon regions, for several years trials have been made on this subject, resulting in a proposed inclusion in the 'Catálogo Nacional de Materiales de Base' [National Register of Resources], of several selected stonepine forests and stands for the source regions called Meseta North and Valleys of Tietar and Alberche. In the area of Meseta North, a selected forest has been delimited, with an area of 360 ha and 6 selected stands with areas ranging from 16 ha to 90 ha; and in the source area, Tietar and Alberche Valleys, three selected stands have been determined with areas ranging from 8 ha to 75 ha. (Gordo and Gil; 1993). In Andalusia, in the area of the Guadalquivir Valley trials were made too, and there will be a possibility to have available some selected stands of this species in the provinces of Huelva and Cádiz soon.

With the seeds obtained from these stands much more productive forests would be established, and if suitable forestry management is given it will increase cone production (wide-spaced plantings with big tree crowns) which will make harvest cheaper, using plants with very short trunks and low crowns. This will increase yields and cone harvesting will be a safer and more attractive job for pickers.

In Portugal, in the area of Alcacer do Sal, this technique is being used for several years past, and currently there are several areas devoted to cone production, with trees having big crowns with short trunks, which enables harvest of cones from the ground.

Selection and propagation of trees for cultivation

The stonepine, although it is mainly a forest species, presents very special features which would allow it to play a very important role as nut tree crop, due to its hardiness, low water requirements, and good resistance to frost. Stonepine could be a very interesting alternative for farming lands, currently devoted to cereals, but with very low yields, which makes their cultivation no longer profitable.

The first requirement to make stonepines produce nuts successfully is the availability of certified and productive propagational material. Thus, it will be necessary to identify, select and propagate stonepine trees standing out for being good cone producers. All Mediterranean forest managers familiar with stonepine know that within the populations exist some individuals that crop better. It is common to find trees that can produce about 1,000 cones per year, and in some cases exceptionally good and large individuals have been found producing more than 2,000 cones in one harvest.

The Spanish genetic improvement programme's main aim is to find and select stonepines considered as good cone producers, to propagate them vegetatively by grafting, and get very productive trees which would start producing in early years. It is known that cones of stonepines take three years from pollination to ripening, and as grafted trees they produce scarcely any flowers during the first years, so it will need 4 or 5 years to harvest the first ripe cones.

Table 1. Estimated pinion production in relation to age and planting distances in Spain

		Pinion production kg/ha	
Years after grafting	Cones/tree	500 trees/ha	400 trees/ha
4	0.73	16.4	13.2
5	3.28	73.8	59.0
6	7.27	163.7	130.9
7	11.61	261.3	209.0
8	15.19	341.8	273.4
9	19.85	446.6	357.3
10	22.13	498.0	398.4
11	25.50	573.7	459.0

4 cones = 1 kg
Shelling percentage:16%
Source: J. L.Gallego

Detail of cone production on a stone pine grafted onto Pinus halepensis as rootstock

The use of a reduced number of genotypes, of very similar characteristics of size and type of cones and pinenuts, will allow to get a much more homogenous product than at present, with a probable increased acceptance by consumers. To start this programme the first consideration was selection of the parameters defining quantitatively the quality of a stonepine, as a good cone producer. Many parameters were studied and the different relationships between the product achieved (number of cones, their weight or shelled pine nut weight) and the crown area (area of the sphere or ellipsoid), or crown projection (considered as a circle or ellipse) were assessed.

In this project the weight of good pine nuts per square metre of ellipse surface was used as the main parameter. This geometric form is considered the closest to that of the productive crown of the stonepine and the weight of good pinenuts is the final aim of the selection. Considering that no important differences are observed using one parameter or the other, it was concluded that the most advisable parameter to define the quality of a tree would be the weight of good unshelled pine nuts per m2 of crown projection, comparing it to a circle of average diameter, as this parameter can also be used to assess harvests if the area covered by the crowns is known (Catalan et al, 1997).

Table 2. Estimated pinion production in relation to age and planting distances in Portugal

Age	Trees/ha	Crown diameter (m)	Crown projection (m^2)	Nº of pinions per m^2 crown projection	Nº of pinions per tree	Nº of pinions per ha
5-9	625	3.5	10	5	50	31.250
10-14	500	5.5	24	8	192	96,000
15-30	300	7.5	44	11	484	145,000
31-80	100	10.0	78	15	1,170	117,000

Source: Lopes Barreira (1989)

For each source region of this project, 200 plus trees were identified by the selecting team, using information provided by foresters, cone pickers and local people. From these 200 selected trees all cones were gathered, weighed, and counted, also the bad cones were separated, weighed and counted. A sample of 20 good cones was chosen at random, weighed, and their pinenuts were taken out and were weighed too, determining blanks. Finally, the weight of good pine nuts under crown projection was determined (g/m^2), based on an average diameter circle among the measures in direction N-S and E-W.

From the 200 plus trees selected at the start, the best 100 trees were chosen and propagated by grafting, at the start of the following spring, applying the substitution method of terminal guide (Gil and Palomar, 1987). In grafting, young dormant shoots, preferably when starting their vegetative growth, were used on rootstocks already moving of about 2 or 3 years old. These grafts can be made with a relatively high percentage of success (30-80%), on plants of the same kind or on other stonepines.

Grafts have been done on rootstocks of several species (*P. halepensis* Mill. and *P. eldarica* Medw.) and at least during the first 15-20 years, no incompatibility has been observed. Recently, another grafting method has been developed in which a pair of leaves are grafted with their corresponding patch, this technique, simple to make, allows to enlarge the period for grafting and the possibility to increase the grafts per donor tree (Palomar et al., 1993).

With these clones two gene banks are being established in two different places; one in Madrid and another in The Almoraima (Cádiz). Each source is represented by 90-95 clones and each clone repeated 8 times; planting distance is 3 m x 3 m, and it is expected to reduce the number of rootstocks by half, but always keeping four repetitions of each clone, at a final spacing of 3 m x 6 m. In these two clonal banks it has been planned that every year cones will be gathered, counted and weighed, and the pinenuts will be extracted, determining the average weight of good pine nuts with shell for each clone. With these records and repeating for several years, it will be possible to determine the best clones for each location.

Mixed plantation of lavender and stone pine grafted onto P. halepensis at Pezuela de las Torres, in Madrid, Spain

Table 3. Source regions: valleys of 'Tietar' and 'Alberche'. Data of the best 15 trees and average of the selected trees

Age (years)	Cone			Pinion				Pinion production/ circle surface
	Nº	weight kg	% spoilt	Total weight kg	Good kg	Blanks %	Weight	g/m^2
80	370	86	5.41	20.90	18.73	10.40	477.88	556.00
93	183	34	10.93	16.97	14.92	12.07	781.78	342.40
78	289	120	18.34	23.36	20.39	12.72	787.85	201.03
59	102	31	17.48	6.63	6.28	8.03	543.52	200.22
69	298	114	33.56	12.57	11.28	10.28	612.64	186.64
72	230	60	9.57	12.65	9.67	23.56	675.59	175.44
76	138	36	6.52	7.93	7.54	4.97	530.86	168.53
90	214	81	6.07	17.66	16.29	7.74	545.23	166.70
76	117	37	7.69	8.31	7.95	4.32	907.07	166,68
86	120	45	10.00	9.29	8.75	5.89	710.12	165.89
68	112	45	14.29	9.12	8.10	11.23	753.56	159.47
62	140	52	5.71	11.06	10.44	5.64	720.16	158.79
70	158	27	5.06	5.84	4.70	19.55	390.03	157.75
87	110	28	22.73	5.37	4.68	12.95	513.07	157.03
68	178	62	7.30	13.92	12.06	13.36	615.47	156.74
AVG. 200	111	32	11.49	6.18	4.98	22.22	574.11	71.61
AVG. 15	184	184	57	12.12	10.78	10.84	637.65	207.95
MINIMUM	1.006	225	43.18	43.20	30.77	91.03	907.07	556.00
MINIMUM	19	3	00	2.20	0.18	2.20	329.19	3.60

It is still too soon to have production records of these clonal banks, but several Spanish and Portuguese authors, based on the outputs obtained in the first years have developed some preliminary tables of pine nut production in grafted stonepine orchards. Gallego's tables of estimated production, for orchard densities of 400 and 500 stems per hectare, are reported in Table I. Lopes Barreira (1989) developed some preliminary production tables for the region of Alcacer do Sal (Portugal), in orchards of grafted stonepines (Table 2). This author considers an initial density of 625 grafted trees per hectare and some tree removal, after 12, 22 and 32 years, until reaching a final density of some 100 trees/ha. The estimated yields seem high, even for well managed orchards.

It is important to consider that during the first 15-20 years, grafts of stone pines behave like female individuals, only producing female flowers, and it takes more than 15 years for the first catkins to appear. This circumstance makes it necessary to plant next to mature stands that produce large amounts of pollen, to ensure good pollination, or resort to artificial pollination until the grafts produce enough pollen. This circumstance is especially significant when grafting on different pine species, as where these grafts are made, stonepine does not adapt well and consequently, it is very difficult to grow adult trees of this species in its environment. In these cases there always has to be artificial pollination or a wait of more than 20 years in order to harvest the first pine nuts.

The interest of growers in this crop is clear and there are some orchards of stonepine grafted on seedlings of the same species in several Portuguese and Spanish sites. There also are orchards with grafts on seedlings of *Pinus halepensis* Mill. (Catalan. 1996), sometimes in combination with other species. Near Madrid, in calcareous-loamy soils and with low rainfall, a mixed plantation of stonepine was made, grafted on Aleppo pine, in alternate lines with Lavandula, with the aim to get benefits from the year after plantation (Catalan and Catalan, 1996).

As soon as certified material for propagation is available, demand is expected to increase, and many new orchards would be planted. To extend this cultivation nurseries are needed which sell, at a reasonable price, grafted stonepines or experts looking after the grafting in situ. Stonepine grafting is a very specialized job which is out of reach for most farmers.

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CASHEWS: A NEW INDUSTRY FULL OF PROMISE

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Seven years ago, the crown land now home to Cashews Australia was on the extreme fringe of Atherton Tablelands farming country. When Peter Shearer took up the land near Dimbulah from the Queensland government, it was generally considered not to be worth any expensive development efforts. The only attractive feature was the water available from the Tinaroo Dam via the Mareeba-Dimbulah Irrigation Area.

But Mr Shearer was looking for a fresh challenge. He had succeeded in the retail clothing trade, developed businesses in Papua New Guinea, created a model macadamia plantation to the cast of Mareeba, Queensland. and was looking for something new.

After a lot of investigation and consideration, he decided to “give cashews a go”.

At the start

Interest in cashews and the potential of the crop for northern Australian conditions was developing during the mid to late eighties. Except for a couple of individual plantations that were being developed, there were no significant cashew orchards in Australia.

However, the Rural Industries Research and Development Corporation (RIRDC) as well as the Queensland Department of Primary Industry (QDPI) and the Northern Territory Department of Primary Industry and Fisheries were financing research into agronomy and the potential for cashews in Northern Australia.

The results of this early research had a significant influence on Mr. Shearer’s decision to invest in this totally new project.

Initial clearing of the Dimbulah property started in 1989. At the same time, just about all known cashew trees on the north-cast coast of Queensland were inspected and suitable plants were used as a source of propagation material for the new development.

Well-established trees existed on private properties and government research stations from Ingham to Cooktown. A major contribution to the early Dimbulah plantings was approximately 3300 hybrids bred by the CSIRO, grafted at the nursery stage and planted between July 1990 and June 1993. The QDPI and CSIRO have monitored these hybrid trees since they were established, and the most promising of these are now being used for supplying bud wood to graft onto seedlings both in the nursery and field planted.

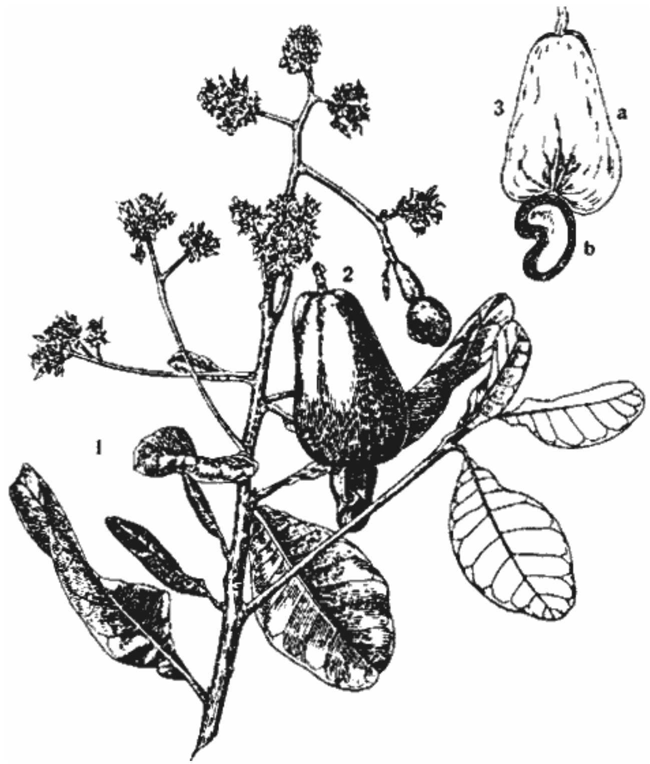
As well as the Australian-bred hybrids, other significant plantings have been made from seeds collected overseas by Mr. Shearer. These were selected from trees showing high yields of large nuts.

There are now about 55,000 trees planted on the Cashews Australia property. These vary in age from six years old to newly planted lines.

Because the commercial cashew business is still new to Australia, and a great deal is still to be learned about growing and processing the crop, the Cashews Australia property has become a virtual cashew-research station as well as a fast-developing farming enterprise.

Much learning has taken place since the first small tree was planted only a few years ago. Norm Butler has been manager of the cashew farm since day one. He was previously employed at Mr Shearer’s Big Macadamia Plantation, and even though cashews were new, growing trees by the thousand was not a daunting proposition. Like his boss, Mr. Butler looked forward to the challenge of the new venture.

The cashew apple fins out considerably during the last two weeks before it - and the attached nut - fall to the ground. The apples vary in colour from bright yellow to bright red and may be used in jam, jelly, syrup or wine.



The Cashew, Anacardium occidentale. From J J Ochse’s “Indische Vruchten

After about seven years involvement in the cashew business, Mr Shearer and Mr Butler discussed their situation. Some of their observations are listed below.

• *“Some promising cashew trees are starting to show up. Yield per hectare is the criteria to aim for, and not particularly yield per tree.”*

At present the tree spacings are six metres between trees in rows that are eight metres apart. If the yield currently being harvested from four-year-old trees continues to increase as expected, then totals of up to six tonnes per hectare are a possibility.

Considering a world production average yield of only 0.75 to 1 tonne per hectare, then this potential is an attractive proposition.

• *"Do not rip out young hybrid trees because they have failed to show promise during the first two or three years after planting out. Some young trees, due to be pushed out after a disappointing first couple of years, were left to be removed later. Fortunately, they soon improved dramatically, and were subsequently retained to show a lot of promise."*

Juvenile instability was the condition suggested as causing the initial poor performance. How many potentially good hybrids have been removed before they were properly assessed? Nobody win know.

• *"Start shaping the trees as soon as possible. Do not leave any growth below the graft. The sweepers need a clear passage to retrieve all the nuts under the whole tree canopy."*

Early shaping is best. Heavy and late pruning sets the tree back and should be avoided. A vase shape is ideal, with the single stem to a height of about one metre above the ground.

Botany of the cashew explained

Cashew (Anacardium occidentale) is a member of the family Anacardiaceae, which also indudes other agriculturally important plants such as mango (Mangifera indica) and pistachio nut (Pistacia vera). It is a tropical evergreen tree that produces kidney-shaped nuts suspended below a colourful swollen peduncle commonly called a cashew apple.

The apple is pear-shaped and varies in size, shape, and colour (yellow, through to red). Weight usually ranges from 15 - 200 grams, but extremes of 650 g do occur. It can be eaten raw or processed into a variety of products including juice, jelly, wine and chutney. It is very juicy, somewhat fibrous and has a very thin skin that bruises easily. Taste varies in sweetness and astringency according to the tannin content. The Vitamin C content is very high (200 milligrams/100 g), four times that of citrus.

The nut varies in size and shape as does the per cent of its components (shell, shell oil, testa and kernel). Weights up to 30 g occur, but they are more commonly 4-8 g.

The kemel contained within the shell and testa can be eaten cooked or raw. It is a highly nutritious food, being richer in protein than the equivalent weight of beef. Small or broken kernels may be used in confectionery or made into a butter similar to peanut paste. A high quality oil may be extracted from the kernel. Kernel weight commonly ranges from 25- 32% of the total nut weight.

The oil contained within the shell of the nut is known as cashew nut shell liquid (CNSL). It is pale yellow to dark brown in colour, has caustic properties and when heated gives off pungent choking fumes. People sensitive to the oil can, in worst cases develop acute dermatitis on areas of the skin coming in contact with the oil.

Care must therefore be taken during processing of the nut to prevent skin contact or contamination of the kernel. The oil constitutes 20-25% of the total nut weight.

More than 200 patents exist for different industrial uses of CNSL. It is mainly used in the production of brake linings of motor vehicles. Other uses include the manufacture of water and heat-proof paints, corrosion-resistant stove varnishes, insulating enamels for the electrical industry, waterproof emery paper and heavy duty grinding and cutting disks.

• *"If the flowering and fruiting can be controlled by water and fertiliser management, then some ofthe major problems currently encountered can be significantly reduced."*

While some trees do not have a pronounced flowering period, others flower all year round. This results in a prolonged and difficult-to-manage harvest period.

Ideally a concentrated fruit drop should occur at a time that allows the harvest to be completed before the wet sets in during late November.

• *"The biggest and most expensive problem is the inability to efficiently separate the nut from the apple at harvest ."*

When the apple and nut fall to the ground at maturity, the apple is juicy and bulky in comparison to the smaller hard nut. The nut is firmly attached to the apple and does not break off naturally.

The cashew apple fills out considerably during the last two weeks before it - and the attached nut - fall to the ground. The apples vary in colour from bright yellow to bright red and may be used in jam, jelly, syup or wine

Regular sweeping and harvesting is required to avoid any costly losses through spoilage on the ground. The harvested product is extremely difficult to handle and process after collection. It is damp and soggy, it does not flow or move easily, it is difficult to separate from unwanted trash, and it must be dried straight away.

The sequence of operations from harvest to shelling is as follows:

1. Harvested material is taken to shed.

2. Passed over a trash belt to take out as much rubbish as possible.

3. Put it into a series of dryers and dried for at least three days.

4. The nuts with dried apple skin attached are moved into a large holding silo.

5. After storage for up to a year the crop is removed from silo and cleaned yet again to remove all remaining loose sticks, trash and stones.

6. The latest and best of many machines that have been developed for removing the dried apple from the nut is then started up. This American machine has been modified by Cashews Australia, but is the best yet of a long line of hopeful prototypes that have been discarded to the scrap heap.

7. Into storage again, until a final separation before bagging, containering and off to China for shelling and testa removal.

Mr Shearer would like to be able to economically process his cashew crop in Australia. Unfortunately, as is the case with apple separation, there is no machine that can efficiently and properly shell the cashews and remove the unwanted testa (skin) from the shelled nut.

At the moment, India and Vietnam are competing with China to carry out this important process. Mr Shearer cannot see any possibility of this job being done in Australia in the next few years.

Value adding

At the Big Macadamia plantation to the east of Mareeba, a well-equipped processing factory has been developed to value-add macadamias and cashews.

As yields of nuts and demand for the finished product have increased, much larger and up to-date facility has been needed. The foundations of this new factory have been laid and it should be finished before the start of the 1996/97 wet season. A successful chain of small self-service 'hot nut bars' has been established in selected supermarkets. These sell premium quality kernels of a variety of nuts both separately and as mixtures.

Fertiliser research underway

Noel Grundon of the CSIRO is developing a method of establishing site-specific recommendations for fertilising cashew seedlings and young cashew trees. He is mainly concerned with phosphorus and potassium nutrition, but other important elements are also under investigation. Another segment of this project is looking specifically at the Zinc fertiliser requirements of the cashew.

Nitrogen fertiliser efficiency is important for all crops. This is especially so in the high temperature tropical situation of Dimbula. The nitrogen researeh is aiming to develop a site-specific soil-plant N budget for cashew trees that encompasses knowledge of tree water use, N requirements, efficiency of N uptake, and timing of application of N fertilisers.

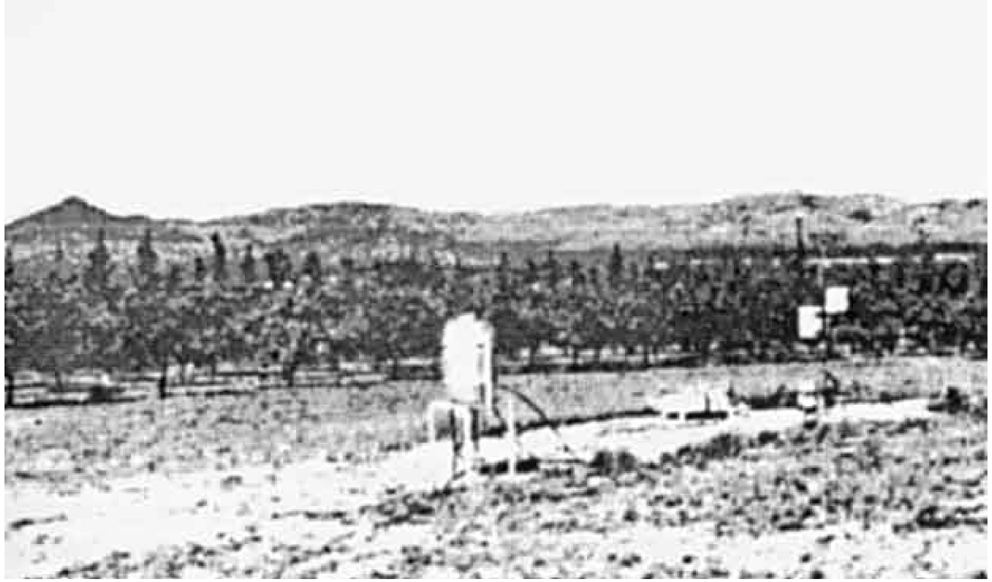
This study combines with Queensland Department of Primary Industry research into the N fertiliser of cashew trees. Pat O'Farrell leads the QDPI team looking at the effect of nitrogen on the growth and nut yield of established trees of a promising hybrid cultivar. The specific objectives of his experiment are as follows:

- *to describe an appropriate phenological growth model on which to base a management system;*
- *To understand the effect of N on vegetative and reproductive growth; and to develop a calibration system to guide N applications.*

1996 was only the second year of this trial, but some promising results are being obtained. The team is optimistic that an N-management system based on leaf sampling can be developed.

There are two rates of nitrogen being compared at three different application times, and despite the preliminay nature of the first-year data, some fascinating insights into the impact of N timing on vegetative and reproductive growth have been gained.

With the timing of nut harvest and rainfall being of such importance in cashew growing, the management of water and nutrition in the right variety should eventually make a significant contribution to the commercial success of the infant industry.



Researchers at the Cashews Australia plantation Dimbulah, Far North Queensland, established a weather station to help their investigalions. The hills in the background indicate the semi-arid nature of the country surrounding the property.

Machinery is installed at the factory to produce the high-value chocolate-coated nuts for both pre-packing on site and bulk supplies to other end-users.

A test unit has been established to develop recipes that will use up the very small nut chips that are an inevitable product of shelling and processing. (The cashew-nut biscuits and cheese cakes have been eagerly adopted by a major hotel chain as a house speciality.)

Small pre-packs are prepared at the value-adding factory, with some bearing the house brand name and special lines provided for any customer. A quality assurance standard is in place at the processing plant.

Established export markets for the Shearer macadamias exist in the Netherlands, Germany, Belgium, Taiwan and China for bulk nuts, with value-added product going to Singapore, Japan, Belgium and Korea.

As the yields of cashews increase and continuity of supply can be maintained, it is expected that some high quality cashew lines win be exported to these existing nut markets.

The future

Mr Shearer said the industry should be proud of the present stage of development.

"It is all open and cooperative with everyone helping and talking to everyone else. There is no cloak and dagger stuff like we found in the macadamia business when it began," he said.

"Within the next four years we should have about 75% of the answers we are currently researching. We should be beating the drum now and let people know what has been done and what is possible. To do this we must actively promote what has been achieved.

"The continuation of the hybrid breeding and evaluation program will have a major influence on the future of our Australian cashew industry. We must set up specific budwood nurseries to provide material for grafting and the increased planting of the best varieties.

"We are getting enquiries now from people who have land in potentially good cashew growing areas. I believe plantings of up to 1000 ha are the way to go. We must help with such developments. Finally, let us continue along the way we are, and work smarter, but not necessarily harder."

Efficient use of water needed for a healthy cashew crop

As tree numbers at Cashews Australia have increased in the past few years, and as the water requirement of the developing trees has also increased, the limited amount of water allocated to the properry from the Mareeba-Dimbulah Irrigation Scheme has all been booked for the existing trees.

Unless an increase in the allocation can be negotiated, the only way to build up tree numbers is to find another source of suitable water or use what is already available more efficiently. Dr Sam Blaikie and his research group from the CSIRO are showing that the latter option is a possibility.

Initial work carried out in the Northern Territory, and follow-up investigations under way at the Cashews Australia property, are showing that strategically placed drippers with a lower out put than under-tree sprinklers can reduce water usage per tree by upwards of 50%. The experiment has indicated that it is possible to greatly reduce the amount of irrigation water applied to cashew without affecting the potential yield of the crop.

It will need more than one season to verify this valuable work, but there is every indication that it will be possible to maintain a significant increase in total tree numbers while using only the currently allocated water supply.

The experiments at the Dimbulah property are mainly looking at the placement of the drippers and sprinklers in relation to the tree, the output of the different drippers and sprinklers under investigation, and the development of the root systems when grown under the various watering systems.

All those involved in the cashew business are following this line of investigation with keen interest. The findings will have a major influence on the future of this developing industry.

Based on an article appearing in Good Fruit and Vegetables

Good Fruit and Vegetables: <A 1382>

J K Consulting<A3320>

QUANDONG AND SANDALWOOD: ARID-LAND CROPS AT THE NECTARBROOK DISCOVERY PLANTATION

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Development started with a one hectare section in 1993 (A West) that was to be all Quandong but with the delay in supply of grafted trees and the subsequent discovery of sandalwood, another hectare (B West) was developed in 1995 and 1.2 hectares in 1997 (C East) This 3.2 hectares of over two thousand trees must be seen as an experiment in the establishment of four potential future managed crops for the arid lands of Australia.

Experiment 1: The Quandong (*Santalum acuminatum*)

Initially this plantation (A West) was to be all grafted Powell-1 Quandongs (A West 2) and 300 trees at $20 each were ordered in 1993. Over 1994 and 1995 one third were supplied and we were able to get 60 of these to grow on. This may be a poor result with trees from this source.

Twenty-five seedlings (B West 2) from the best tree in our country (Nectarville) from a population base of over three hundred trees were planted.

Twenty-five purchased seedlings (B West 3) from N. Sargent at Gladstone were planted (Sargent). The seed was sourced from two good trees in the town of Gladstone.

The extreme variation between these seedling trees encouraged us to look for a Quandong population in which all the trees produced good fruit. This we may have found on the North end of Nonning Station. Two hundred seedlings (Nonning) were propagated from this tree and ninety (A West 5) are in the plantation. The balance were sold, but are available for assessment.

Conclusions

Grafted trees, presented as the Powell-1s were, are, difficult to establish. All the losses we attribute to root disease that came with the trees.

With the seedling trees from all sources we have achieved better than ninety eight percent establishment. It is too soon to categorically state that seeds from an isolated Quandong population in which all the trees are good will produce seedlings that are equally as good, however the limited amount of fruit from the Nonning seedlings suggest that this may be possible. If this is correct, careful selection of seed from the wild will allow the Quandong industry to develop faster.

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§ Member, WANATCA

Visitors will note the extreme variation of fruit and tree shape between the Nectarville trees, even though they were all from our best tree (B West 2), and the more even shape and habit of the Nonning seedlings (A West 5).

Experiment 2: Australian sandalwood (*Santalum spicatum*)

The sandalwood is now the purpose of this plantation, with one thousand trees up to five years old from as many distinct plant populations we could find in Australia. The names we have given to the various plant populations are for identification only and only reflect the general area of seed collection. Researching quandong led us to sandalwood. Sandalwood seemed too good to be true, an arid land plant with an existing export market, collected and sold for over the last one hundred years, with a continuing up trend in value for all that time.

The cultivars in trial are :- South Australian: Wandearah (C East 17): Bookaloo (B West 3) Nonning (B West 12): Nunjikompita (B West 14): Nectarville.

West Australian :- Eucla (C East 6): Gold Fields (C East 15): Gascoyne (B West 6): Nanga (C East 9): Shark Bay (C East 5): Pilbara (A West 4).

There is considerable diversity in leaf shape and growth habit with plants from each area. From this we hope, in the future, to select the most suitable cultivar for irrigated managed plantations.

The type code named "Eucla" (C East 6) has a red skinned, yellow fleshed edible fruit and the timber is high in sandalwood oil. This may be an as yet unnamed subspecies of *Santalum*.

Another area of interest is the nuts from these trees. The nuts are excellent eating and we feel they have a future as a nut crop. In addition recent research has shown that there is a range of important pharmaceuticals in the nut, including an anti-inflammatory, an anti-carcinogenic, and an anti-oxidant.

Conclusions

We made many mistakes in the first years with this experiment but with the plantation section "C East" we feel that we have overcome the problems. Here we have achieved germination rates of 90+ % and plantation establishment rates of 96%.

There are unknowns. How long to harvestable timber? Will growth rates be able to be maintained with the host trees we have? Will there be a market in the future?

Looking to the future optimistically and calculating on the basis of 'best case scenario', this plantation is a million dollar exercise!

Visitors remark on the appearance of sandalwood trees with a vigorous *Myoporum* under them, in comparison to those without.

Experiment 3: Tropical sandalwood (*Santalulm album*)

The first 15 trees in row (C East 2) are tropicals. The seed was sourced from Mysore, India with the help of Diana Barrett of Curtin University, WA. The balance of this row is Plum bush (*Santalum lanceolatum*). The tropical sandalwood, with a value of double the Australian sandalwood, have grown so well we feel that in a frost free area with plentiful water they could be an important crop. Further trials are under way with 40 more seedlings to plant out this spring.

Experiment 4: Blue Bush (*Maireana sedifolia*)

Over one thousand five hundred blue bush have been interplanted with the Santalums as host plants as well as in the hope of finding a commercial cultivar. Israel has been commercially growing Blue Bush for the Amsterdam Flower markets for some time, and earning millions of dollars from the commercial exploitation of this Australian plant. To get the long spikes necessary for a cut foliage from this plant they grow it under shade and apply growth hormones.

We have found one plant in the wild that spikes naturally and we are now propagating by cuttings to establish a commercial planting.

Statistics

Water: Seven kilometres of dripper pipe from three manifolds water the plantation.

Watering is initiated by Irrometer sensing of soil moisture and controlled by a 'Boss' solar powered water control computer. The water supply is ground water delivered through the old Nectar Brook reticulation system. The water is mineralised with sodium, calcium and magnesium to 2,300 ppm.

Soil: From heavy red clay to clay loams, low fertility, with a pH of 8.5 to 9.

Preparation: The area was cleared and stone-picked. Tree lines were deep ripped prior to planting. Gypsum at the rate of two tonnes to the hectare was spread over the A and B area.

Host plants: Trees: Acacia (*A. victoriae, A. peuce, A. iteaphylla*). Casuarina, Mulberry., Pistachio, Jujube (*Ziziphus jujuba*), White cedar (*Melia azedarach*), Olive (root stock only), kurrajong.

Host plants: Shrubs: Blue Bush (*Maireana sedifolia*), Old man salt bush (*Atriplex nummularia*).

Host plant: Ground cover : Creeping Boobialla (*Myoporum parvifolium*).

Conclusions

Host plants need to be surface rooted and store both water and nutrient in these roots. The osmotic pressure of the host plant must be high enough to resist the Santalum but not too high. In *Acacia iteaphylla* the osmotic pressure is too low, in *Atriplex nummularia* it could be too high.

Based on material from an Australian Quandong Industry Association field day during the 1999 AQIA Conference at Port Augusta.

Australian Quandong Industry Association: <A 1645>

THE ROLE OF POLLINATION IN LYCHEE FRUIT PRODUCTION

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Unknown in the wild, the Litchi, or Lychee, tree (*Litchi chinensis* Sonn., family Sapindaceae) is native to southern China and southeastern Asia where it has been widely cultivated for its prized fruit for over 3000 years. It is considered the most important fruit species in the Sapindaceae.

The fruit consists of a single seed covered by a sweet-acid, crisp, white, juicy, translucent aril or pulp, which is high in vitamin C. It may be eaten fresh, frozen, canned in syrup, or dried to produce 'litchi nuts.'

Lychee trees differ greatly in growth habit among varieties: Trees may have erect or drooping branches and grow from 6 to more than 12 metres in height. They make beautiful landscape specimens with their dark-green leaves and bright red fruit. These dense, symmetrical, oval evergreen trees with their dark brown, short, thick trunks may live for centuries. Two trees in China are said to be 1,200 years old, the largest having a trunk that is 3.2 metres in diameter.

Lychee is adapted to areas of the tropics and warm subtropics with cool, dry winters and warm, wet summers. It thrives in subtropical climates at higher altitudes in acidic loamy soil with abundant moisture. It will grow about anywhere citrus will grow, but young plants are extremely sensitive to cold and require cold protection. Mature trees can tolerate a few degrees of frost.

Commercial cultivars are geographically adapted and number over 100 worldwide.

Lychee can be propagated by seed, grafting and air layering. The last method is most preferred as the trees thus produced begin to bear in from 3-5 years.

Well-managed mature lychee orchards, usually 20 to 50 trees per acre, can produce as much as 18 tonnes of fruit per acre in a good year: A 4-year-old tree will produce 1-1.5 kg of fruit, while a 12-year-old tree will yield in excess of 135 kg. A maximum yield of 450 kg for a single tree in Asia has been recorded. The round fruit, a drupe about the size of a large strawberry, is pendant in a loose cluster (up to 75 cm long) of several dozen fruits. The leathery skin is covered with sharp-tipped tubercles and the seeds are dark brown. The fruit must ripen on the tree, then is harvested over a six-week period. The shelf life of the fresh fruit is only 10 to 14 days.

Lychee is grown commercially in California, Florida and Hawaii. However, yields are commonly unreliable and erratic and rarely approach the capacity of the tree. Lychee was introduced into Hawaii in 1873, Florida in the 1870s, and California in 1897. In Florida, it remained only a novelty until 1940 when an association of growers was formed and some 100 to 120 hectares were cultivated. In 1996, Florida had more than 200 ha producing barely 3200 kg of lychee per hectare. Thirty of 90 cultivated hectares were harvested producing only 1732 kg of fruit per hectare in Hawaii in 1997. Lychee production in California is limited and confined to southern coastal areas.

The Lychee, Litchi chinensis [from J J Ochse's 'Indische Vruchten']

Inflorescence

The inflorescence consists of small, white to greenish-yellow flowers on the current season's wood in terminal clusters (panicles), a foot or more in length. They are present from mid February through March. The flowers have sepals but no petals, about eight stamens, a two-lobed stigma, an ovary on a short stalk, and one ovule in each of its two or three sections (carpels). Three types of flowers bloom in stages: Male or staminate flowers (M1) with no functional ovaries bloom first; female or functionally pistillate flowers (F) with anthers that do not dehisce constitute the second stage; and imperfect hermaphrodite flowers (M2), also lacking functional ovaries, bloom last. Each phase of bloom consists of flowers of the same type. F flowers comprise approximately one-third of all flowers produced.

The onset and duration of anthesis (bloom) are highly variable among cultivars. Lychee flowers open throughout the day, but mostly before 0600 h. Anthers dehisce continuously throughout days 2-5 of bloom reaching a zenith around 1000 h each day. The fruit-bearing flowers in at least one cultivar (Mauritius) studied are normally receptive on days 2-5 following anthesis, although the bloom period may be significantly reduced when ambient temperatures are high. Fruit set occurs when pollen, primarily from M2 flowers, is transferred to F flowers. The respective stages of bloom overlap between panicles and trees, but rarely overlap within individual panicles. There is considerable variability in the number of F flowers per panicle (10-60%); cultivars with the greatest number of F flowers per panicle produce the highest yields. The duration of flowering is 20-45 days.

Floral aroma has been described as "not particularly pleasant." A nectary occurs on every flower as a large fleshy crenulate gland within a cup-shaped calyx and to which the stamens and pistils are inserted. Nectar, secreted only in the morning, is particularly attractive to honey bees and flies. Nectar production is highest at 0600 h, while honey bee foraging peaks in mid morning with the F flowers being most attractive, followed by M2 and M1 flowers respectively. Nectar volume per flower is highest in F flowers followed by M2 and M1 flowers. Size of the nectary and nectar sugar concentration follow a similar pattern. There are no significant differences in sugar (fructose, glucose and sucrose) ratios among the three flower types.

Pollen produced by the M2 flowers is most viable. The amount of pollen on individual foraging bees is two orders of magnitude greater on bees foraging on M2 and F flowers. Corresponding pollination rates are lowest (0-20%) during the M1 and F bloom periods and highest (80-90%) with the onset of the M2 bloom. Lychee pollen seems unattractive to wild bees.

Fruit set in Lychee is climate dependent and profoundly affected by temperature and humidity. Fruit set is also affected by cultivar, age of tree, soil conditions including fertilizer regimes, and cropping practices. Winter/spring temperature extremes affecting bloom phenology and unsettled weather affecting bee flight during bloom have been further identified as causes of reproductive failure. In some years, isolated trees produce few, or only male flowers and, as a result, little or no fruit is set. Fruit set varies greatly within panicles, and ranges from 1-50 percent of the F flowers produced. Yields can be improved through the use of better-adapted varieties and management methods to retard growth and induce flowering, as well as by pollination.

Pollination Requirements

Lychee F flowers are self-sterile and require insects, usually honey bees, to transport pollen from anthers to stigmas for fruit set. Fruit does not set on bagged panicles or on trees caged to exclude insect pollination. Early studies have suggested that Lychee is self-fruitful and that interplanting of compatible cultivars may not be required. However, abscission of fruitlets resulting from self-pollination occurs at high rates in some cultivars, resulting in high levels of hybrid fruit (76-95%) at maturity. Moreover, hybrid fruit are heavier and have larger seeds. Recent studies have shown that yields with two cultivars adjacent to each other are higher than at greater distances from the pollenizer.

Pollinators

Honey bees (*Apis mellifera* L) are the principal pollinators of Lychee. They forage primarily between 0600 and 1200 h, although foraging continues later in the day at much lower levels. Flies, ants, wasps, beetles, and other bugs have been noted among insect visitors to Lychee flowers. No wild bees have been seen on Lychee blossoms even when present foraging among flowers of other plant species nearby. In India, honey bees comprise 98-99% of all floral visitors and are considered the most outstanding beneficial insects on Lychee. Here the value of the honey bee in the setting of Lychee fruit is considered obvious. When Lychee trees are plentiful, honey bees gather immense quantities of high-quality nectar. In Thailand, *A. cerana* is the preferred species for small-scale pollination of Lychee.

Pollination Recommendations and Practices

Although no specific number of colonies per unit of Lychee has been recommended, supplying honey bees in Lychee orchards is important and practical for assuring adequate pollination and fruit set. The bees should be present continuously throughout bloom. In the absence of more definitive data, strong (>8 frames with bees and brood) colonies should be provided at a minimal rate of 2.5 per hectare.

There is an obvious advantage to cross-pollination since the resulting fruitlets from cross pollination have better survival rates, are heavier and contain heavier seeds. Even though Lychee cultivars differ in their responses to cross- vs. self-pollination, interplanting can greatly improve yields in cultivars that benefit from cross-pollination. Since there is only a partial overlapping of F and M2 flowers within a single Lychee cultivar, interplanting of two or more cultivars provides optimal overlap of floral stages and ensures maximum yield potential.

Clearly, honey bee colonies can produce a substantial surplus honey crop in Lychee stands. Unfortunately, there is little information regarding the quality of Lychee honey, the extent to which honey bees gather Lychee pollen, or its nutritive value for brood rearing. While honey bees gather Lychee pollen, it appears that Lychee does not compete well with other plants as a pollen resource for honey bees. Further definitive research is needed before more meaningful recommendations for honey bee management strategies for Lychee can be made.

Further information

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Based on an article in *Fruit Gardener* (California Rare Fruit Growers), Sep/Oct 1999.

Metric conversions by the Tree Crops Centre.

Carl Hayden Bee Research Center (USDA-ARS): <A3299>

California Rare Fruit Growers: <A 1115>

AUSTRALIAN NATIVE RASPBERRIES

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Raspberries (and Blackberries) belong to the vast genus *Rubus* in the family *Ro*saceae. *Rubus* species are found all over the world, but especially in the northern hemisphere.

The centres of diversity for *Rubus* appear to be Europe, Asia and North America. China, for instance, has around 100 species; the tiny country of Bhutan has 41 species; Indonesia has 40 species. In Australia, there are just eight indigenous species and one hybrid of *Rubus*.

Broadly speaking, raspberries are red-fruited and blackberries (naturally enough) have black fruit, and they belong to different subgenera in *Rubus*. Australia has no indigenous blackberries, but we have inherited quite a few from other countries, notably the common blackberry (*R. fruticosus* agg.) from Europe which is rampant in many parts of southern Australia. All *Rubus* species, as far as I know, have edible fruits, but there is a lot of variation between species in their flavour and succulence.

Queensland is the stronghold for Australian *Rubus* species. This is probably because Queensland has most of the rainforest, and *Rubus* characteristically grow in rainforest or on rainforest edges. However, the widespread *R. parvifolius* grows in eucalypt woodland, well away from the rainforest. Another notable feature of *Rubus* species are their very prickly stems and even leaves. There is again an exception, as *R. gunnianus* from Tasmania is totally without prickles.

My recent taxonomic studies into *Rubus* have resulted in the naming of a couple of new taxa, and regrettably, a few name changes. Here is a summary of raspberry species occurring in Queensland.

1. *Rubus probus* - a pinnate leaved species, with 5-petalled flowers and bright red fruits which are considerably broader than they are long. It is widespread in Queensland, from Helidon Hills to Cooktown, and also in New Guinea. It was named in 1923, strangely enough, from Puerto Rico, where it is naturalised.

Apparently, seeds were sent to the USA in the early part of this century and then distributed. It obviously thrived in Puerto Rico. *R. probus* was previously known by the name of *R. fraxinifolius*, but that species occurs only in south-east Asia and Indonesia. A photograph of *R. probus* appears in 'Australian Plants' Volume 18, page 76, but labelled as *R. rosifolius*.

2. *Rubus rosifolius* - a pinnate leaved species. The red fruits are somewhat conical in shape, longer than they are wide. It is very widespread, extending from China and Taiwan to southern Australia. In Queensland it occurs from the NSW border to as far north as Kroombit Tops. It is photographed in Keith Williams' Native Plants of Queensland, Volume 3, p. 274. There are two varieties, which look identical, but differ in the number of petals; var. *rosifolius* has 5 petals and var. *commersonii* has 9-13 petals.

Rubus fraxinifolius [From J J Ochse's 'Indische Vruchten']

3. *Rubus queenslandicus* - a pinnate leaved species which is closely related to *R. rosifolius*, but differs by the hairless stems and leaves, the longer stalks on the leaflets, the sparse cover of glands on the leaves, and the hairy petals. It has red fruits, rather dry in texture. It is endemic to coastal ranges of north Queensland, especially the Atherton Tableland.

4. *Rubus parvifolius* - a small species which is often quite prostrate, but can form a shrub to 90 cm high. The leaves are generally trifoliate, but sometimes have 5 leaflets, and the red fruits, while rather small, are very succulent and tasty. *R. parvifolius* occurs in Japan, southern China, and North Vietnam, and throughout south-eastern Australia. In Queensland it is distributed from the NSW border to Eungella National Park near Mackay.

5. *Rubus moorei* (Silky Bramble) - this palmate leaved species (like spokes of a wheel), is a vine which scrambles over rainforest vegetation and can reach tree canopy height. It is dioecious, which means that there are separate male and female plants. The fruits, which are borne in summer, are succulent and black at maturity. It is relatively restricted in distribution, from Lismore to the Conondale Ranges, but it is quite common around O'Reillys and adjacent areas of Lamington National Park. *R. moorei* is photographed in Keith Williams' Native Plants of Queensland, Volume 3, p. 274.

6. *Rubus nebulosus* (Green-leaved Bramble) - another palmate leaved species. Like *R. moorei*, it is a dioecious vine which can reach canopy height. The fruits are borne in the summer. It is easily distinguished from *R. moorei* by the longer, virtually glabrous leaflets. It is widespread in NSW, but in Queensland is confined to the high altitude areas near the border. It is most readily seen at Springbrook, where it often grows adjacent to *R. moorei*. As this species was only recently named, it was referred to in the Flora of NSW as *Rubus* sp. A, and illustrated in Nicholson's Rainforest Plants Volume 4, page 61, again as *Rubus* sp. A.

7. *Rubus ellipticus* - a trifoliate species with long arching canes bearing red bristles. The fruits are bright yellow, and fairly succulent and tasty. It is an introduced species which comes from India, Sri Lanka, south-east Asia and the Philippines. Seeds were sent to Brisbane (from India) in 1891, and these were distributed to various parts of the state. It first became naturalised at Eumundi, and now is quite common on the Blackall Range. While it is a weed, it never forms large thickets and does not seem too serious.

8. *Rubus alceifolius* - a vigorous shrubby - vine or sprawling shrub up to 4 metres high, with simple 5-7 lobed leaves, with all lobes more or less equal. The fruits are red and succulent. It is a naturalised weed which is a problem at low altitudes in the Wet Tropics of north Queensland. It is indigenous to south-east Asia and the western parts of Indonesia. It is illustrated in Noxious Weeds of Australia (1992) p. 576.

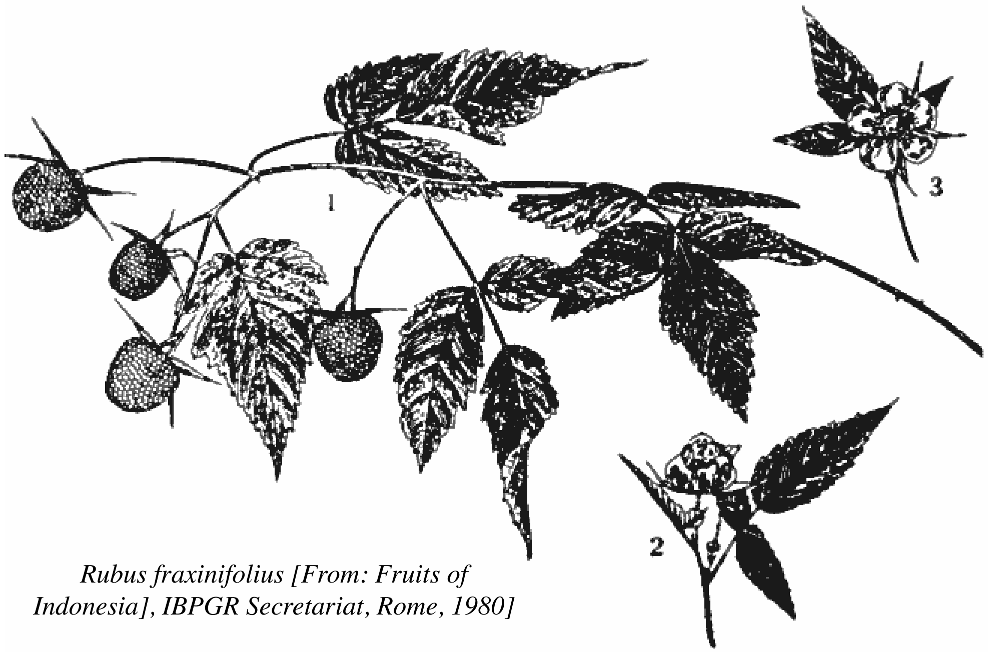
9. *Rubus moluccanus* - a simple leaved species which forms a scrambling shrub to 3 metres high. It is a native species, but its natural range extends far beyond Australia into southeast Asia. There are five taxonomic varieties, of which two occur in Queensland:

moluccanus var. *moluccanus* has a shallowly lobed leaf, white petals, and erect brown to yellow hairs on the leaf stalks and branchlets. This variety is common in north Queensland, but does occur sporadically in the south, at low altitudes. It includes *moluccanus* var. *dendrocharis*, a name which has appeared in some books in recent years.

moluccanus var. *trilobus* has a distinctly 3-lobed leaf, mostly pink petals and appressed greyish hairs on the leaf stalks and branchlets. This variety is common in New South Wales and extends into eastern Victoria. In Queensland, it is mainly in the south, but does extend to the Atherton Tableland. It was formerly (incorrectly) known as *R. hillii*.

The fruits of both varieties are red, succulent and tasty.

10. *Rubus* x *novus* - this is a naturally occurring hybrid between *R. moluccanus* var. *trilobus* and *R. parvifolius*. The 'x' in front of the species epithet indicates that it is a hybrid. It is usually trifoliate, with leaflets much larger than *R. parvifolius*. The flowers are pink. Interestingly, this hybrid is sterile - it never sets fruit. This explains why it is not terribly common. It occurs very sporadically from eastern Victoria to near Sarina in central Queensland,



Rubus fraxinifolius [From: Fruits of Indonesia], IBPGR Secretariat, Rome, 1980]

and could be expected to occur wherever the two parents are growing in close proximity.

Why not try growing a *Rubus* or two? Admittedly, they are not ideal for beside the driveway or where young children play, but they would make a good hedge or fill in a sunny hole in your rainforest planting.

They are readily propagated by cuttings and I have observed layering on *R. moluccanus* var. *trilobus*, where a branch has lain on the ground and struck root. I have not tried raising them from seed, and I suspect they may take a long while to germinate as the seeds are enclosed by a very hard case, as those of you who like blackberry jam will know.

All *Rubus* are light loving, and will flower and fruit best in full sun. On the down side, they have quite a high water requirement, so unless you live near the coast, they will need supplementary water (except *R. parvifolius*, which is quite drought tolerant); and they don't like poorly drained soil. They do respond well to pruning, so could be made to fit the space you have available, and the big bonus of course is that they will bear edible fruit for you.

Based on an article which appeared in SGAP (Society for Growing Australian Plants), Queensland Region Bulletin, March 1999.

Queensland Herbarium: <A3321 >;

Society for Growing Australian Plants <A 1030>

THE HICKORIES

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Introduction

The hickories, *Carya* species, are closely related to walnuts (both are members of the family Juglandaceae), and like them are usually large deciduous trees which can live to a great age, 4-500 years, which tend to form upright cylindrical crowns when grown in the open. They have alternate pinnate leaves each with 3-17 leaflets. Male flowers are borne in catkins and female flowers in spikes, to be followed by large fruits consisting of a single nut surrounded by a leathery skin (or outer shell) which splits open at maturity. The foliage is aromatic. All species have pronounced taproots which securely anchor the trees if soil conditions allow. Hickories can easily be confused (especially by leaf) with walnuts: differences are that young shoots have non-chambered pith, and the nuts are smooth-shelled.

Some 14 species of *Carya* are found in Eastern North America (plus at least 12 interspecific hybrids), and a further 6 in China. The nuts, which are of comparable sizes to walnuts, are rich in oils and edible from most, though not all, of the species. The better ones have a rich walnut-like flavour. Most nuts are hard shelled, like black walnuts. Breeding work has been done on some species, especially the pecan (*Carya illinoinensis*), with good fruiting varieties available, often with thinner shelled nuts.

Cultivation

The limitations to economically feasible orchard establishment of hickories are the long period of juvenility (over 10 years until trees start to crop), low yields (often 22-45 kg per tree, once every 2-3 years), and large tree size. They are better suited to low input, sustainable agricultural systems, where the long-lived multifunctional trees are a valuable resource for food, fuel and high quality timber.

Most species are quite hardy, but young plants are sometimes damaged by late spring frosts. All hickories prefer a climate with hot summers, and they need a position in sun but with shelter from strong winds in Britain. The most promising species for nut production in Britain are (in order of merit) *C. ovata. C. tomentosa, C. ovalis, C. glabra, C. cordiformis* (not edible!)

Hickories prefer a good fertile soil, preferably a deep moisture-retentive loam, though they tolerate both light and heavy soils, and acid and alkaline conditions. Transplanting should be undertaken with care because of the long fleshy tap root: for their first few years, young trees form a taproot with only a few lateral feeder roots, and this taproot is usually longer and thicker than the above-ground stem. If buying or raising plants, either grow them in open-bottomed containers that air-prune the tap root, or undercut the taproot (at 20-25 cm below ground level) at least a year before transplanting. They are very slow growing for the first 5 years or so, but then make good growth; planting in tree shelters may be advantageous. Hickories become large trees in time, requiring 6-12 m of space, so plant at wide spacing and use the ground between to intercrop for several years.

§ Member, WANATCA

The Pecan, Carya illinoinensis

The flowers are wind pollinated, produced in April-May. Although all species are monoecious (bearing both male and female flowers) and self-fertile, like walnuts very often the male and female flowers are borne at different times and the overlap is not always sufficient for good pollination (a tree may be protandrous, shedding pollen before the female flowers mature - or protogynous, female flowers maturing before the pollen is shed). Better crops are thus produced when cross pollination takes place between different tree selections. Like walnuts, large trees will pollinate 2-3 trees away. Different species may also cross pollinate. Male flowers are produced on slender, drooping catkins which arise from lateral buds; female flowers are borne in a spike at the end of the current season's shoot.

In the wild, large crops are normally borne every 2-3 years, and biennial cropping is common in cultivated trees - this is regarded as a major problem in the pecan industry. In Britain, most species bear fruit only after a hot summer. The fruit ripens and falls in the autumn; the outer husk (outer shell) splits along sutures and either releases the hard-shelled nut or falls still encasing the nut. Most hickory seedlings from named varieties start to fruit about 10-12 years from seed; precocious cultivars start fruiting in 5-7 years. Seedlings from wild trees can take 20-40 years to crop.

Hickories are late to leaf out - usually late May or June in Britain - and relatively early to drop their leaves in autumn - October in Britain. There is thus good potential for growing an undercrop, particularly one which is cropped in late spring. When in leaf they cast a relatively heavy shade.

All hickories are resistant to honey fungus (*Armillaria mellea*). Outside of North America, there are few pests and diseases. Squirrels are a serious hickory and pecan pest and have to be controlled where these are grown. Hickories, like walnuts, contain juglone in the leaves (and probably the roots too); this substance can have detrimental effects on some other plants, such as apples and the white pines.

Grafting of hickories, like walnuts, is difficult, but remains the only way of propagating named selections at present. Rootstocks used are normally seedlings of the same species (or one of the parents), which make strong graft unions. Grafting onto other species has variable results, but grafting pecan onto a hardier species rootstock (e.g. *C. cordiformis* has been used) may improve its performance in cool areas.

Seeds of most species require 3 months of cold stratification before germination will take place. Seeds from named cultivars have a high chance of being good productive, precocious trees themselves, but such seeds are difficult to acquire outside of North America.

Uses

Edible nuts (i.e. from most species) have a sweet kernel contained within a shell varying in thickness from species to species and within the species also. Thick-shelled species are difficult to crack and may contain kernels weighing only 20% of the total nut. The kernels can be eaten raw, like other nuts, and can also be made into an oily 'hickory milk' used like butter, and ground into a flour and used in breads etc.

Kernels are rich in oils and resemble walnuts in richness of flavour. Pecan kernels typically contain 3.4% water, 71.2% fat (687 calories/100g), 9.2% protein, 14.6% carbohydrate, 2.3% fibre, and are high in phosphorus, potassium, Vitamins A, B-complex, C and E; the oil is 93% unsaturated. Hickory nuts (probably *C. ovata*) are listed in Howes with the following composition: 3.7% water, 67.4% fat, 15.4% protein, 11.4% carbohydrate. Both of these breakdowns are very similar to that for walnut (*Juglans regia*).

An edible oil can be extracted from the species with edible nuts, of good quality and suitable for any culinary uses. The oil is also used in making paints in China and has been used for oil lamps and medicinally for rheumatism.

Several (probably all) species can be tapped for the sap, which is concentrated to make a syrup like maple syrup, or made into a wine etc.

The shells are used for making activated charcoal in China.

The wood of hickories is well known for its strength and resilience and is excellent for tool handles (hammers, picks, axes etc.). The heartwood is brown or reddish-brown and sold as 'red hickory', and the sapwood is sold separately as 'white hickory'. The wood is straight grained, coarse textured, heavy (820 kg/m^3), with high bending and crushing strength, stiff and highly shock resistant, with excellent steam bending properties. High quality timber is used for the manufacture of skis, gymnastic bars, and other athletic equipment (golf club shafts, lacrosse sticks, tennis racquets, basketball bats, longbows) and as a flooring material for gymnasiums, roller skate rinks and ballrooms.

Some wood is used in making furniture, in piano construction, for butchers' blocks, wall panelling and interior trim, dowels, ladder rungs and pallets, heavy sea fishing rods, drum sticks, wheel spokes and vehicle bodies. It makes excellent firewood and charcoal, and is used in the smoking of meats and cheeses. Note that the wood of *C. aquatica, C. cordiformis* and *C. myristiciformis* is considered inferior to other hickories.

The bark of the shagbark, *C. ovata*, has an antifeedant action on the Elm bark beetle, *Scolytus multistriatles*, which spreads Dutch elm disease.

Several species have been used in traditional medicine: a bark tea of *C. cordiformis* was used by the Fox Indians for bowel and urinary problems; the Comanche used pecan leaves for ringworm; the Kiowa used a bark decoction for tuberculosis; and the Cherokee used several species for colds, polio and female complaints and used the bark for cuts; the Delaware for debility and female ailments; and the Iroquois for arthritis and worms. Several of the Asiatic species have also been used medicinally.

A yellow dye is obtained by using the bark of several species with an alum mordant, including *C. carolinae-septentrionalis*, *C. cathayensis, C. cordiformis, C. glabra, C. laciniosa, C. myristiciformis, C. ovalis, C. ovata, C. pallida, C. texalla* and *C.tomentosa*. Other dyes are obtained from the leaves (eg. of *C. tomentosa*), and the fruit husks (eg. of *C. illinoinensis*).

Species and cultivars

Cultivars which are underlined are currently commercially available from North American nurseries. Many of the older cultivars have probably been lost.

C. aquatica - Water hickory. SE USA (esp. Mississippi valley).

Medium or large sized tree up to 20 m high. Has light brown bark, peeling in long thin plates. Leaves with 7-13 leaflets, each 8-12 cm long. Fruits ovate, 3-4 cm long and wide, in groups of 3-4; nut flattened, 4-sided, reddish-brown, thin shelled, somewhat wrinkled, kernel bitter and astringent - not very edible (though it has been eaten). Hardy to zone 6 (-20° C). Starts bearing in about 20 years. This hickory can tolerate wetter sites and more poorly drained clay soils than any other.

C. x brownii (*C. cordiformis x C. illinoinensis*) - American hybrid.

Very similar to *C. illinoinensis,* but with 9-11 leaflets; fruit more ovate, nut flattened and 3-4 cm long; kernels may be astringent or sweet. Hardy to zone 6 (-20°C). Several named cultivars of this cross exist, including:

Galloway (sweet), Jay Underwood (a cross with *C. laciniosa*), Mall, Nelson, Pleas (astringent, medium size nut, 54% kernel, protogynous, good in N), Pooshee, Westbrook.

C. carolinae-septentrionalis (Syn. *C. ovata* var. *c.-s.*) - Southern shagbark hickory. Very similar to *C. ovata*, growing to 20 m. More tolerant of alkaline soils than *C. ovata*, Hardy to zone 6 (-20°C). Named cultivars include:

Grainger (reasonable producer, nuts crack easily - small nuts poorly filled in Canada), Guilford, Nugget.

C. cathayensis - Chinese hickory, Mountain hickory. Eastern & Southern China. Medium or large tree to 20 m high. Leaves with 5-7 leaflets, each 10-14 cm long; fruits 4- winged, nuts round-ovoid, thin shelled (1 mm), somewhat 4-sided, 25 mm long, kernel sweet and edible, with a good flavour. Hardy to zone 6 (-20°C). Cultivated as a nut tree in China; the nuts produce a fragrant oil used in foods and in making paint, while the shells are used to make activated charcoal. The timber is used for building. Trees are grown at densities of 225/ha and mature trees typically yield 450-750 kg/ha. The variety *dabishanensis* (which may be a separate species) is probably hardier and has larger fruits.

C.* x *collina (*C. texana x C. tomentosa*) - hybrid.

C. cordiformis (Syns. *C. amara, C. minima*) - Bitternut hickory. Eastern N. America (esp. river valleys).

Large, fast-growing tree to 30 m high with thin scaly bark. Leaves with 5-9 (usually 9) leaflets, each 8-15 cm long; fruit round, 2-4 cm across, 4-sided; nut ovate to heart-shaped, to 3 cm long, flattened, very thin-shelled, grey, smooth, pointed; kernel bitter and astringent -not edible. Hardy to zone 5 (-23°C).

Grows very well in Britain, probably the best hickory here, but unfortunately the nuts are not edible! It also has inferior timber. Two named cultivars have been selected for their very thin shelled nuts: Halesite (69% kernel), Hatch (65% kernel). This species shows some promise as a cold-hardy pecan rootstock.

C. cordiformis* x *C. tomentosa - hybrid. Represented by the cultivar: Siers.

***C.* x *demareei* (*C. cordiformis* x *C. ovalis*)** - hybrid.

***C.* x *dunbarii* (*C. laciniosa* x *C. ovala*)** hybrid. Cultivars include:

Abundance (nuts medium-large (7 g), cracks well, kernel 36%. Precocious, regular bearer; good potential in Northern locations), Beam (50% kernel), Fluhr, Roddy, Stauffer (good potential for Northern locations grown in Canada), Weiker, Yoder No.1 (often listed under *C. ovata*, but more likely to belong here. A well-known old cultivar; nuts are medium-sized, thin shelled, cracks well and yields 40% kernel; excellent flavour. Good precocious bearer. Good potential in Northern locations), Zimmerman.

C. floridana - Scrub hickory. USA (Florida).

Very variable, from a multi-trunked shrub bearing fruit on stems 1 m (3 ft) high, to a large tree to 20 m (70 ft) high, very similar to *C. texana*. Nuts to 3 cm long, with thick shells; kernels sweet and edible. May only be hardy to zone 9 (-5°C).

C. glabra (Syn. *C. porcina*) - Pignut hickory. Eastern USA (esp. dry fertile slopes). Medium or large tree, to 20-30 m high with finely grooved, dark grey bark. Leaves with 3-7 leaflets, each 8-15 cm long, the lowest pair smaller. Fruit round or pear-shape, with slight wings near tip; nuts 25 mm long, brownish, thin-shelled, kernel of variable quality - sometimes bitter, sometimes sweet and edible. Hardy to zone 5 (-23°C).

Grows well in Britain, often bearing fruit here. Has been cultivated for seed in N. America and named varieties have been selected. May take 25-30 years to fruit, with peak production from 80-200 years.

C. glabra megacarpa (Syns. *C. ashei, C. austrina, C. megacarpa*) - Coast pignut. Differs from the species by its larger fruit, 3-5 cm long and to 3 cm wide; nuts large with thick shells, kernels sweet and edible.

C. hunanensis - Hunan hickory. China (esp. in river valleys.)

Leaves with 5-9 leaflets. Distinguished from *C. cathayensis* by its larger nuts, 3 cm long by 2.5 cm diameter; shell thickness is variable. The kernel is sweet and edible but the seed coat is astringent. Cultivated in China, the nuts there are eaten fresh and pressed for edible oil; they are also used as an ingredient of a folk medicine. Most of the production is from wild trees, cropping from 10-200 years of age and yielding up to 300 kg/tree. Hardiness unknown.

C. illinoinensis (Syn. *C. pecan*) - Pecan. SE USA (esp. Mississippi valley).

Large tree, growing 30 m high or more, with deep furrowed, irregular brownish-grey bark. Leaves with 11-17 leaflets, each 5-17 cm long; fruits in spikes of 3-10, oblong, 3-8 cm long with a slightly 4-winged outer shell; nuts smooth, light brown, thin-shelled, sweet and edible. Hardy to zone 6 (-20°C) but needs hot summers to ripen wood. In the wild there are several disjunct populations.

Cultivated for centuries in warm areas (needs a continental climate) and numerous cultivars exist - over 1000 are documented. Some 220,000 hectares are grown in the USA. Seedlings start bearing in about 20 years, but named selections start within 4 - 10 years, with maximum production from 75-225 years; yields of 225 kg per tree are common. This article does not intend to go into pecan cultivation in great detail, particularly because the pecan is unlikely to do very well in British conditions (although a tree at Wisley in Surrey does fruit). Pecans are higher in oil (about 73%) than walnuts (64%), and much more energy is required to assimilate oil compared with other kernel components, hence pecans need significantly warmer weather in September and October than walnuts.

Unlike most crops, pecan is generally cultivated near its geographical area of evolution, and is therefore plagued in North America by numerous disease organisms, including scab, vein spot, downy spot and shuck disease. Insect problems are also common, including the pecan nut casebearer, hickory shuckworm, pecan weevil and aphids.

Of the numerous cultivars, the following early-ripening selection are known to do well in the NE USA or even in Canada; they hold the best hope for cool temperate areas:

Best's Early, Campbell 4 (originated in Canada), Carlson 3 (nuts small to medium size, thick shelled, average quality. An alternate bearer, very early ripening. Grown in Canada), Coffee, Cornfield (nuts medium size, regular bearer, average shell thickness, reasonable kernel quality. Grown in Canada), Deerstand (grown in Canada), Devore (small nuts (264/kg), excellent flavour), Gibson (precocious, nuts medium sized, good flavour, precocious), Grandview, Green Island (nuts of good size and flavour), Lucas (nuts small to medium size and shell thickness, good kernel quality. Regular bearer. Grown in Canada, early to mid ripening), Mullahy (precocious, very productive, nuts medium size, excellent flavour. Has ripened nuts in Ontario), NC-4 (good producer of large nuts, thin shells, well-filled kernels of good quality. Grown in Canada, early to mid ripening), Snag, Snaps Early (very early ripening. Nut small, thin shell, good kernel quality. Moderate bearer. Grown in Canada), Theresa Foster (very early ripening. Grown in Canada), Voiles 2 (has ripened nuts in Ontario.)

C. illinoinensis* x *C. myristiciformis - hybrid.

C. illinoinensis* x *C. ovata - hybrid hicans.

Leaves with 7-9 leaflets; fruit intermediate in characteristics between the parents (pecan & shagbark), often with a reddish tinge. Although nuts are often large they are also often poorly filled. Cultivars include:

Burton (nuts medium size, reasonably filled, crack well, good flavour. Precocious. Seedlings sometimes also exceptionally good. Grown in Canada), Des Moines (light bearing. Seedlings slow to bear, not very fertile), Dooley seedling (a Burton seedling, which crops well and has well-filled nuts. Grown in Canada), Hartmann (nuts medium size, thin shelled), Henke (nuts small to medium but well filled, crack well, good flavour. Precocious, shy bearer. Grown in Canada), Hershey (nuts medium size, well filled), Jackson (nuts medium size, good cropper), Pixley, Wapello.

C. kweichowensis - Guizhou hickory. China (esp. on high forested slopes). Details and description unknown. May be hardy to zone 7 (- 15°C).

C. laciniosa (Syn. *C. sulcata*) - Shellbark hickory, big shellbark. Eastern USA.

Large tree to 30 m or more high, with bark peeling in long strips and thick young twigs. Leaves with 7-9 leaflets, each 10-20 cm long; fruits round-elliptical, to 7 cm long; nuts to 5 cm long, yellowish-red, flattened, somewhat 4-sided, thick-shelled (4 mm), pointed at both ends; kernel sweet and edible. Hardy to zone 6 (-20°C).

Bears nuts within 15 years. About 40 cultivars have been named, originating in Iowa or Pennsylvania. Those with best potential for Northern and cool summer regions include:

CES-1 seedlings - yield nuts of medium size and good flavour. Trees healthy, with sturdy crotches. Grown in Canada.

CES-24 - nuts large, excellent flavour, 40% kernel. Precocious biennial bearer, grown in Canada.

Fayette - good nut size and cracking quality; kernel of average to good quality. 84 nuts/kg, 34% kernel. Regular producer. Grown in Canada.

Henry - good nut size, cracking and kernel quality; regular bearer. Grown in Canada.

Hoffeditz - regular bearer, nuts of medium size, good flavour and cracking quality.

Keystone - large nuts, very good cracking quality. Regular bearer.

Totten - 35 nuts/kg, 25% kernel. Its seedlings yield large nuts; healthy fast-growing trees. Grown in Canada.

Other cultivars include: Berger, Big Cypress, Bowman, Bradley (nut large, cracks well, large kernel, precocious regular bearer), Brouse, Caldwell, Calico, Chetopa, Croston, Daulton, Dewey Moore (nuts thin-shelled, 33o/c kernel; poor producer), Dreppard, Ellison No.1, Engeman (Missouri Giant; large nut, cracks well), Etter, Eureka (nut medium size, cracks well, good flavour; precocious), Eversman, Favorite, Florin Smith, Harold, Hoagland, Hill, Kaskaskia (nut medium-large, cracks well, very good flavour; precocious), Lamomi, Landis (Redolay), LeFevre, Lindauer (nuts large, crack well, productive), Longnecker, Mackinaw, Mott (33 nuts/kg), Nieman (nuts large, thick-shelled), Nowrood, Osborn (very thick shell), Piasan, Pleasant Creek 1, Poner (33g nuts, 17% kernel), Ross (large nut, exc cracking quality, good flavour; precocious), Sayer, Scholl (large nut, cracks well, precocious), Stanley (30% kernel), Stephens (very large nuts, late ripening), Super X, Tama Queen, Wagoner, Wampler, Wooley.

C. x laneyi (*C. cordiformis X C. ovata*) - American hybrid.

Similar to *C. ovata* but with dark grey bark, not grooved; leaves with 5 leaflets; ovate fruit; nuts flattened, thin shelled, kernel large, sweet and edible. Hardy to zone 5 (-23°C).

Early bearing; several named varieties have been selected, including:

Beaver (protandrous, 50% kernel), Brackett (wrongly attributed to *C. glabra*; thin shelled, kernel large and full, good flavour), Bridgewater (=Brookfield; nut very large (8 g), 47% kernel), Creager (328 nuts/kg, 49% kernel), De Acer (nut medium, cracks well, good flavour; precocious; protogynous, susceptible to weevils), Fairbanks (48% kernel), Laney (the type), Peck (poorly filled), Roof, Stocking, Stratford (nuts thin-shelled, cracks well), Terpenny (53% kernel), Weschcke (was attributed to *C. ovata*; pollen sterile; nuts medium size, thin shell, 53% kernel, cracks well, very good flavour, precocious).

C. x lecontei (*C. aquatica X C. illinoinensis*) - Bitter pecan. Texas.

Large tree to 20 m high or more with scaly thin bark. Leaves with 7- I 3 leaflets, each 7- 12 cm long; fruits oblong, 4-winged; nuts oblong-ovoid, 4-sided and angular, reddish-brown, very thin shelled, kernel very bitter - not edible. Not very hardy, perhaps zone 7-9 (-5 to- 15°C).

C. x ludoviciana (*C. aquatica X C. texana*) - hybrid.

C. myristiciformis - Nutmeg hickory. SE USA, Mexico.

Large tree to 25 m or more high with dark brown fragmented bark. Leaves with 5- 11 leaflets, each 8-12 cm long; fruits ovate, to 4 cm long; nut to 3 cm across, ovate, reddish-brown with silver stripes (resembling nutmeg), furrowed, thick shelled, kernel sweet and edible. May be hardy to zone 7 (- 15°C) - grows at Kew. In the wild there are several disjunct populations. The nuts have such thick shells that, despite the sweet kernel, most nuts lie where they fall under the tree, of little use to wildlife.

C. x nussbaumeri (*C. illinoinensis X C. laciniosa*) - hybrid hicans. Nuts are large but are often poorly filled. Cultivars include:

Baress, Bergman, Bixby (62 nuts/kg, protogynous), Brewster, Burlington, Chanute (102 nuts/kg, 32% kernel), Clarkesville, Dintelman, Gerardi (large nut, cracks well, very good flavour; very precocious; used as a pecan rootstock in Tennessee), Greenbay, James (nut very large, cracks easily, precocious), Klein (52 nuts/kg), Marquardt, McCallister (large nuts, poorly filled), Norton, Nussbaumer (the type, may be same as Bixby), Oregon, Radcliff, Rockville (poor bearer), Underwood (nut large, thin shelled), Weese (110 nuts/kg, 44% kernel), Wright.

C. ovalis (Syn. *C. microcarpa*) - Red hickory, Sweet pignut. Eastern USA. Tall tree to 30 m high. Leaves with 5-7 leaflets, each 7 cm long; fruits variable, round or pearshaped, 25 mm long; nuts thin-shelled, sweet and edible. Hardy to zone 6 (-20°C). A regular cropper; sometimes included with C. glabra. Two cultivars from Michigan have been named: Green, Huff.

C. ovata (Syn. *C. alba*) - Shagbark hickory. Eastern North America.

Medium or large tree to 20-30 m or more high, with bark peeling in strips. Leaves with 5 leaflets, each 10-15 cm long; fruits round, 4-angled, 3-6 cm long with a thick outer shell; nut to 4 cm long, ellipsoid, pale, 4-sided, thick-shelled (thinner in some cultivars), kernel sweet and edible. Hardy to zone 5 (-23°C). In the wild there are several disjunct populations. Var. *pubescens* has densely hairy lower leaves and twigs.

Grows well in Britain - trees with origins from the north of the range (Quebec) are likely to do best. Fruits in 10-15 years. Over 130 named cultivars have been selected, though many are not propagated. The following have good potential in Northern and cool summer regions:

Cedar Rapids - regular bearing, large nuts of good quality. Medium ripening. Grown in Canada.

Shagbark Hickory, Carya ovata

CES-8 seedlings - grown in Canada.

CES-26 - very early ripening, though an irregular bearer. Cracks well, good quality kernel. Grown in Canada.

Fox -nuts of medium size and quality, crack well. Grown in Canada.

Glover - Nuts small, crack well. Grown in Canada.

Neilson - regular bearer, nuts medium to large; average quality. Precocious. Grown in Canada.

Porter - Irregular bearing, can be very good; nuts large, 47% kernel, cracks well. Grown in Canada.

Walters

Wilcox - precocious, nuts medium size (5 g), cracks well, very good flavour, 41 % kernel, keeps well.

Other cultivars (many of which have probably been lost) include: Abscoda, Adelhurst (good cracking quality), Ancaster, Anthony (162 nuts/ kg, 42% kernel), Barnaby, Barnes, Beeman, Benham, Benthien, Billeau, Blatchley, Bontrager, Book, Bower, Brill, Brooks, Buehring, Camp No.2, Clark, Cline, Coleman, Comins, Cook, Conover, Cotton, Cranz,

Curtis, Davis (nuts medium size, crack well, good quality), Dennis, Deveaux, Doolittle, Dover, Drew, Eller, Elliott, Emerick, Enfield, Fat Boy, Felger (late ripening, poor yields, 30% kernel), Folts, Freel, Froman, Gobble, Goheell, Griffin, Hadley, Hagen, Hales, Hand, Harman, Harold (protandrous), Hasbrouck, Haskell, Haviland, Hefty, Heibner, Heisey, Helmuth, Henever No.4, Hilton, Hines, Holden (ornamental, drooping branches), Huber, Huen, Huss, Ideal, Independence, Iowa, Isham, Jackson, Joliffe, Kentucky (from var. *pubescens*), Kirtland, Lake, Last, Lawyer, Leach, Learning, Leavenworth, Leonard, Lingenfelter, Livingstone No.2, Loomis, Mambert (thin shell), Manahan, Mann (165 nuts/kg, 47% kernel), McLaughlin, Meriden, Milford, Miller (220 nuts/kg, 49% kernel), Minnie, Murdock, Netking, Peschke, Petty, Platman, Proper, Renggenberg, Retzer (cracks well, medium size, good flavour; precocious, productive), Reynolds, Rhinemiller, Rice, Ridiker, Romig, Salisbury, Sande, Sauber (nuts crack well), Schaul, Schinnerling (medium size, good cracking quality & flavour; precocious & very productive), Seaver, Shillar, Silvis 303 (large thin shelled nut, 45% kernel, self fertile), Sobolewski, Sprunger, Stadelbacher, Strever, Swaim (185 nuts/kg, 50% kernel), Taylor, Triplett, Van Orman, Vest (58% kernel), Ward, Warren, Watson, Westphal, Whitney, Wilmoth (thin-shelled nuts, large kernel, good flavour), Wilson, Woodbourne, Wurth (nut large, thin shelled, cracks well; good producer), Zuercher.

C. pallida - Sand hickory. Eastern USA (dry upland sites).

Large tree, leaves with 7-9 leaflets, each 8-12 cm long; fruits round, 2-4 cm long, with a thin outer shell; nuts to 3 cm long, pale, flat, thin-shelled, sweet and edible. Hardy to zone 6 (-20°C).

C. palmeri - Mexican hickory. Mexico.

Trees with smooth whitish bark. Nuts are thin shelled (1 mm) with bitter wrinkled kernels. Hardiness unknown.

C. poilanei - Poilane's hickory. Vietnam, Laos.

A little-known species which may not be hardy in temperate climates, though it is found at elevation on hillsides.

C. x schneckii (*C. illinoinensis x C. tomentosa*) - hybrid. Cultivars include: Bates, Schneck (the type).

C. sinensis. China, Vietnam (esp. along river valleys.)

Leaves with 7-9 leaflets. The Chinese name refers to the 'beak-like' apex of the nut. Nuts are very large (68 x 48 mm). This species is cultivated in Taiwan and Vietnam for its nuts. Hardiness unknown - possibly zone 7 (-15°C); not in cultivation outside Asia.

C. texana (Syns. *C. arcansana, C. villosa*) - Black hickory. SE USA.

Small to medium sized tree, 10-15 m (30-50 ft) high, with furrowed dark bark. Leaves with 7 leaflets, each 10-15 cm long; fruits rounded, 35 mm long; nuts round, pointed, 4-sided at the top, reddish-brown, very thick-shelled; kernel sweet and edible. Hardy to zone 6 (-20°C). A cultivar exists: Aber.

C. tomentosa (Syn. *C. alba*) - Mockernut hickory. Eastern USA.

Large tree to 25-30 m high with furrowed, ridged bark. Leaves with 7-9 leaflets, each 8-18 cm long; fruits round to pear-shaped, 3-5 cm long, with a very thick outer shell; nuts somewhat flattened and angular, 3 cm long, light brown, thick shelled (5 mm); kernel sweet and delicious. Hardy to zone 5 (-23°C).

Grows quite well in Britain. Starts bearing after about 20 years, with maximum production at 40-150 years. One cultivar has been named: Droska (from Missouri, 1929)

C. tonkinensis - Vietnam hickory. Vietnam, SW China, NE India.

Leaves with 5-7 leaflets. Nuts of this species are rounded with a flat apex, 2 x 2.5 cm and thin-shelled (2 mm). Cultivated for nuts where native; an edible oil is extracted from the nuts. May not be hardy in temperate climates.

Carya tomentosa, Mockernut Hickory

Sources

In the UK, the ART, Mallet Court and Nutwood supply seedling hickories and Nutwood have a few grafted types. Most cultivars are available only from North American nurseries.

A.R. T., 46 Hunters Moon, Dartington, Totnes, Devon, TQ9 6JT.

Mallet Court Nursery, Curry Mallet, Taunton, Somerset, TA3 6SY. Tel: 01823-480748.

Nutwood Nurseries, School farm, Onneley, Nr Crewe, Cheshire, CW3 9QJ. Tel: 01782-750913.

Louis Gerardi Nursery, Garden Center, 1700 E Highway 50, O'Fallon, IL 62269, USA.

John Gordon Nursery, 1385 Campbell Blvd., Amherst, NY 14228-1404, USA.

Grimo Nut Nursery, 979 Lakeshore Rd, R.R.3, Niagara-on-the-Lake, Ontario. CANADA L0S 1J0.

Nolin River Nut Tree Nursery, 797 Port Wooden Rd., Upton, KY 42784. USA. Tel: 502-369-8551.

Oikos Tree Crops, P.O.Box 19425, Kalamazoo, Michigan 49019, USA. Tel: 616-624-6233.

Cultivar-Species index

There is continuing confusion over the misidentification of the species or hybrids to which some cultivars belong. This index includes cultivars which have been listed under one species but are now considered to belong to a different one.

Cultivar	Species / hybrid	Cultivar	Species / hybrid
Aber	C. texana	Henke	C. illinoinensis x C.ovata
Abundance	C. x dunbarii	Hershey	C. illinoinensis x C. ovata
Barnes	C. ovata	Iowa	C. ovata
Berger	C. laciniosa	Jackson	C. illinoinensis x C.ovata
Bergman	C. x nussbaumeri	James	C. x nussbaumeri
Bixby	C. x nussbaumeri	Joliffe	C. ovata
Brackett	C. x laneyi	Kentucky	C. ovata pubescens
Bridgewater	C. x laneyi	LeFevre	C. laciniosa
Burlington	C. x nussbaumeri	Marquart	C. x nussbaumeri
Burton	C. illinoinensis x C.ovata	McCallister	C. x nussbaumeri
Country Club	C. illinoinensis x C.ovata	Nieman	C. laciniosa
De Acer	C. x laneyi	Please	C. x brownii
Des Moines	C. illinoinensis x C. ovata	Roof	C. x laneyi
Dintelman	C. x nussbaumeri	Sande	C. ovata
Dooley	C. illinoinensis x C.ovata	Scholl	C. laciniosa
Etter	C. laciniosa	Siers	C. cordiformis x C. tomentosa
Eureka	C. laciniosa	Stratford	C. x laneyi
Gerardi	C. x nussbaumeri	Underwood	C. x nussbaumeri
Grainger	C. carolinae-septentrionalis	Weschcke	C.x laneyi
Hartmann	C. illinoinensis x C.ovata	Yoder No.1	C. x dunbarii
Haviland	C. ovata		

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THE POTENTIAL OF NON TIMBER FOREST PRODUCTS OF BOTSWANA

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BACKGROUND

Botswana

Botswana is a landlocked country situated in the Southern African Plateau with a mean elevation of 900m above sea level. The climate varies between subtropical arid and semiarid with annual rainfall averaging 655 mm in the north of the country and up to 250 mm in the south. Of the total land area of 582,000 square kms (an area roughly the size of France), only 6% is suitable for arable agriculture with the rest of the land being covered by Kalahari sands. The country's main miombo woodlands (forested areas mixed with grassland and woodland), are situated in the northern and eastern region due to the higher rainfall and more fertile soils experienced in these areas.

The agricultural sector is dominated by the cattle industry which accounts for over 80% of the agricultural share of GOP (UNDP, 1994). Over the last few years, the country's production of major crops has not increased, even though the number of people employed in traditional agriculture and the crop area has increased (MoA, 1990). This would indicate that the relative productivity of the arable agricultural sector is actually on the decline.

The economy of rural areas

The uncertainty of rains means that arable harvests cannot be relied upon; on average one year in three is a crop failure year.

The commercialisation of certain veld products has already made a significant contribution to the rural economy in many areas. The harvesting of Sengaparile (*Harpagophytum procumbens*), also known as Devil's Claw (see 2.1), and the basket weaving industry based on the makola palm (*Hyphaene benguellensis*), have provided cash incomes to many thousands of people who otherwise have little access to the cash economy.

The 1992 population of Botswana was estimated to be 1,327,000 with most people living in rural areas (CSO, 1992). The actual quality of life in rural areas is declining in relation to that of urban areas; according to 1989 government statistics, 64% of rural people were living below the poverty datum line. The potential for food insecurity and land degradation is alarming. It is believed that the process of land degradation is being exacerbated by drought, sustained cultivation of marginal soils and overgrazing. Both household and food security are lacking for most rural poor.

At the end of 1992 the national unemployment rate was estimated to be just over 16%. With the above in mind it would appear that NTFPs have enormous potential to alleviate poverty and unemployment in rural areas.

NON TIMBER FOREST PRODUCTS OF BOTSWANA

The traditional role played by NTFPs.

NTFPs have traditionally played an important role in Botswana. The most important NTFPs would include foods, medicines, building materials and fuelwood. Although certain types of NTFPs have been successfully exploited on a commercial basis, the full potential of many NTFPs has still to be realised.

The Marula, Sclerocarya birrea [From Tredgold, 1986]

Many NTFPs in Botswana tend to circulate through the local informal markets where significant sums of money are not generated. However, this does not mean that these markets are not important; for many rural poor this is their sole means of income. Evidence suggests that it is the rural poor and marginalised groups (especially women), which are most actively involved in the harvesting and trading of NTFPs. This can be illustrated by the case of *Harpagophytum procumbens* (sengaparile). An interim report on the harvesting of sengaparile (Ntseane, 1990), outlined that of the harvesters, 80% were female, 80% had never been to school and 64% had no other source of income.

With the above knowledge, it would still be very unwise to assume that the commercialization of NTFPs would automatically lead to these groups of people realizing the benefits. If any tangible benefits are to be realised by marginalised groups then it is imperative that any commercialisation programme encompasses every related facet. Failure to do so could not only result in marginalised groups not benefitting from a valuable resource base, but also in the NTFP resource base being severely damaged or destroyed.

Table 1. Some NTFP's of Botswana with economic potential

CATEGORY	SPECIES	PRODUCT	COMMENTS
1. FOODS	*Amaranthus* sp. Thepe	Leaves: wild spinach	Reported to be used as a staple
	Azanza garckeanu Morojwa	Fruit: fresh, dried	Hard, woody yellowish fruit; mucilaginous pulp
	Cleome gynandra Rothwe	Leaves: wild spinach	A tasty relish, reputedly sought after as a cure to scurvy
	Cucumis metuliferus Magabala (horned cucumber)	Vegetable: eaten raw, cooked Leaves: eaten cooked	The leaves have ben known to be eaten as a side dish
	Grewia flava Moretlwa	Fruit: dried, fresh	Raisin-like veld food, high carbohydrate content
	Mimusops zeyheri Mmopudu	Fruit: fresh, juice, dried pulp, cake	Important dietary component for some tribes
	Portulaca oleracea Serepe	Leaves: wild spinach	100g of seeds contain 250mg iron (over 100x the RDA)
	Schinziophyton rautenenii Mongongo	Fruit: dried powder Nut: roasted, oil	Very rich oilseed (over 60%) Oilcake has over 60% protein
	Sclerocarya birrea subsp. *caffra* Morula	Fruit: fresh, jam, beer, fruit rolls Nut: oil	Fruit contains high vitamin C content (up to 200mg/100g)
	Strychnos cocculoides Mogorogorwane	Fruit: fresh, dried, juice	Can be stored for several months
	Terfezia pfeilii Mahupu	Fresh, pickled	Also known as the Kalahari truffle
	Tylosema esculentum Morama bean	Bean: cooked, oil Tuber: cooked	Bean contains 38% oil, 35% protein. Food source for RADs
	Vangueria infausta Mmilo	Fruit: fresh, dried, juice	Dried fruit can be stored for winter
2. MEDICINES & OTHER BIOACTIVE PRODUCTS	SPECIES	PRODUCT	COMMENTS
	Artemisia afra Lengana	Leaves used to make an infusion	Herbal tea used for general well-being
	Croton megalobotrys Motsehe	Bark, leaves, fruit: used as as fish poison	Used in Okovango Delta and Botletle River areas
	Diamphidia nigra-ornata x'apa	Larvae: used as a poison	Main poison used by Basarwa on their arrows
	Harpogophytum procumbens Sengaparile	Tuber	Used mainly as a treatment for arthritis
	Lippia javanica Mosukujane	Leaves used to make an infusion	Herbal tea used for general well-being
	Lippia scaberrima Mosukudu	Leaves used to make an infusion	Herbal tea used for general well-being
	Mentha longifolia subsp *polyadena* Kgomodi metseng	Leaves and seeds used to make an infusion	Herbal tea used for general well-being
	Swartzia madagascariensis Moshakestela	Plant: used as a hunting poison	Also used in water to kill *Schistosoma* larvae (Bilharzia)

CATEGORY	SPECIES	PRODUCT	COMMENTS
3. EXTRACTIVE PRODUCTS	*Acacia karroo* Mokha	Exudate	Used for pharmaceutical purposes
	Acacia nilotica Mooka	Pods: tannin	Used for tanning
	Acacia robusta Moga	Bark: tannin	Used for tanning
	Artemisia affra Lengana	Stem and leaves: essential oils	
	Combretum sp.	Exudate	Used for industrial purposes
	Elephantorrhiza sp.	Roots: tannin	Used for tanning
	Peltophorum africanum Mosetla	Bark and leaves: tannin	Used for tanning
	Tagetes minuta	Stem and leaves: essential oils	
4. PLANTS & PLANT PRODUCTS	SPECIES	PRODUCT	COMMENTS
	Cyperus papyrus	Stems	Used to make mats, papyrus parchments
	Hyphaene benguellensis Makola palm	Leaves	Leaves used to make baskets
	Wood: assorted sp.	Driftwood, assorted creepers	Used for ornamental displays
	Wood: assorted sp.	Carvings, furniture, building	
	Wood: assorted sp.	Charcoal, fuelwood	
	Various sp.	Stems, leaves, flowers, seeds	Florist material: used for dried flower displays
	Various succulents Various bulbs	Living plant	Used as ornamental plants
		Stems	Used as thatching grass for the rooves of buildings
5. ANIMAL & ANIMAL PRODUCTS	SPECIES	PRODUCT	COMMENTS
	Emponia melanobasis	Jumping bean	
	Various	Feathers, furs, skins, hides, etc.	Can be processed into a variety of different goods

Source: Fox & Norwood Young (1982), Watt & Breyer-Brandwijk (1962), Wehmeyer, Lee & Whiting (1969). Modified by author.

Diversity

The term non timber forest product refers to all tangible products obtained from forests (or any land under similar use as well as woody plants) other than timber but including fuelwood and charcoal (FAO, 1993).

Broadly speaking, NTFPs can be divided into five separate categories; namely food, medicines and bioactive products, extractive products, animals and animal products, and plants and plant products.

Table 1 shows the range of some NTFPs available in Botswana. This list is not comprehensive but it includes the major NTFPs with commercial potential.

Potential

Stabilizing and diversifying the rural economy

The rural economy is heavily reliant on arable crop harvests. The uncertainty of a successful harvest, means that there is always an element of instability in the rural economy. Diversification would in turn lead to increased stability, as less reliance would be placed on several key items.

NTFPs would appear to have the potential to diversify the rural economy; the range of NTFPs available in Botswana is vast and as such, NTFPs are available throughout the year. This diversity means that the 'risk' is spread wider: should a year be particularly bad for one NTFP, then due to the range available, the impact will be minimal. This contrasts markedly with the consequences of an arable crop failure.

Increasing food and household security

Food and household security are lacking for most rural poor.

The NTFPs of Botswana are by their very nature suited to Botswana's climate. With certain exceptions, most years will produce at least a reasonable NTFP harvest. A wide range of NTFPs is available throughout the year, either fresh or stored. Table 2 shows the availability of some NTFPs of Botswana. The availability of these NTFPs means that the potential exists for a steady income to be earned from them throughout the year, be it through harvesting, processing or selling.

Many NTFP foods may be stored for long periods, for example mogorogorwane may be stored for several months without any pretreatment. This property means that theoretically many foods can be stored for the hungry season.

From a nutritive point of view, NTFP foods can make a significant contribution to improved nutrition in rural areas. The mongongo nut contains over 60% oilseed and the oilcake has over 60% protein (Wehmeyer et al, 1969). These figures are both higher than for soy beans and groundnuts. The morama bean is another protein rich food source and the morula fruit contains a higher concentration of vitamin C than oranges (see appendix for further details).

NTFP foods can not only contribute to food security but they have the potential to contribute to improved nutrition in rural areas.

From Table 2 it can be seen that, due to availability, NTFP utilisation can contribute significantly to both food and household security; a range of NTFPs are available throughout the year, either fresh or dried. This means that theoretically food is available throughout the year and the potential exists to earn an income throughout the year.

Mongongo, Schinziophyton (Ricinodendron) rautenii. From Tredgold, 1986

Other benefits

The benefits of NTFP utilisation are not just limited to those outlined above. Environmental and social benefits may also be realised.

The output of the arable agriculture sector has decreased over the last few years, even though the land area under arable agriculture has increased. It has been suggested that this is in part due to marginal soils becoming exhausted, as such, the sustainability of this kind of agriculture is questionable.

It has been suggested that because the use of NTFPs does not cause the kind of environmental degradation associated with arable and livestock agriculture (i.e. soil erosion, habitat destruction, reduction of biodiversity etc.) they could be sustainably utilised as a valuable aid in increasing food and household security. There are however other problems associated with NTFP use. It is not implied that the use of NTFPs will result in a complete reversal of the environmental degradation associated with commercial agriculture, it is merely suggested that the use of NTFPs could help to reduce the levels of land degradation currently being experienced in rural areas.

Another possible social benefit of NTFP use could be a reduction of the workload on women. Women account for over half of Botswana's population and 52% of households in rural areas are headed by females (CSO, 1992). This is primarily due to outmigration by males to seek wage employment in the major conurbations.

In Botswana there has traditionally been a division of labour by gender. However, due to male migration (and other factors), this appears to have broken down. Women are now doing the work and assuming the responsibility for what was previously carried out by men. This is true for agriculture. Women are predominantly involved in subsistence agriculture, in terms of agricultural production, women carry the heaviest burden (Merafe, 1995).

Table 2. To show availability of some of the more important NTFPs of Botswana

CATEGORY	SPECIES	J	F	M	A	M	J	J	A	S	O	N	D
FOODS	*Amaranthus* sp. Thepe	X	X	X	0	0	0	0	0	0	0	X	X
	Azanza garckeanu Morojwa	0	0	0	0	0	0	X	X	X	0	0	0
	Cleome gynandra Rothwe	X	X	X	0	0	0	0	0	0	0	X	X
	Cucumis metuliferus Magabala (horned cucumber)					X	X	X	X	X	X		
	Grewia flava Moretlwa	0	X	X	X	X	0	0	0	0	0	0	0
	Mimusops zeyheri Mmopudu	0	0	0	0	0	0	0	X	X	0	0	0
	Portulaca oleracea Serepe	X	X	X	0	0	0	0	0	0	0	X	X
	Schinziophyton rautenenii Mongongo	0	0	0	X	X	X	X	X	0	0	0	0
	Sclerocarya birrea subsp. *caffra* Morula	X	X	X	X								
	Strychnos cocculoides Mogorogorwane							X	X	X			
	Terfezia pfeilii Mahupu				X	X							
	Tylosema esculentum Morama bean	0	0	X	X	X	0	0	0	0	0	0	0
	Vangueria infausta Mmilo	0	X	X	0	0	0	0	0	0	0	0	0
MEDICINES & OTHER BIOACTIVE PRODUCTS	*Artemisia afra* Lengana	X	X	X	X								
	Harpogophytum procumbens Sengaparile	0	0	0	X	X	X	X	X	X	X	0	0
	Lippia javanica Mosukujane	X	X	X	X								
	Lippia scaberrima Mosukudu	X	X	X	X								
	Mentha longifolia subsp *polyadena* Kgomodi metseng	0	X	X	X	0	0	0	0	0	0	0	0
EXTRACTIVE PRODUCTS	*Acacia karroo* Mokha	X	X	X	X						X	X	X
	Acacia nilotica Mooka	0	0	0	X	X	X	X	0	0	0	0	0
	Acacia robusta Moga	X	X	X	X	X	X	X	X	X	X	X	X
	Artemisia affra Lengana			X	X	X							

CATEGORY	SPECIES	J	F	M	A	M	J	J	A	S	O	N	D
	Combretum sp.	X	X	X	X						X	X	X
EXTRACTIVE PRODUCTS	*Elephantorrhiza* sp.	X	X	X	X	X	X	X	X	X	X	X	X
	Peltophorum africanum Mosetla	X	X	X	X	X	X	X	X	X	X	X	X
	Tagetes minuta				X	X	X						
PLANTS & PLANT PRODUCTS	*Cyperus papyrus*	X	X	X	X	X	X	X	X	X	X	X	X
	Grewia flava Moretlwa	X	X	X	X	X	X	X	X	X	X	X	X
	Hyphaene benguellensis Makola palm	X	X	X	X	X	X	X	X	X	X	X	X
	Ornamentals: various succulents & bulbs	X	X	X	X	X	X	X	X	X	X	X	X
	Wood: assorted species	X	X	X	X	X	X	X	X	X	X	X	X
5. ANIMAL & ANIMAL PRODUCTS	*Emponia melanobasis*											X	X
	Various species	X	X	X	X	X	X	X	X	X	X	X	X

Note: harvesting dates are approximate as rainfall is a major factor for many species

KEY: x= available fresh; 0 = available dried

Source: Fox & Norwood Young (1982), Wan & Breyer-Brandwijk (1962), Wehmeyer, Lee & Whiting (1969). Modified by author.

Subsistence agriculture is characterised by requiring low technology, high inputs (in terms of labour and draught power), and having low outputs. As such, subsistence agriculture is very time consuming, especially considering the fact that it is very likely that the harvest will be unsuccessful.

By contrast, the harvesting of NTFPs requires very little in the way of external inputs; there is no ploughing, sowing or weeding that needs to be done. By nature, the NTFPs are suited to Botswana's climate and so a reasonable harvest can be expected in most years, the prospect of a harvest is far more certain than for arable agriculture.

NTFP use could drastically reduce the workload on women.

LIMITING FACTORS TO NTFP UTILISATION

Problems

Inadequate policy measures

NTFPs have been neglected by policy makers and foresters alike. For a natural resource such as NTFPs it is imperative that there are adequate control measures to protect it from overexploitation; with a common resource most people wish to see the immediate monetary benefits with little regard for the future.

The Forestry Act of 1968 advocated the establishment of forest reserves for the protection of trees and other woody vegetation, this was only in the reserves and on state land. The actual policy was inefficiently implemented due to its non specific and uncoordinated nature, lack of personnel was also a contributing factor to the failure of the policy. The end result was deforestation, overgrazing and resource depletion.

There are six forest reserves in Botswana covering about 1% of the country. The standing stock is estimated to be about 10,000 cubic metres. The main species harvested are mukwa (*Pterocarpus allgolesis*) and mukusi (*Baitiaea plunjuga*), both for timber production (MoA, 1991).

Shrub and woodland areas are extensive, covering over 60% of the country, however, whilst they do not have the same commercial potential for timber they do have commercial potential for non timber forest products (primarily foods and medicines).

The 1968 Forestry Act did not address natural woodlands and if the use of this resource continues unchecked (eg. as a source of fuelwood) then the resource base will be severely damaged or even destroyed. This could have other environmental repercussions; the current rates of land degradation, soil erosion and localised deforestation are likely to increase, thus compounding the problem of bush encroachment.

The need for a revision in the Forestry Policy has been recognised by the Government, and The National Policy on Agricultural Development (1991) and The National Development Plan VII (1991-1997) address the relevant issues to enable sustainable development to be made in the forest sector. Whether this revision will help to protect NTFPs remains to be seen. Legislation and policy measures are not enough to protect a common resource such as NTFPs. If the resource base is to be adequately protected then the policy measures need to be actively enforced.

Motivation

At present in Botswana, there is little incentive for rural communities to become involved in the management of their natural resources. Notable exceptions would be wildlife management and the harvesting of sengaparile. In both these instances direct benefits, in the form of a cash income, are realised.

The use of common natural resources requires adequate control measures to safeguard the future of these resources. As such, for these control measures to successful, there must be complete cooperation between the policy makers and the communities utilising the resources.

The overriding concern of many rural communities is that of subsistence. It is thus very unlikely that issues such as resource sustainability will receive much attention; with far more immediate concerns, such as surviving to the next season, long term management goals are very unlikely to be a priority.

This lack of motivation to get involved in managing NTFP use could possibly be overcome by handing back a degree of control to the rural communities. Rather than imposing regulations, government would be encouraging communities to become actively involved in their own community based natural resource management programmes. If communities are empowered to manage their natural resources then there is a strong possibility that the future of that resource may be safeguarded.

The nutritional composition of some important NTFP foods

Analysis of *Sclerocarya birrea* subsp *caffra* (morula) fruit and kernel/100g edible portion (Source: Wehmeyer, 1966)

	FRUIT	KERNEL
Moisture	91.7g	4.0g
Protein	0.5g	30.9g
Fat	0.1g	57.0g
Ash	0.2g	4.2g
Fibre	0.5g	2.4g
Carbohydrate	7.0g	1.5g
Calcium	6.2mg	106.0mg
Magnesium	10.5mg	467.0mg
Phosphorous	8.7mg	836.0mg
Iron	0.1mg	0.42mg
Copper	0.04mg	1.99mg
Sodium	trace	3.38mg
Potassium	54.8mg	637.0mg
Thiamine	0.03mg	0.04mg
Riboflavin	0.05mg	0.12mg
Nicotinic acid	0.25mg	0.71mg
Vitamin C	67.9mg	-

However, given the current situation with sengaparile harvesting and wildlife management, it is more likely that individuals will be motivated to get involved in management programmes if a monetary value is placed on the NTFP. With the commercialisation of NTFPs a host of very serious problems arise.

There is still the possibility that rural communities will be reluctant to become involved in community based management programmes, and this issue would need to be thoroughly addressed if the sustainability of NTFP utilisation is to be safeguarded.

Restricted access to technology

For many NTFPs the greatest profit margin is realised after processing, and many NTFPs require some level of processing. Processing requires access to the appropriate technology. Although many NTFPs may be processed utilising very basic technology, (eg. foods and craft material), if these NTFPs are to be sold outside rural areas then some further processing may be required. This is especially true for products such as medicines, bioactive products, and extractive products. In this instance quality control is also a very important factor.

The people most likely to be involved in NTFP use (namely rural communities) have very limited access to technology. As such, it is likely that they will end up selling the NTFP in a relatively 'raw' state to an intermediary who will then end up selling it to a processor. The profit margin increases the further up the chain you go and the harvester would thus realise the least profit margin.

This is the current situation with a number of NTFPs in Botswana, sengaparile (*Harpagophytum procumbens*) is a medicinal plant used by many people for the treatment of arthritis. The active ingredient is found in the tubers. Although the level of processing required is low, ie. the crushed tubers can be compressed into tablets, this level of technology still appears to be out of reach of the harvesters. Harvesters sell the raw material for a preset price to intermediaries or processors. In this instance the harvesters do not realise the maximum benefits, even though they do earn a cash income from harvesting.

Quality control

Being natural products, the quality of NTFPs varies greatly. If the NTFP is to be sold on the international or national market then it is essential that there are adequate quality control measures to ensure that the final product is consistent and of high enough quality to ensure that it is marketable.

This could be a major problem if the NTFP is to be exploited on a commercial scale. This would be especially true for medicines and bioactive products. Appropriate processing techniques would be needed so as to ensure that the final product is consistent and of the necessary quality. Unfortunately this would mean that in many cases the processing stage would not be carried out by the rural communities due to restricted access to technology.

Risks and dangers

Conflict

The harvesting of NTFPs could cause conflict situations to arise, as groups and individuals would be competing for the same common resource. Each individual would be understandably trying to maximise their benefits, and this would invariably be at the expense of another individual.

To use an example; in Botswana, most Bakalagadi villages have Basarwa groups living within a 15-20 km radius. The Basarwa are highly dependent on NTFPs and could easily be overwhelmed by the more dominant Bakalagadi. If there is to be equitable exploitation of NTFPs, then the two groups have to collaborate to develop a mutually beneficial management strategy. Such issues are very sensitive and any management strategy would need to take such ethnic differences into account.

Exploitive commercialisation

When a monetary value is placed on a NTFP then there is a very real risk that the resource base will be placed under severe pressure. Individuals will be trying to earn as much as possible before somebody else harvests the product, the pressure to earn an income would greatly outweigh the need to conserve the resource base. In this instance the NTFP resource base may not be left with sufficient time to regenerate.

This would be especially true for medicinal plants; for most medicinal plants, the active ingredient is found in the roots and bark. Overharvesting in this case could have disastrous consequences. It has been noted (Taylor, 1981), that even with strict control measures, many species of plants have completely disappeared from certain areas of South Africa, as the

Analysis of *Grewia flava* (moretlwa) and *G. bicolor* (100g)

(Source: Wehmeyer, 1980)

	Grewia flava	*Grewia bicolor*
Ash	**2.8g**	**5.9g**
Protein	**5.4g**	**10.3g**
Fat	**1.1g**	**0.1g**
Fibre	**22.1g**	**13.5g**
Carbohydrate	**57g**	**57g**
Energy	**1,090KJ**	**1,134KJ**
Calcium	**1.49mg**	**1.29mg**
Magnesium	**217mg**	**317mg**
Iron	**4.82mg**	**5.92mg**
Copper	**139mg**	**268mg**
Zinc	**1.87mg**	**1.59mg**
Sodium	**1.86mg**	**3.1mg**
Potassium	**71mg**	**181mg**
Phosphorous	**62mg**	**845mg**
Thiamine	**0.064mg**	**0.200mg**
Riboflavin	**0.040mg**	**0.253mg**
Nicotinic acid	**2.353mg**	**3.471mg**
Vitamin C	**0**	**9.3**
Moisture	**11.6g**	**13.2g**

roots or bark of the plants are highly valued for their medicinal properties. This may be the extreme as harvesting NTFPs for their medicinal properties is perhaps the most destructive, it does however outline the possible consequences of placing monetary values on NTFPs.

Any management programme must address these issues and it is not sufficient that control measures to limit habitat and ecosystem disturbance are in place, they must be actively implemented as well.

Adverse effects on rural poor

Although rural communities and marginalised groups may benefit from the commercialisation of NTFPs, it is possible that they could also be the biggest losers. The harvesting and selling of NTFPs provides the opportunity to earn an income but it is possible that two adverse situations may arise.

Wild foods are the most marketable NTFPs in Botswana and the pressure to earn money may mean that individuals will harvest and sell as much as they can. Traditionally many of these wild foods are preserved and stored for food security during the hungry season. If these foods are sold for cash then food security will be lacking when it is needed most.

Another possible situation that may arise is that the income generated from the sale of NTFPs may be wasted on items such as alcohol.

Constraints

Land use changes

The habitat for NTFPs is declining due to lack of attention on the management and conservation side.

NTFPs have been ignored by policy makers as the markets are seen to be small and the contribution to GOP insignificant. The emphasis appears to be on livestock and arable agriculture; the land area under arable agriculture in Botswana has increased over the last few years (UNDP, 1994), even so, output from the arable agriculture sector has remained stagnant.

With the agricultural policy emphasising the importance of arable agriculture (Gov. paper no. 1), it is likely that the land area under arable agriculture will continue to increase and thus the habitat for NTFPs will continue to decline.

Government policy

Government policy may be seen as a constraint to the development of NTFP utilisation. The perceived unimportance of NTFPs has resulted in government policy ignoring the issue of resource sustainability. The agricultural policy emphasises arable agriculture, it would appear to the detriment of NTFPs.

Breakdown of traditional management systems

Much of the pressure on the NTFP resource base can be attributed to the breakdown of traditional management systems (Parratt & Taylor, 1994). Traditional management systems were controlled by the Chiefs and Headmen.

Modernisation has resulted in erosion of the power and control traditionally commanded by these leaders.

One example of the breakdown of traditional management systems can be seen in the case of the makola palm (*Hyphaene benguellensis*). The palm frond is used in the basket weaving industry. Traditionally, every third leaf was harvested, however, due to commercial pressure every second leaf was then harvested. The current situation is that every single leaf is now harvested, inevitably killing the palms. A once lucrative activity is now in difficulties.

Traditional management systems can protect a valuable resource base such as NTFPs, but the biggest obstacle will perhaps be convincing rural communities that the traditional ways are better than the new ways. It is likely that individuals would be reluctant to return to traditional management practises when the current practises give far higher monetary returns.

Lack of support infrastructure

Lack of support infrastructure could pose a major constraint to the commercial development of NTFPs in Botswana.

Many NTFPs are found in the more rural areas and as such transporting the products to the major markets could be a problem. The actual marketing could also be a constraint.

Analysis of *Schinziophyton rautenenii* (mongongo) 100g
Source: Wehmeyer, 1980)

	Dry flesh	Kernel
Ash	5.6g	4.1g
Protein	9.4g	26g
Fat	1.2g	57.3g
Fibre	2.5g	2.5g
Sucrose	29.8g	-
Glucose	0.2g	-
Fructose	0.5g	-
Carbohydrate	72.9g	5.9g
Energy	1424KJ	2692KJ
Calcium	104mg	193mg
Magnesium	266mg	527mg
Iron	4.3mg	3.7mg
Copper	1.6mg	2.82mg
Zinc	1.79mg	4.09mg
Sodium	1.86mg	3.1mg
Potassium	2666mg	673mg
Phosphorous	62mg	845mg
Thiamine	0.49mg	0.31mg
Riboflavin	0.21mg	0.21mg
Nicotinic acid	4.79mg	0.32mg
Vitamin C	14.7mg	-
Vitamin E	29mg	
Vitamin E	536mg	
Moisture	8.4g	4.2g

The limited access to technology could pose a problem in producing a product that is acceptable to both the national and international markets. If NTFPs are to be successfully commercialised then it is essential that a reliable buying and marketing network is established.

However, perhaps the biggest constraint is the lack of information on Botswana NTFPs; there is no database outlining the resource base of NTFPs and research is lacking. What research has been carried out appears to be uncoordinated and the dissemination of research information is distinctly lacking.

It is not possible for government, or other policy makers, to determine what the sustainable yields for specific NTFPs are if the actual resource base is not known. This is a major constraint and further research needs to be carried out on this issue before any commercialisation/management programme can be successfully implemented.

SUMMARY

NTFPs possess great potential for improving the long term quality of life in rural areas and also for reducing the current levels of land degradation. The above outlines the absolute necessity of a holistic approach to NTFP management, every issue is interrelated and the utmost caution must be taken to pay attention to the links between different issues.

Any commercialisation programme of natural resources is fraught with dangers, but with a thorough, holistic approach the dangers can be overcome and the benefits can be great.

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BREEDING NEW KIWIFRUIT CULTIVARS:

THE CREATION OF HORT16A AND TOMUA

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With the recent introduction of the two new kiwifruit cultivars Hort16A and Tomua, it is important we don't lose sight of the years of scientific research that led to their development. It is also important to properly document their origins and to acknowledge some of the key people involved in their development. This article outlines the history of the kiwifruit breeding programme in New Zealand that produced Hort16A and Tomua.

Introduction

Until recently, all the kiwifruit plantings in New Zealand were derived from a single introduction of seed from China in 1904, one very limited sampling of the gene pool. The export industry began with several cultivars but rapidly developed into a monoculture, based on one female cultivar, Hayward, selected over 60 years ago.

Other countries that grow kiwifruit have also mainly used the cultivars developed in New Zealand. Therefore, the world kiwifruit industry has relied on one fruiting cultivar. Such a situation has several negative aspects, including potential for pest or disease epidemics, logistics of a single short intense harvest season, competition among Southern Hemisphere producers to have the first fruit of the new season in the marketplace, and decreasing ability to maintain product differentiation based on quality.

These shortcomings were recognised and foreseen by researchers from the Department of Scientific and Industrial Research (DSIR) quite early in the life of the industry. DSIR started a breeding programme in the mid 1970s with the general aim of strengthening the industry by selecting and developing improved new cultivars or strains of kiwifruit, ultimately leading to greater diversification.

Dr Ted Bollard brought *Actinidia* seed back to NZ as a gift from the Beijing Botanical Gardens in 1975, while on a brief trip to China. His visit was followed up by Dr Don McKenzie in 1977, who returned with *Actinidia* seed from both China and Japan. Resulting seedlings were planted out at the Te Puke Research Centre in the Bay of Plenty.

Seedlings from crosses were planted initially at Te Puke and then Kumeu, Auckland by Dr Ron Davison and Russell Lowe, and a year or so later at Riwaka, Nelson by Dr Ron Beatson. Plantings at Kumeu were supplemented by further Actinidia accessions obtained by Drs Ron Davison and Michael Lay-Yee on their study visit to China in 1981.

Initially it wasn't easy for DSIR researchers to convince the kiwifruit industry that it needed a long-term breeding programme. The industry was in its infancy, Hayward was the perfect variety on many counts, growers were very optimistic, and early pioneers were receiving high prices for their fruit.

It was only through the establishment in the early 1980s of a Scientific Advisory Committee that it became possible for the DSIR to convince industry of the benefits of contributing to a long term breeding programme. The industry also provided considerable assistance to purchase additional land at Te Puke to grow more seedlings, and gradually increased their annual contribution to the research from the mid-1980s onwards.

Several approaches were followed as part of this formal breeding programme:

Selection of Hayward mutants or sports

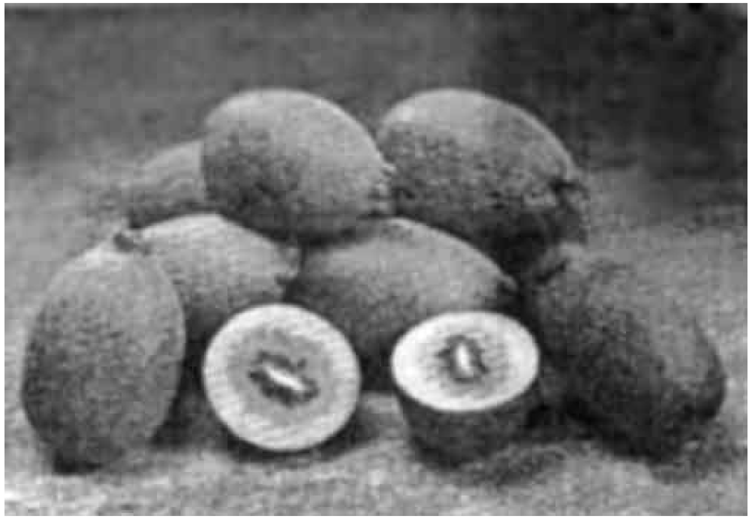
As with other fruit crops there is spontaneous natural mutation occurring at a low frequency within the kiwifruit population. Such mutations often affect no more than a single bud so that at first, only part of the vine may show a change. These changes away from the standard Hayward type are usually small, but nevertheless, can sometimes represent significant improvements. Growers (in the 1980s) were encouraged to keep an eye on their vines and notify researchers of any naturally occurring sports. Scientists also irradiated Hayward scionwood to increase the mutation rate. The aim of this project was the selection of an improved Hayward.

Seedling selection from open pollinated populations and controlled crosses

Much greater genetic variation occurs within seedling populations produced by open pollination or controlled crossing. Almost all the progeny are inferior to Hayward or other cultivars, but some show improved fruit or vine characteristics. By using a recurrent mass selection process in which vines with these improved characteristics are used as parents for the next generation, a continuous improvement of the breeding population is possible. Selection efficiency can be improved by genetic studies to identify parents with good breeding values for desirable characteristics. Selections were made with the aim of developing cultivars that were superior to Hayward for the fresh fruit market.

Use of other Actinidia species

There are at least 60 *Actinidia* species described in the literature. Until recently only *A. deliciosa* has been grown as a large commercial crop. There are several other species with potential as crops in their own right, and there is also the possibility of obtaining a completely new crop through interspecific crosses. This would allow diversification within the industry. Collections of plants from a number of different *Actinidia* species and of selected kiwifruit material were established at DSIR research orchards for closer evaluation.



The golden flesh of Hort16A has a sweet, tropical flavour and a melting texture when ripe. Photo: HortResearch

Some of the selection criteria for the kiwifruit improvement programme include:

• improved fruit characteristics, e.g. more regular shape, larger, more consistent size, absence of Hayward mark, reduced hairiness with a smoother, more attractive skin, resistance to windrub, different flesh colour, higher vitamin C content, smaller internal core, earlier maturity giving an extended harvesting season;

• reduced vine vigour. The pruning of vines, especially the regular summer pruning, is the main labour input in kiwifruit management;

• greater climatic adaptability, eg reduced water requirement, greater wind resistance, increased cold hardiness, reduced requirement for winter chilling;

• precocity, ie a reduction in the time required for newly planted vines to come into bearing. This would also be of significant advantage in breeding programmes;

• improved flower characteristics, eg more intensive flower bud initiation and burst (ie higher yield), better overlap of flowering in male and female cultivars, greater attractiveness to bees, hermaphrodite flowers that are self-setting; and

• disease resistance, both of roots and storage rots of fruit.

Origin of Hort16A

Dr Mark McNeilage made the cross which ultimately led to the selection of Hort16A, at the Kumeu Research Orchard in October 1987. The cross was between a female and a male derived from two seed introductions of *A. chinensis*, CK01 and CK15, obtained from China in 1977 by Don McKenzie and in 1981 by Ron Davison and Michael Lay-Yee. The female parent was identified at harvest in April 1987 as having small ovate fruit (average weight

40 g) with good flavour and pale yellow flesh. The male was selected because of its female siblings' superior fruit size. The objective of the crossing was to combine fruit size, good flavour and yellow flesh.

Seed from these crosses was the first to be put through the 'fast-track' procedure initiated by Dr Mark McNeilage and Sigrun Steinhagen. Seed was extracted in April 1988, given a dormancy-breaking cold treatment, and germinated. The resulting seedlings were grown with heat and light treatment (to simulate long-day growing season conditions) in a glasshouse over the 1988 winter, and 605 seedlings were planted out at the Te Puke Research Centre in November 1988.

Russell Lowe and Hinga Marsh selected the Hort16A seedling in 1991. It was included in a replicated clonal trial in 1993 and small-scale grower trials under contract began in 1995. The selection has performed well in trials, with good yields, fruit size and sensory attributes. In 1995 HortResearch applied for Plant Variety Rights under the name Earligold. However, the appropriate harvest period for good development of colour and flavour has proven to be not early, consequently the denomination Earligold was abandoned, and this cultivar was renamed Hort16A. The commercial name has yet to be decided.

Vines of Hort16A grow vigorously and rapidly establish a fruiting canopy within two seasons after grafting. Several growth flushes occur from spring to late autumn and this growth must be managed carefully to avoid a jungle of tangled growth. Flowering occurs two to three weeks before Hayward, and the harvest period is in mid-May, similar to Hayward.

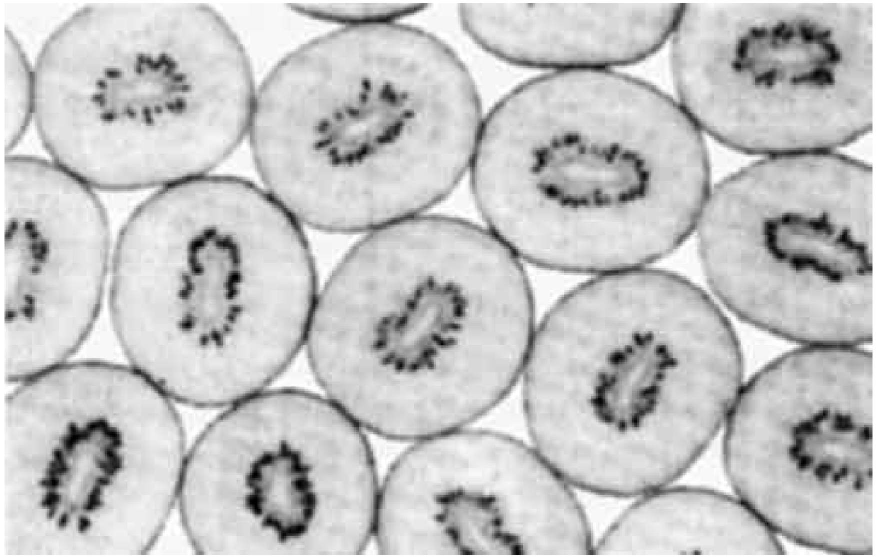
The distinctive, ovoid-shaped fruit appear hairless, but are covered with a very fine downy hair. The stylar end of the fruit protrudes significantly which is different to that of the rounded end of Hayward. The golden flesh has a sweet, tropical flavour, which has a melting texture when ripe. The flavour has an instant appeal to most consumers even those who do not usually eat the green-fleshed Hayward. The vitamin C content of Hort16A is up to 50 percent higher than Hayward.

Hort16A is the first yellow-fleshed cultivar available in New Zealand. Whilst a number of other selections are being trialled by HortResearch it is likely to be many years before any of these are made available to growers.

Origin of Tomua

Another cultivar released recently from the kiwifruit breeding programme is Tomua. It is derived from an *A. deliciosa* accession obtained from China in 1975 by Ted Bollard. The resulting seedlings were identified in the early 1980s as having early flowering and early maturing (but small) fruit. Russell Lowe made crosses between early flowering males from this accession, and early maturing and Hayward females. Seedlings from these crosses were planted at the Te Puke Research Centre in 1985.

In 1989, large-fruited, early maturing individuals were selected and propagated by Russell Lowe and Hinga Marsh. In 1990, four of these and another selection from Riwaka were planted in a trial at the Te Puke Research Centre. Two of these early maturing selections were also included in a regional trial of large-fruited selections. From these trials, Tomua was fast tracked and planted in small-scale grower trials in 1993.



Fruit of Hort16A have a distinctive, ovoid shape with a protruding stylar end which is quite different to the rounded end of Hayward. Photo: HortResearch.

This selection has continued to reach harvest maturity two to four weeks earlier than Hayward, depending on the site. In 1995 HortResearch applied for Plant Variety Rights under the name Tomua (meaning early in Maori). The commercial name for this cultivar has yet to be decided, although it is being marketed as Early Hayward.

Tomua vines have a similar appearance and growth habit to that of Hayward, although spring growth and flowering occur two weeks earlier in the season. Growers have commented that Tomua is slightly easier to manage than Hayward due to its moderate growth habit. Fruit shape is slightly more tapered than Hayward, with a similar external appearance although the hairs are quite easily removed with light brushing. Flesh colour is emerald green and the flavour is slightly sweeter than Hayward.

The storage life of Tomua fruit is shorter than that of Hayward fruit, although adequate for an early-season cultivar. Vitamin C content is similar to that of Hayward.

Pollination

Existing pollenizers for Hayward are ineffective for Hort16A and Tomua as they flower too late to coincide with the females. Two pollenizers have been selected for planting with each of these new cultivars.

Males selected for Hort16A are named Meteor and Sparkler. Meteor is slightly earlier flowering than Sparkler to give a good spread of flower. Each male carries an amazing flower load, which almost obscures shoot growth over flowering.

Males selected for Tomua are named King and Ranger. They coincide well with the female flowering period and have very large sized flowers comparable to that of the female.

All cultivars, both females and males, are protected by Plant Variety Rights in New Zealand and are licensed exclusively to the New Zealand Kiwifruit Marketing Board. Applications for PVR or Plant Patents are also underway in other significant kiwifruit growing countries to protect the considerable investment made in research and development.

Summary

Hort16A and Tomua are the first two cultivars to be released from the HortResearch kiwifruit breeding programme. There is great hope and promise that these new cultivars (and those still underdevelopment) will revitalise the New Zealand kiwifruit industry as the leader in developing, producing and marketing innovative new varieties.

Acknowledgements

HortResearch appreciates the valuable financial and other assistance given to it by KNZ in the development of these cultivars. To Paul Glucina and Ross Ferguson for their constructive comments on this manuscript.

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HortResearch: <A 1250>

The Orchardist: <A 1759>

THE SOUTH AMERICAN SAPOTE - *QUARARIBEA*

WILLIAM F WHITMAN

The South American sapote (*Quararibea cordata* Visch.) was introduced into South Florida from the Amazon Basin in 1964. The first crop of large "top-shaped", orange-fleshed fruit appeared nine years later. This medium-size ornamental tree, with big bold attractive "lollipop" shaped leaves, appears adapted to our warmer areas where several specimens now fruit regularly. It is thought that this interesting fruit from South America warrants further planting, both for the beauty of the tree and the quality of the sweet mango-melonlike flavoured fruit.

The South American sapote is in the family Bombacaceae along with the kapok (*Ceiba pentandra*), the balsa (*Ochroma lagopus*) and the durian (*Durio zibethinus*) of the Asiatic tropics. According to Hodge (1), "*Quararibea* is, to my knowledge, the only New World genus of the family producing an edible fruit."

The tree is indigenous to northwestern South America, where its range in elevation extends from the lowlands to over 1500 metres. Popenoe (2), describing the fruit under the Latin name *Matisia cordata*, observed it as one of the common fruit trees of the Ecuadorian lowlands.

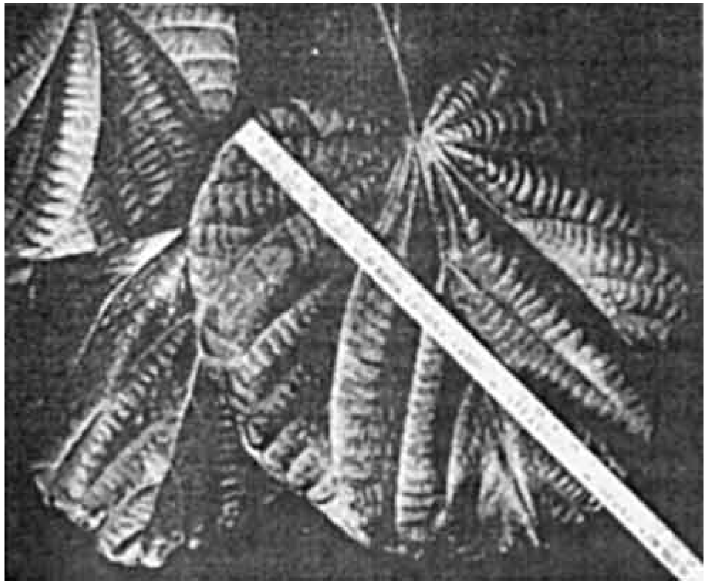

Fig. 1. Florida South American sapote leaf 52 cm across. Photo: Wm. F. Whitman

In its natural habitat *Quararibea* is reported to be a medium-size tree with a rounded crown reaching a height of about 11 m. The upright cylindrical grey brown trunk can be devoid of branches for over half its length. Large 15-30 cm, deep green above, lighter green below, cordate leaves (Fig. I) with prominent coarse veins are borne in terminal clusters on the ends of stiff branches. The cream-coloured cauliflorous flowers (Fig. 2) appear in random patches among the smaller branches of the inside growth. These are 2.5 cm in diameter by 10 cm long, including the stem. Eight months after blooming the 'top-shaped' brownish green sapotes mature. These large pear-size fruit (Fig. 3) are firmly attached to the branches by a short stout stem. Upon ripening the heavy, persistent calyx contracts slightly, displaying a perimeter of lighter coloured skin which it formerly covered. The thick leathery pubescent peel surrounds an orange coloured pulp containing two to five 4-cm long hard seeds with attached fibre similar to that of the mango (*Mangifera indica*). Popenoe (2) described the fruit as having a sweet and pleasant taste. Hodge (1) speculated "It (the South American sapote) is undoubtedly tender and would probably not thrive in subtropical areas like southern Florida."

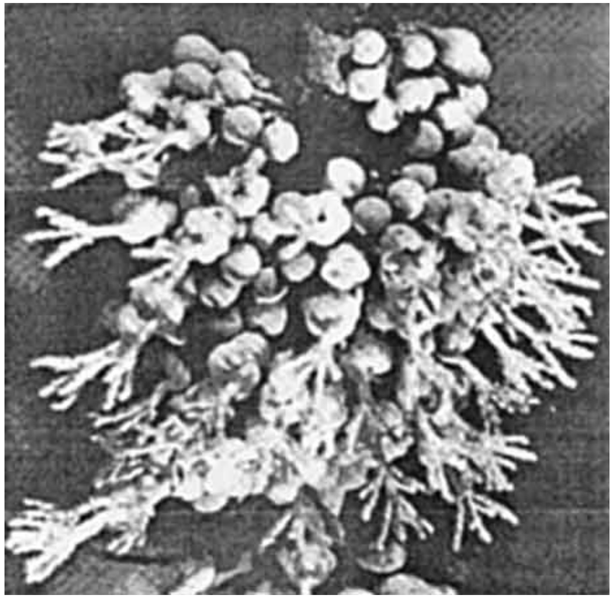

Fig. 2. Cauliflorous bloom of Quararibea cordata. Photo: Wm. F. Whitman

Seeds of the South American sapote were introduced into South Florida in 1964. These had been obtained, at the request of the writer, through Lee Moore from trees in the Amazon Basin at Iquitos, Peru. The resulting Florida grown seedlings were later distributed among various members of the Rare Fruit Council International as a new introduction for further trial and observation. First fruiting occurred in 1973 on a tree grown in Miami by Bernard C Bowker.

There are now several additional bearing specimens of the South American sapote in Dade County, Florida. One of these, in the yard of the writer, is 7 m high with an 8.5 m spread and a trunk diameter of 30 cm near ground level. Although Williams (3) writes of buttressed trunks, this tree is showing only a slight tendency in this direction. There are no limbs for the first eight feet then branches appear in groups of five equidistantly spaced around the trunk in the same plane. These radiate out and ascend at varying angles of inclination from nearly horizontal to about 60 degrees. This branching pattern is repeated at four to five foot intervals with bare trunk in between. The tree has a spreading growth pattern with heavy dense foliage dropping to within a foot or so of the ground. The leaves, up to 55 cm across, tend to thin out in winter. Their petiole is long, measuring about two thirds the leaf's width.

In South Florida the *Quararibea cordata* should be grown in full sun, and under favourable conditions can increase in height at a rate of 60 cm or more per year. First fruit set for a young tree can be preceded by three or more unsuccessful annual flowerings. This bloom occurs during mid-winter, with the resulting crop ripening the following November. Eight or more of the 11-cm diameter sapotes can be clustered around a foot or less of branch, although usual fruiting patterns are more dispersed. The writer's tree, previously described, currently is carrying 58 of the "mango-melon" flavoured fruit.

The South American sapote will grow and fruit under both acid and alkaline soil conditions, although it prefers a lower pH than that usually occurring in Dade County. Temporary defoliation can be caused by cold weather, and young trees should be protected from low temperatures. The tree is subject to attack by the Keys White Fly (*Aleurodicus dispursus*) and the Cuban May Beetle (*Phyllophaga bruneri*), a scarab beetle that has been known to strip it of foliage. It is possible that the Amazon Basin South American sapote is a superior strain compared to those occurring in other areas. This may account for the larger leaf size and the bigger, less fibrous fruit appearing on Florida grown seedling trees which originated from this 1964 Amazon introduction.

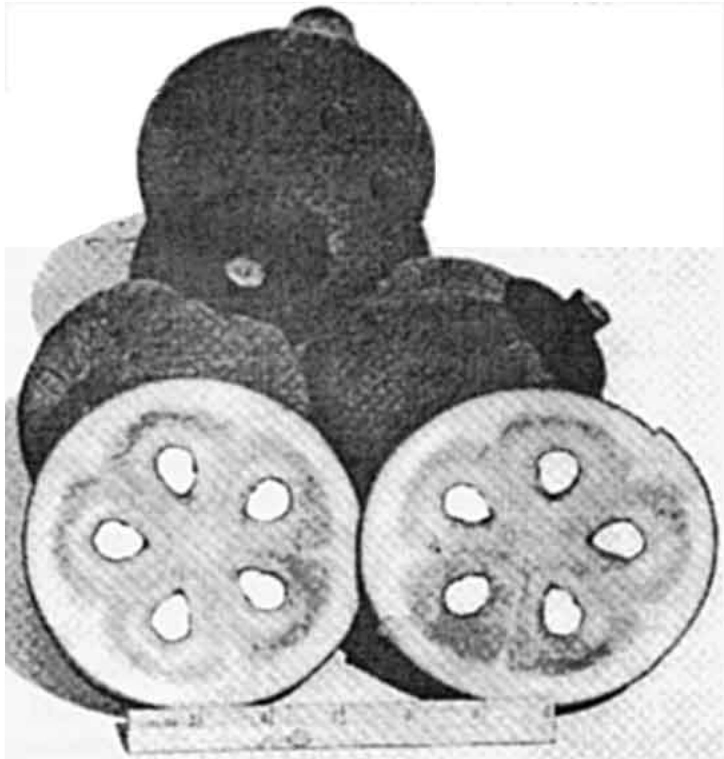

Fig. 3. Dade County grown South American sapote nearly 12 cm in diameter. Photo: Wm. F. Whitman

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2. **Popenoe**, Wilson. 1924. *Economic fruit-bearing plants of Ecuador*. Contrib. U.S. Nat. Herb. 24: 122.
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Metric conversions by the Tree Crops Centre.

Based on an article which first appeared in 1976, in the Proceedings of the Florida State Horticultural Society (Vol. 89, p. 226-227). William Whitman's address was that of the Rare Fruit Council International.

Rare Fruit Council International: <A 1475>

THE MYCORRHIZAL CONNECTION:

THE CHEMICAL FIX, THE NATURAL SYSTEM OR A BIT OF BOTH?

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The use of naturally occurring mycorrhizae, fungi symbiotically associated with most of the plant world, could lead to some of the biggest breakthroughs in the nursery industry for decades.

The fungi, usually destroyed in the preparation of potting mixes or through the use of pesticides and other chemicals, have an amazing number of benefits. They protect against disease and water stress, advance flowering, contribute to soil aggregation and stability, combine with soil bacteria to enhance plant growth-and provide food for use by these organisms. In addition, they also have positive effects on the acquisition of phosphorus, important for plant nutrition.

The new technology could result in nurseries having the best of both worlds. Some reliance may still be placed on selected chemicals, but under a regime that supports a biologically active ecosystem. The inevitable outcome would be a reduction not only in costs, but also in chemical use and leachate - and most importantly, lead to more robust plants.

For more than 20 years, it has been shown that under some natural systems, nutrients are used more efficiently, plant growth is enhanced and the activity of pathogens and even nematodes are reduced to acceptable levels. Only a minimum application of pesticides is necessary.

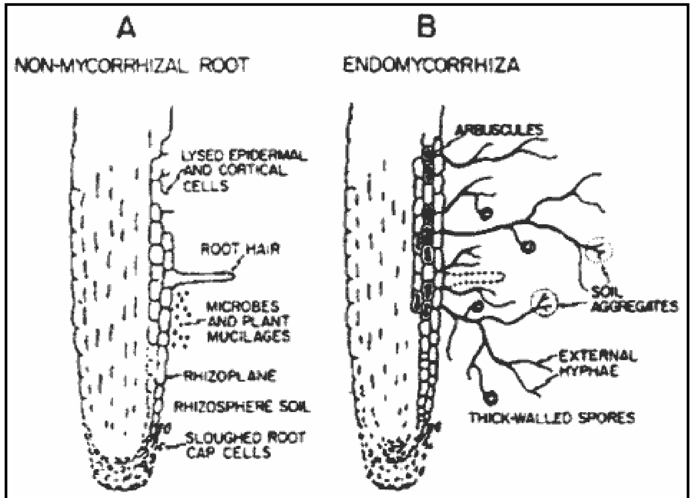
Most natural systems at present seem complicated and unpredictable, simply because they have not been studied closely enough. Apart for some rare exceptions, they have not been attractive enough to be adopted by industry.

Unfortunately, short-term returns on investment into natural systems have not shown the profitability of the chemical option - fertilisers, pesticides, herbicides. This is reflected in the paucity of funds for research into natural systems compared with those available for chemical agriculture.

However, there is now increasing interest throughout the world on how to better manage the biological environment and offset continuing reliance on chemicals. In some cases, communities have insisted that current practices be modified. Putting natural strategies in place becomes even more urgent as chemicals are withdrawn.

What are mycorrhizae?

The somewhat daunting scientific term mycorrhiza is derived from the Greek **mykos** meaning mushroom and **rhiza** meaning root. Simply stated, it describes an association between a fungus and a root that is beneficial to both the organisms. Such an association may be regarded as a symbiosis.



A. Non-mycorrhizal root. B. Endomycorrhiza. From Linderman, 1988

The fungal component has been around for at least 400 million years. Some ecologists believe the organisms were instrumental in the evolution of plants from the aquatic to the more stressful land environments.

It is therefore not surprising to learn that most plants growing in their natural environment are mycorrhizal. Only a few plant families do not have this relationship (see below).

How the symbiosis works

Ectomycorrhizae form associations mainly with temperate tree species (oaks, pines, and birches), while endomycorrhizae are found on most plant species, including agricultural and horticultural species and most of those grown in nurseries.

There are more than 150 different species of endomycorrhizal fungi. They are found within plant roots as hyphal networks of very fine threads connected to nutrient transfer organs (arbuscles) and oil filled storage organs (vesicles). They may be referred to as vesicular arbuscular mycorrhizae or V AM for short.

The hyphal network extends into the surrounding soil, often well beyond that tapped by root hairs. This network is able to pick up nutrients, particularly phosphorus and zinc, which are out of reach of the plant itself, and transport these back to the plant.

These nutrients are made available to the plant via the transfer organs. In exchange, the plant provides all the fungus' energy requirements in the form of sugars again via the transfer organs. This mutually beneficial association is called a symbiosis.

The fungus produces asexual spores mainly outside the root, and these, plus bits of hyphae and vesicles, are able to infect other root systems. While the fungus is completely dependent on the plant for its growth, it will remain infective in the soil (or as dried root inoculum or spores) for some time after plant death. This infectivity declines with time.

All it takes is a pinch of this inoculum placed underneath a mycorrhizal receptive transplant to ensure mycorrhizal infection (provided the medium soil is compatible and is not heavily fertilised and drenched with fungicide). With some basic knowledge and attention to hygiene, it is relatively easy to produce inoculum.

The following chemicals have been found not to be significantly injurious to endomycorrhizae:

• Resin coated slow-release fertiliser (8-6-12, eight months) at the lowest recommended rate, and also as a supplemental. Other soluble nutrients can be used but not at rates that exceed immediate plant demands.

• Many fungicides may be injurious but metalaxyl, mancozeb, and copper sulphate have been used successfully at the Tree of Life Nursery in the United States. The root-inhibiting paint that is used to prevent root accumulation at the edge of the pot does not appear to reduce mycorrhizal growth. However, these chemicals should be tested for their effect on mycorrhizae in the local environment before being applied on a large scale. Until more experience is gained, their safe use must be assessed locally.

• Many organic media are suitable but some peats may depress colonisation. Testing is recommended. Most commonly used mycorrhizal fungal species colonise well at pH of 6.5.

• Excessive soil temperature is damaging. Pasteurisation at 60° C for one hour will eliminate mycorrhizal fungi. In contrast to most other root fungi, including ectomycorrhizae, endomycorrhizae do not change the appearance of the root system and their structures are not visible to the naked eye.

This may be one reason why they have been largely disregarded by many practitioners. However, they can be seen with a microscope within the root, after treatment to remove the cell contents, and then stained to show up the fungal structures. The presence of these structures will confirm that the fungus is a mycorrhiza and not a pathogenic fungus.

Absent from nurseries

Mycorrhizal associations, common in nature, are rarely found in nurseries, unless there is fortuitous contact with the underlying soil (Galea and Poli, 1993). The use of composted, pasteurised or sterilised soilless mixes, high levels of fertiliser and the regular application of fungicidal drenches not only keep plants well nourished and free from disease but also conspires to keep the fungi out.

Conscientious attention to nursery hygiene further minimises their accidental entry. The question is: What do normally mycorrhizal plants miss out on in a non-mycorrhizal environment, whether it be in the nursery or after planting out into the landscape?

World conference

Almost 500 delegates attended the first world conference on mycorrhizal technology at the University of California in 1996. Among them were more than a dozen Australians, including Mal Hunter and Dr Vic Galea, a research scientist at the University of Queensland's Gatton College. Australia has 5% (65) of the world's 1154 registered mycorrhizae specialists, ranking fourth in numbers per country.

A total of 88 plenary papers and oral presentations were delivered. Another 326 poster papers were hung. Information provided suggests mycorrhizae are beneficial because they:

• aid plants' protective reaction to disease (*Phytophthora, Fusarium, Pythium*);

• advance flowering;

• improve plant ability to withstand water stress;

• contribute to soil aggregation and soil stability;

• provide food for use by beneficial soil organisms;

• provide a framework for beneficial soil bacterial colonisation; and

• combine with certain soil bacteria to enhance plant growth.

In addition, the fungi have well known positive effects on plant nutrition, particularly in the acquisition of phosphorus.

Effect of nursery media

The activity of mycorrhizae is significantly affected by the organic components of nursery media, but the response is specific to both medium and fungus (Linderman and Davis 1996). This suggests that media must be checked before being used to support mycorrhizal plants.

The establishment and growth of Sturt's desert pea (*Clianthus formosus*) in a soilless medium was greatly enhanced by the presence of either the mycorrhizal species *Glomus intraradicies* or *Scutellospora pellucida* or a blend of *G. mosseae* and *G. etunicatum* (Poli and Galea 1996). Thus the use of mycorrhizal inoculum may provide a solution for hard-to establish species.

The mycorrhizal species *Glomus intraradicies* significantly improved the growth of miniature roses in soilless media even under high nutrient conditions. This confirms observations that some mycorrhizal species are active despite high nutrient levels. However, most are greatly suppressed under these conditions. For example, *Scutellospora pellucida* had inconsistent effects (Poli and Galea 1996)

Studies suggest mycorrhizal plants further benefit from the symbiosis when planted out into low nutrient or heavily disturbed or degraded sites.

Research

About 7S% of mycorrhizal (ecto and endo) research is being done by or is associated with universities. The rest is conducted at government institutions, apart from less than the 3% done by private organisations. Much of the research is focused on the symbiotic association at the cellular level. Relatively little attention is paid to field applications. Ecological studies, some quite excellent, highlight the relevance of mycorrhizae to stable ecosystems.

While a few papers reported the practical application of mycorrhizae to horticulture and agriculture, there are still only a few examples of routine inoculation of plants with mycorrhizae. Mycorrhizal management is still not generally perceived by these industries as a significant issue.

However, conference participants agree mycorrhizae have a major role to play in reducing reliance on pesticides for the control of soil-borne pathogens: and that this should be promoted together with the well documented role of mycorrhizae in the efficient uptake of phosphorus and other nutrients.

The theme adopted by the conference organisers, to bridge world information gaps on mycorrhizae, also extends to the future role of the fungi in linking the chemically dependent present to a more natural system. This is an important message to extend to industry.

US specialist

Bob Linderman from the United States Department of Agriculture, Corvallis, is the leader of the Horticultural Crops Research Laboratory. Since 1973, he has been studying the interaction of mycorrhizae and soil-borne diseases.

Since then, his output has been prolific. He has produced a host of papers and at least 14 important review articles dealing with the interaction. In 1983, Linderman and Brenda Biermann published a pivotal paper that highlighted the compatibility problems of potting media and mycorrhizal colonisation.

At the conference, Linderman gave an oral presentation and presented or co-presented three posters. Linderman's views on the role of mycorrhizae in the ornamental industry are shared in part, at least, by Davis (1982), Cooper (1982), Johnson (1982), St John and Evans (1990) and Galea and Poli (1993).

In his latest review article 'Managing soil-borne diseases: the microbial connection' (1995), Linderman said soil microbes undoubtedly limit the incidence and severity of root diseases, and future innovations will allow them to be exploited to reduce root diseases more effectively.

"Mycorrhizal fungi are a key component of the rhizosphere microbial composition and processes, and managing the rhizosphere for disease suppression should involve them and their antagonistic microbial associates," he said. "Applying such microbial combinations or encouraging an increase in their indigenous populations and function by specific production practices should lead to more effective management of soil-borne diseases. Concepts and strategies that are being developed are reasons for optimism regarding the management of soil borne diseases."

The writer believes the Australian nursery industry can convert such a perspective into a reality to the advantage of itself and the community.

US example

Early in 1996, Mike Evans, one of the principals of Tree of Life Nursery, near Los Angeles in California, presented a paper to the International Plant Propagators' Society conference in Melbourne on the commercial use of mycorrhizae.

The Tree of Life Nursery grows about 400 Californian native species or varieties, principally for habitat restoration (specific site provenance), as well as propagating rare and endangered species. The nursery, which is probably unique in its adoption of mycorrhizal technology, consistently wins tenders for large revegetation projects.

Bob Linderman of the United States Department of Agriculture, at Corvallis, is pictured among his mycorrhizae experiments

Evans routinely inoculates all his transplants with mycorrhizal inoculum. This enables him to reduce fertiliser input and use pesticides sparingly. He only uses those that have minimal effect on mycorrhizae. His chemical bills are down and his plants are healthier. Evans is convinced that mycorrhizae are the key to successful plant establishment in rugged sites.

Ted St John, a qualified (PhD) ecologist retained as a part-time consultant to the nursery, was the person responsible for convincing Evans and his coprincipal, Geoff Bohn, that mycorrhizae "are the way to go". He has written a number of short extension articles on the practical management of mycorrhizae in nurseries (St John and Evans 1990, St John 1994, St John 1995).

St John developed an integrated ecosystems method which "unifies the soil biota with plants, integrating above and below ground ecosystems for the specific conditions of the restoration site".

St John suggests that plants be inoculated with mycorrhizae if:

- the species is mycorrhizal in nature;
- they are to be planted out into soil containing inadequate amounts of native inoculum;

or

- they will not receive regular maintenance.

By contrast, he recommends no inoculation if:

- the plant is a non-host or only mildly dependent on mycorrhizae;
- the soil site contains abundant native inoculum; or
- the plant can be assured of a high level of maintenance.

In his 1990 paper with Mike Evans, St John says mycorrhizae form a natural bond with most plant species and that they aid uptake of nutrients and enhance drought resistance. He also says that while they may provide immediate benefit to the nursery, the primary objective should focus on their value after planting out. He adds that while it is simple to inoculate plants, changes in cultural practices may have to follow, for example, reducing chemical inputs and creating conditions favourable for the mycorrhiza.

Information on these and other aspects of mycorrhiza can be accessed on St John's web site: www.prtcl.com/tol/home.htm.

Availability of inoculum

Commercial mycorrhizal inoculum production is a key issue. The availability of viable material of a named species or mixture, free of disease organisms and in a form that can be easily handled and applied at minimum volume and weight is crucial. Costs can be as low as two to three cents per inoculated plant. In the United States the following companies produce mycorrhizal inoculum: • Tree of Life Nursery, 33201 Ortega Highway, PO Box 736 San Juan Capistrano, California 92693. It supplies more than 400 mycorrhizal Californian native species, as well as producing root and medium based inoculum for on-site inoculation.

• Plant Health Care, 440 William Pitt Way, Pittsburgh. It produces Mycor Tree(TM) and supplies mycorrhizal seedlings, native shrub and grass species. This company also produces an all-spore inoculum of a number of mycorrhizal species.

• Premier Tech, 454. Temiscouata, Riviere-du-Loup (Quebec), Canada G5R 4C9. Produces inoculum of *Glomus intraradicies* in a medium of perlite and sphagnum peat, with a guarantee of 2100 propagules-per-litre plus a use-by date. The inoculum is sold as MycoriseTMHX.

• BioScientific Inc, 4405 S. Litchfield Road, Avondale, Arizona 85323. Produces inoculum (MycoRISETM) as a liquid formulation containing viable spores and infective propagules of *Glomus intraradix*.

It is unlikely that inoculum produced overseas can meet the stringent quarantine regulations for direct import into Australia.

The author does not know of any commercial producer of mycorrhizal (endo-) inoculum in Australia. However, Dr David Jasper, director of the Centre for Land Rehabilitation, University of Western Australia (phone: 08 9380 2635) is able to produce inoculum on demand for trial purposes, with a three-to-four month lead time. Hopefully, once a large enough market develops, commercial production will commence.

Some plants do without

Mycorrhizae are rare or absent in the following plant families. Some of these include important nursery species:

Aizoceace, Amaranthaceae, Bromeliaceae, Brassicaceae, Commelinaceae, Chenopodiaceae, Caryophyllaceae, Cyperaceae, Ericaulaceae, Fumariaceae, Hydrophyllaceae, Hyrocharitaceae, Juncacea, Lentibulariaceae, Lecythidaceae, Nyctaginaceae,Orobanchaceae,Phytolaccaceae,Proteaceae,Podostemaceae.Portulacaceae, Polygonacea, Papaveraceae, Rhizophoraceae, Restionaceae, Scrophulariaceae, Sapotaceae, Urticaceae, Zygophyllaceae. (After Brundrett 1991).

The importance of media compatibility

It is known that some potting media suppress mycorrhizal colonisation, but the formation of specific guidelines that apply to particular media is not currently possible. This is a major deficiency since the adoption of mycorrhizal technology will only succeed if compatible media is used.

Nursery operators who wish to test this technology must do so with the appropriate media. To do otherwise would greatly mar the adoption process, in some cases irrevocably.

Currently, the compatibility of 22 commercial media is being studied. More specifically, peat, bark, pine sawdust and coir media, amended with either sand or zeolite and supplied with two levels of nitrogen and phosphorus. In the peat and pine sawdust media, another four levels of phosphorus have been included. Sunflower is being used as the test species because it grows rapidly, is highly mycorrhizal, and its reaction to phosphorus has been extensively studied.

From these and other studies on the composting age of media, a practical test is expected to be developed for assessing the mycorrhizal computability of potting media. This Horticultural Research and Development Corporation (HRDC) funded research is being carried out at the Centre for Amenity Horticulture.

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