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CONTENTS

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Santalum album: flowering branch; also flower and fruit, enlarged.

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CONTENTS

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BASE-UP TREE CROP DESIGN —

DESIGNING NEW TREE CROP VARIETIES USING NATURE, LOGIC, GENETICS, AND FAMILY CONNECTIONS

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Abstract

Derivation of new varieties of nuts, fruits, and other tree crops has until now been an essentially ad hoc process, using plant materials available to hand.

This paper proposes a new approach to the process, operating from the base up. It starts by asking what are the most desired characteristics of the plant product, and brings in a range of techniques to create varieties with these properties.

All of the techniques used are well established, and although some genetic knowledge of the crop is involved, they do not involve 'genetic engineering' in the modern popular sense.

Application of the Base-Up approach has the potential to create startlingly advanced varieties of plant species which bypass many of the industry limitations of conventional crops. Not only might a better product be available, it might carry with it savings which render conventional varieties economically redundant.

Examples will be outlined of application of Base-Up to crops such as coffee, pecans, almonds, pistachios, dates, avocados, and argan.

Background

In the distant past, new tree crop varieties were invariably the result of selecting and propagating plants thrown up in the view of the user by chance. Mostly these were the result of sexually-produced seeds which happened to have good combinations of genes from their parents, although some could have been bud sports, the result of chance mutations at a growth point.

Once the mechanics of plant genetics was worked out in the 1800s, the possibility of intentionally breeding new varieties of plants by crossing was realized. Since then, the techniques involved have been greatly improved and refined.

In the area of tree crops, where the subject plants are long-lived perennials, many new

§ Member, WANATCA

varieties are still the result of chance variations noticed by orchardists and nurserymen. Even for the rest, where scientific breeding principles are followed, there is still the tendency to use ad-hoc principles.

For example, an apple breeder seeking to produce fruit of better appearance or flavour, or apple trees with improved disease or drought resistance, will use a combination of materials to hand which have some of the desired characteristics in different varieties. The aim is to produce a combination plant with all the desired characteristics in the one variety.

There is a different way, and that is the subject of this paper. With Base-Up Design, the approach is to say what characteristics would we like in a particular crop, and how might we generate them?

"What characteristics would we like in a particular crop, and how might we generate them?"

Here I'll be going into both these aspects, and I'll start with the second aspect first. Techniques. Once we have an idea what the possibilities are from particular techniques, we will be better able to see how they might be applied to particular crops.

None of the techniques I'll be referring to are particularly new, although some of them are not widely appreciated. We'll start off with Polyploidy, and to understand this, we need a little simple genetics.

Polyploidy

Typical plant cells each contain two different variations of each of the chromosomes which define them, one variant from each parent. They are called 2n plants or diploids. In normal growth, each cell divides in half, splitting each chromosome down its double helix, and the cell mechanisms match the halves with matter reserves so that both new cells also contain 2n chromosomes each.

When a plant is making sex cells (pollen or ovules), however, a different mechanism comes into play and these cells contain only half the double set of chromosomes. These are 'n' plants or haploids. When an ovule is fertilised by a pollen grain, the resulting embryonic cell again contains 2n chromosomes, but these are a random set derived from both parents. All this is a simple case, there are many more complex ones.

Plants can be found, or made, which contain more than 2 sets of chromosomes in each cell. They are called polyploids, and have a number of useful characteristics.

First, all polyploids tend to have larger fruits and larger or more fleshy leaves than their 2n relatives.

Plants with 3 sets of chromosomes are called triploids, 3n. Triploid tree fruits are usually seedless or contain poorly-formed, infertile seeds. This can be a useful feature if you want your

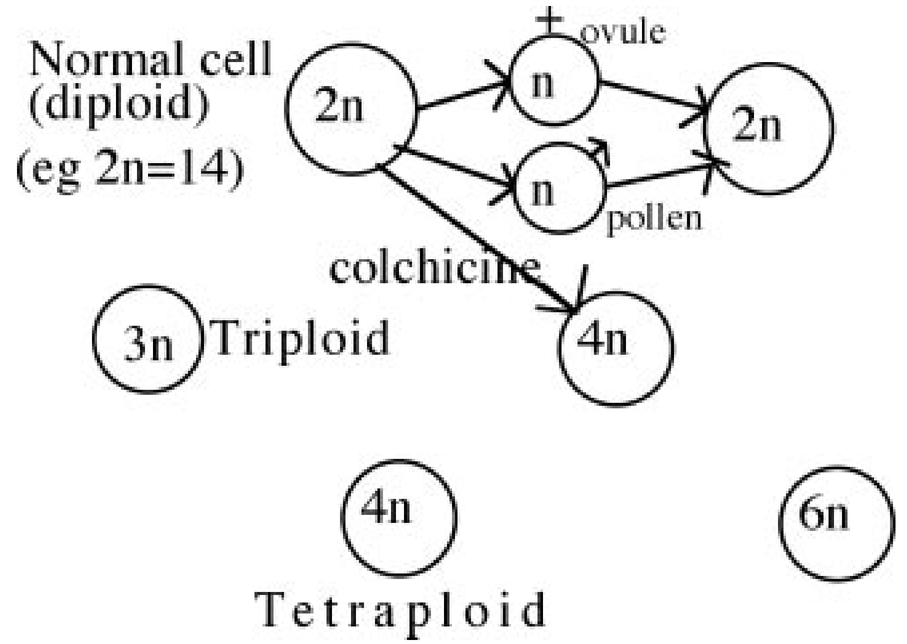


Figure. 1. Ploidy in plant cells

mangos, say, to be seedless, although there may be complications when proper fruit growth depends on substances produced in the seeds. But you would want to avoid triploids in nut varieties, as they would be nutless!

All sorts of polyploids occur naturally from time to time, for example, apple growers may know of the 'Bramley' cooking apple. This variety of fruit is a triploid, 3n. It is seedless and tends to be larger than most varieties.

Plants with 4 sets of chromosomes are called tetraploids, 4n. They occur naturally — the most important coffee varieties are tetraploids — and can also be made by treating seeds or buds with a plant chemical called Colchicine, extracted from crocuses.

Tetraploids are very important in managing variety incompatibility -- all the business of plants requiring cross-pollination for good crops. There are two main types of tetraploids, autotetraploids and allotetraploids.

If you use colchicine to make a 4n plant from a 2n variety, each 4n cell will have exactly the same chromosomes as the 2n one, but there will be 2 copies of each chromosome instead of one. This 4n autotetraploid will normally have the same incompatibility characteristics as its parent 2n diploid, so if the 2n is self-incompatible, the 4n variety will also be.

Now for the cunning part. If you take, say, two interpollinating, self-incompatible varieties of a 2n fruit and make each of them into 4n varieties, the new varieties will still be self-incompatible. But they will cross to give seeds which will be new, sexual 4n varieties which are likely to give self-compatible fruiting, as the cells contain both 'yin' and 'yang' components. These are called 'allotetraploids', and contain four different variations of the same chromosome in each cell.

Two varieties of a species with different chromosome numbers will not normally interpollinate, so although 4n plants may be formed from 2n ones in the wild, they are usually lost as they have no companion 4n plants to pollinate with, and if 3n seeds are produced by the cross, they can't develop normally. In the laboratory, however, these 3n seeds can be grown on artificially in a plant medium ('embryo rescue') to give triploid varieties.

Higher 'ploidy' is possible, for example kiwifruit is hexaploid, 6n. Its uneven 'ploidy' (3 x 2n) probably explains why self-compatible kiwifruit varieties are not known.

An interesting point about natural polyploidy is that it increases as you go towards the poles. Commercial strawberry varieties are based on a Chile species which is octoploid, 8n. Its even 'ploidy' explains why it is self-compatible, and its high 'ploidy' explains why the fruit is so large.

Typical values for 2n in plants are 10 to 18. Repeated use of colchicine can give chromosome numbers of 100 or more, but at levels of 80 or more, cell division gets so cumbrous the plant is no longer very viable.

Self-incompatibility

An interesting point about self-incompatibility is that it appears to have value for plants native to arid conditions. Most palms are self-fertile, date palms are not. Almonds, evolving in dry areas of Central Asia, are usually self-incompatible, while their close relatives the peaches are not. Pistachios express self-incompatibility strongly, by having plants either male or female.

Self-incompatibility is a major consideration in tree crop economics, as we'll see in some of the case studies below.

Plant relatives

As plant species, genera, and families have evolved in past geological times, movements in the Earth's land masses, and natural dispersion mechanisms, have split and spread related plants around the globe.

Plant distributions have been a great interest of mine. In 1989 I published a book, 'Nuteeriat' [Noel, 1989a], which examined present distributions in many families of plants, and the land movements which must have occurred to bring them about. This book is now available for free downloading from the Web.

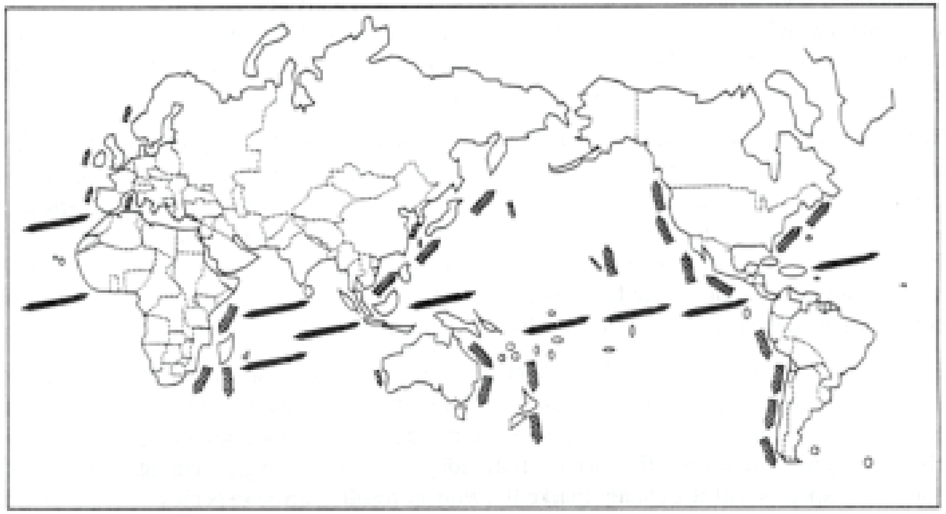


Figure 2. Former connections Between Earth domains, from plant distributions

For particular genera of plants, including many yielding tree crops, we know their distributions in great detail. Figure 2 is a summary of the way these distributions occur today, from a paper I gave in South Africa [Noel. 1989b].

The importance of this data in tree crop variety design is that it indicates where genetic material may be found in a particular family with characteristics useful for your purpose. For example, if you are working with a tropical fruit species, and want to incorporate genes which will give it cold resistance, or drought resistance, you can look for close relatives which live in cold or arid areas.

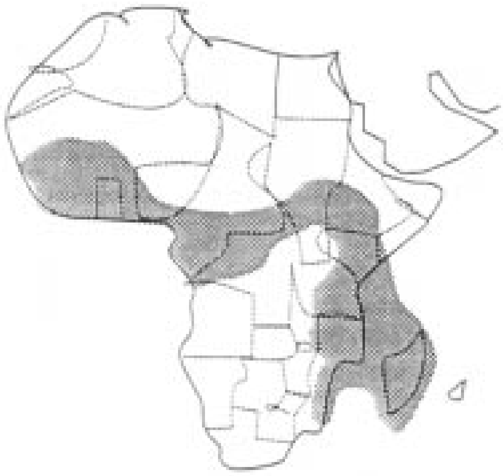
In the short term, you may be able to achieve your aim by grafting a desirable fruiting variety onto the rootstock of a relative with the ability to thrive under harsher conditions than the fruiting variety can cope with. In the longer term, trees with a combination of the desired characteristics might be obtained through crossing.

In the case studies I'll be talking about now, we'll see how these related plant distributions represent a rich source of genetic material for use in tree crop variety design.

Coffee

Coffee is the most important traded agricultural item in the world, it is the only one on which the United States spends more than a billion dollars each year.

If you wanted to redesign coffee as a crop, what changes might you make, what limitations are there in its current culture and processing?



Fig, 3. Natural range of Coffea species

Look at Figure 3, which shows the natural range of *Coffea* species. First, you can see it fits with the general distribution trend map in Figure 2, in that natural spread is along a tropical band, with some species moved into the subtropics by domain movements.

The two most important Coffee species are Arabica, *C. arabica*, and Robusta, *C. canephora*. Both are native to the tropics. Arabica Coffee, regarded as the best, originated high up in Ethiopia.

As a highland species from the tropics, Arabica will grow quite well in subtropical climates, although it doesn't have much cold resistance. That is one limitation to growing it in more temperate climates.

But the biggest problem with coffee culture is that the crop lacks what can be called 'seasonality'. The plant produces beans gradually, throughout the year. This makes it difficult to harvest mechanically, as a single fruiting branch will carry beans with a range of maturity.

You could overcome both these limitations if you could find a different species with good coffee, a short harvest period, and more cold resistance. And in fact there is such a species, *Coffea racemosa*, which is native to the Natal region in South Africa.

Racemosa produces good coffee, the plants are very hardy, and there is a defined harvest period of 3-4 months. Individual clones would probably have much tighter harvest times.

There is a limitation with Racemosa, it is a diploid and needs cross-pollination. Doubling its chromosome numbers to 4n and crossing the resulting autotetraploids should give self-fertile varieties, which could also be crossed with Arabica, already at 4n, to bring in desirable traits.

Pecans

Pecan nut production is well researched and developed, and at first sight might not have a lot of scope for redesign. It is true that there is some degree of self-incompatibility, as male and female flowers appear separately on the tree and do not always coincide in time. This situation could be improved by autotetraploiding, as mentioned, and this should also give larger nuts.

Bur there is another limitation, of special relevance to Australia. Although pecans grow well and fruit in Western Australia right up to Carnarvon, which is on the Tropic of Capricorn, even there they are a deciduous tree.

Now of course deciduousness developed in trees as a method of winter protection. The tree loses its leaves and shuts down, then it is much more able to cope with frost and snow. But it is also unable to photosynthesize, the light it receives during winter is wasted.

In contrast, evergreen fruits such as citrus use received light all year round, and so have greater potential yields than deciduous fruit trees. So there is the possibility of increasing pecan yields by finding or creating varieties which retain their leaves for most of the year. This could be important in growing pecans in essentially frost-free areas of Australia.

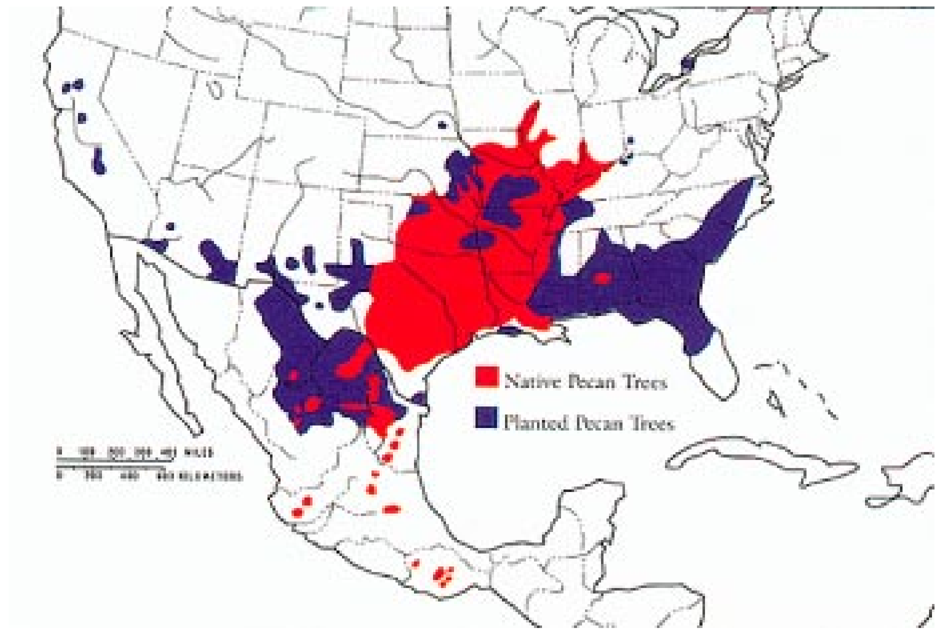


Fig. 4. Ranges of native and planted Pecan trees. From Manaster (1984)

There are various ways this could be done. Figure 4 shows the natural distribution of the

Pecan, *Carya illinoensis*. Like most of the rest of the Hickory family, it is native to eastern and southern North America, although Pecan goes further south than any other *Carya*.

In fact, notice that a small occurrence is shown in Oaxaca, one of most southern states of Mexico, not that far from Guatemala. It is possible that that area contains examples of pecans which naturally have a much longer period in leaf than those in current cultivation.

The family is subject to the usual distribution trends, and other species of *Carya* are found in southern China, Burma, and northeast India. These species may also have much longer in-leaf periods, with genes that could be incorporated into commercial pecan varieties through breeding or intergrafting.

Almonds

Almonds are one of those arid-origin plants where all current commercial varieties are self-incompatible. The flowers are perfect, but the ovaries contain genetic flags which do not permit self-pollination by the same or a closely allied variety.

Bee pollination of commercial almond crops is intense, demanding, and expensive to get the high yields now expected. To achieve these yields, the percentage pollination needed is much higher than for other common orchard crops. So present-day almond production is heavily dependent on the supply of active bees in high numbers at the right time of the year.

If the almond varieties used were self-fertile, as in many other crops, the difficulty and expense of bee pollination could be avoided. And so, self-fertile almond varieties have been produced.

These new varieties were obtained by crossing with related *Prunus* species which already had self-fertility, and backcrossing to obtain a varieties which presented as conventional almonds, but had self-compatibility genes built in.

The product of these varieties is acceptable, but the yield and growth factors have not been good enough to challenge the established self-incompatible varieties in the marketplace, even allowing for the savings from less bee use.

In the present context, the obvious suggestion to eliminate the need for bee pollination is to tetraploid good interpollinating 2n variety pairs and cross these to give 4n allotetraploids. Selections of these should give all the characteristics of their first-rate parents and yet be self-compatible. As an added bonus, the nuts should be larger than those of the parents.

Clearly a successful breeding program along these lines could change the face and economics of modern almond production.

Pistachios

Commercial pistachio varieties present as distinct male and female varieties, although rare hermaphrodite examples are known. Pollination occurs mostly by wind, and so is quite complex, with the need to interplant compatible (non-fruiting) male trees among the female

trees in the right positions relative to the prevailing winds expected in the flowering season.

Clearly the same approach as suggested for almonds could be used to create self-compatible 4n varieties of pistachios, eliminating the costs associated with current pollination practices, and possibly yielding bigger nuts.

At the same time, there is scope for a radical re-think of the market for pistachios, and for elimination of a couple of minor drawbacks.

The minor drawbacks include firstly the high need of most commercial varieties for long winter chilling periods. Above-normal winter temperatures can hugely depress yields in pistachio-growing areas, and these occurrences can be expected to increase with global warming.

So in redesigning pistachios, it would make sense to include genes with less dependence on winter chilling. These already exist in *Pistacia vera* itself -- as in varieties grown in the Greek islands -- and could also be drawn from related species not from cold areas -- for example, there is a *Pistacia* species native to Burma.

A second drawback is the existence of biennial bearing, where particular tree crops over large world areas have 'on' and 'off' years, with big yields one year, and small yields the next. Interestingly, biennial bearing is also associated with arid origins, being noted in almonds, and particularly apparent in pistachios.

Incorporating pistachio genes from non-arid origin plants could eliminate this drawback.

Fig. 5. Pistachio nuts split nturally. From www.adamscandy.com

For the radical part, look at Figure 5, showing pistachio nuts as sold in the stores. You can see the characteristic split appearance which allows the consumer to easily open the shell.

This splitting characteristic is regarded as highly desirable, and good commercial varieties have low percentages of 'non-split' nuts, regarded as undesirable and needing separation off before sale.

In my view, the emphasis on splitting in pistachios is a great limitation on expansion of the trade, as it limits the market to snack use. These days the big markets for nut products have moved out of the snack market and into areas where the machine-shelled product is used, in particular confectionery and factory-prepared cakes, biscuits, icecream, and meals.

Split pistachios cannot be easily machine-cracked, and also make harvest processing difficult, as the splits allow staining and contamination. In contrast to most nuts, pistachios may need processing after picking within hours, instead of days or weeks.

Fortunately, splitting is a non-typical characteristic of the fruits of *Pistacia* species. In my view, in re-designing pistachio species it would be sensible to include genes which give closed shells amenable to machine cracking.

Dates

Date Palms, *Phoenix dactylifera*, are yet another arid-country tree with male and female flowers on separate plants. Hence pollination is complex and expensive; but the products are enough sought-after that hand-pollination is often done in commercial plantations.

These pollination problems might be solved in the same way as in the examples given -- tetraploiding to give self-fertile plants, or incorporation of genes from related self-compatible species. The common Canary Island Date Palm, *Phoenix canariensis*, seems to set fruit in isolated specimens.

Avocados

Avocados may have similar self-incompatibility problems as other fruits, and these should be solvable by tetraploiding as above. On the minor side, most commercial varieties have poor salt tolerance, and this might be combatted by incorporating genes from a coastal relative, the Red Bay, *Persea borbonia*.

What is interesting here, is that it appears that a natural tetraploid avocado variety, the 'Don Gillogly', has already been found. Details are at www.avocadotrees.com. The description does not say the variety is a tetraploid, but it has all the characteristics -- large thick leaves, compactness, self-fertility -- and is supposed to bear good fruit even as as indoor plant!

Argan

Finally, let's look at an unusual and under-developed tree crop, the Argan, *Argania sideroxylon*, from Morocco. This one doesn't involve pollination.

Argan is a member of the Sapotaceae family, most of which are found in the humid tropics, and include such well-known fruits as the Sapodilla or Chico. So in arid, subtropical Morocco

it's well out of the family's usual range.

Argan is the source of an excellent oil extracted from the seeds, considered by many as superior to the best olive oils. As a valuable tree crop capable of growing in desert conditions, it would seem to be well worth developing for arid subtropical areas, of which we have no shortage in Australia.

However, Argan is somewhat endangered, for the usual reason, the activities of man. The trees are subjected to relentless pressure by the animals of nomadic herders, particularly goats.

So the only Argans which have survived are those which have evolved a ferocious array

Fig, 6. Goats climbing in an Argan tree. From Morton (1987)

of thorns to protect themselves from goats, and even this protection only limits the damage.

These thorns make Argan unpleasant to work with or harvest. Thorns are an unusual feature of Sapotaceae family trees, so in redesigning Argan it would be good to incorporate genes which did not promote the production of thorns.

Argan is the only member of its genus, so to look for these genes we need to look at close genera. And we can find these in the Canary Islands, just off the coast of Morocco, where the species *Sideroxylon argenteum* and *Sideroxylon mastichodendron* are native. These Argan relatives are thornless. From the plant distribution viewpoint, these species link Argan to its many relatives across the Atlantic, in Central America.

The Canary Islands are also the home of another useful tree, Tagasaste. This leguminous plant bears high-nitrogen leaves which are excellent for animal fodder. In contrast to many other tree fodder legumes, Tagasaste has neither protective thorns, like the African Acacias, nor appetite-reducing chemicals, like the tropical fodder tree Leucaena.

These examples illustrate another point in using plant distributions as genetic sources. It seems very probable that Tagasaste and the Canary Island Sapotaceae do not have animal-browse deterrents because the Islands have no native browsing animals. So to look for a particular characteristic within a plant distribution, look where the absence or presence of the characteristic would be useful.

In conclusion, I hope that I have opened up the topic of plant variety design, working from the base up, rather than the usual one of working from the top down.

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References

Manaster, Jane (1994). *The Pecan Tree.* Austin, University of Texas Press.

Morton, Julia (1987). *The Argan Tree, a Desert Source of Edible Oil.* Economic Botany / 41(2), pp 221-233.

Noel, David (1989a). *Nuteeriat: Nut Trees, the Expanding Earth, Rottnest Island, and All That....* . Subiaco, Cornucopia Press. Available as PDF downloads at http://www.aoi.com.au/matrix/Nuteeriat.

Noel, David (1989b). *Fugitive Earth Domains as Sources of Useful Fruit and Nut Genes*. WANATCA Yearbook / 14, p18-25.

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EARLY BEARING AND HIGH YIELDS IN NUT ORCHARDS

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Introduction

Nut growers embarking on new plantings are seeking better ways to shorten the lead-time until the first commercial crop, followed by a steep rise in the level of production to achieve world-class yields. Although recent, significant advances have been achieved in the individual disciplines of soil science, irrigation management, tree training and propagation, they have yet to be effectively combined into an integrated management package for nut production.

A typical yield curve for one hectare of nut orchard shows that we have around 4 years of lead-time until nut production begins (Ramos, 1998). There is a steady rise in yield until year 7, and then a slow down or plateau, or even a decline in yield is reached for the next 10 years or so.

In orchards based on venture capital, the economic life of the enterprise is often 15 years, and so an early return on the capital invested is important. When the orchard is between 10 to 15 years old, yields still need to be increased, but more time is available to achieve it. Reducing the lead-time to the first harvest by one year can have a large impact on profitability as can the increased rate of production in successive years.

There is a narrow window of opportunity to achieve earlier bearing and higher yields, but recent advances in orchard management and new technologies have provided encouraging results.

The relationship between tree density and yield illustrates that the more trees planted on a hectare of land, the higher the initial yield, until the plants begin to shade each other. Competition between orchard trees for water and nutrients should not be an issue where irrigation and nutrient supply is provided at levels that are non-limiting to root growth.

Under intensive management, the orchard tree develops through two major growth stages in its life. The first-stage objective of the orchard manager is to grow the tree as quickly as possible to fill the available space. The second-stage objective is to reduce vegetative growth and channel the resources of the tree into nut growth. This has been highly successful in stone and pome fruit orchards, where the tree canopy is established in the first year and cropping commences in the second year with yields of 30 to 50 tonnes per hectare.

In stone and pome fruit orchards, the lead time to the first crop has been successfully shortened by establishing the canopy quickly and filling the allotted tree space by arranging limbs to maximise light interception and/or by trellising. Trellising has the advantage of allowing even the thinnest of branches to be positioned correctly by tying at the correct angle plus it provides support for the crop load. In the absence of a trellis, trees can be trained into a central leader (pyramid) shape to increase the surface area of the canopy and to minimise the shading of the lower parts of the tree.

Other ways of shortening the lead time are to commence tree training in the nursery so that custom designed trees are planted into the orchard. The same philosophy can be applied to nut crops.

The challenge remains for nut growers to achieve earlier returns on their investment together with higher levels of production. Although we do not have all the answers, this paper explores some of the indicators and drivers we have to enable us to move further on in this direction.

Important drivers in nut production

Soil management

Soil texture, porosity, hardness and temperature can have a profound effect on the ability of tree roots to grow and take up water and nutrients. Considerable effort by researchers and practitioners has been focussed on providing a soil environment that is non-limiting to tree roots. Soil organic matter, soil chemistry, and soil biology are important properties in creating a soft, stable, and nutrient-rich medium for tree growth.

Shallow soils can have an important part to play in controlling excessive vegetative growth, as roots find it harder to explore deeper due to an impeding layer or an abrupt change in soil texture. When topsoil has been hilled into a treeline bank the lateral spread of roots into the traffic lanes is also restricted.

Hilling confines the bulk of the root system of the tree to a finite volume of soil. Research on Partial Rootzone Drying (PRD) and the Tatura Soil Management System for Orchards has demonstrated that orchard trees can be productive even where there is a reduced volume of soil at their disposal (Adem et al., 2000, Adem et al., 2002).

Irrigation management

Regulated Deficit Irrigation (RDI) is a technique where water is withheld at strategic times to reduce excessive shoot growth in the tree (Mitchell & Goodwin,1996). Preliminary trials with PRD in fruit trees demonstrated that half the volume of irrigation water was used by keeping one half of the tree root system dry and the other half wet for the whole growing season.

PRD gave up to a 40% water saving for the same tonnage of fruit whilst fruit size and quality appear to be unaffected. Careful scheduling of irrigation, the use of fertigation and slowing the wetting rate, whilst improving the distribution of water in the soil, can be used to enhance tree production.

Tree training

The amount of intercepted sunlight in the orchard has a strong bearing on tree water use and nut production per hectare. Sunlight has a profound effect on shoot growth, flower formation, nut set, nut development and nut quality (Somerville, 1996; Van Ende, 1997; Ross, 1982; Adem, 2002). In an umbrella-shaped nut tree, unpruned and separated from neighbouring trees, production is limited by the shadow it casts upon itself. At a distance of more than say 1.5 m in from the edge of the canopy, light levels can fall to less than 30% resulting in little or no nut production.

The shape of the tree also has an effect on the volume to surface a ratio of the canopy. Ideally, a well-planned orchard should intercept 70-80% of sunlight falling on the land. Traffic lanes for machinery make up the rest of the land area. Sunlight interception is also influenced by tree height and therefore the maximum tree height in summer should not exceed 80% of the row width.

Many species of fruit and nut trees have an apically dominant structure and grow naturally into a central leader tree. This tree shape is one of the most efficient for light interception and crop production. In a tree trained as a central leader, less feeder leaves are needed per nut for its development and more nuts can be produced per unit stem diameter. On the negative side are claims that central leader trees are harder to prune, more mistakes are made, and the risk of sunburn may be slightly higher. In a hedgerow orchard, nut trees trained to a central leader shape have the potential to yield higher and for longer than either a vase-shaped or umbrella-shaped tree (Germain et al. 1977).

Propagation

Tree vigour is a desirable characteristic in the nut orchard that enables the tree to fill its allotted space quickly to intercept the energy from the sun and convert it into nut production. Nurserymen have often selected rootstocks on this basis so they could generate nursery stock quickly and cheaply. Orchardists often associate vegetative vigour with productivity. Highly vigorous stocks are useful early in the life of an orchard but once the canopy has reached the desired size, excessive vigour may cause shading, increase the cost of pruning, and decrease nut production. Dwarfing rootstocks are available in some tree species and may prove useful, eg apple rootstocks from the East Malling series, when grafted to commercial apple cultivars, have produced compact trees and yet produced high yields of fruit.

In-Vitro propagation techniques produce trees with a characteristic root system of multiple growing tips that tends to spread horizontally as opposed to seedling rootstocks that send a single taproot downward (geotropism) with little branching (Lopez, 1999). During the evolutionary process, taproots extending deeply into the soil helped to ensure the survival of the fruit tree. In intensively managed orchard where water and nutrients are provided at high levels, this characteristic is not always desirable. A shallow, fibrous root system produces a large number of root tips that are considered the most active organs in the uptake of water and nutrients for the tree. The fibrous root system is therefore the desired form for a productive orchard.

Designing a new system of orchard production

The soil system

Soil raised into a treeline bank and managed to provide a soft, permeable, stable and uniform medium will support a healthy, shallow root system confined within a limited volume of soil. Shallow roots can take advantage of the high levels of aeration, temperature, biological activity, and low levels of soil strength as well as being closer to irrigation and nutrients applied at the soil surface. The soil is managed to keep the physical, biological and chemical properties within defined limits that are not limiting to tree root growth. The increased porosity and stability of the soil will allow frequent irrigation on demand with a reduced risk of waterlogging and disease affecting the tree roots.

Irrigation

Irrigation by microjet will wet the soil slowly to reduce structural breakdown and produce uniform water distribution within a wetted diameter between one and two metres wide. Irrigation supplied by two laterals, one on either side of the tree with one microjet per tree connected so as to alternate between each of the laterals provides greater flexibility in water management. This allows for roots on one side of the tree to be irrigated independently of the other, or both sides to be irrigated together. Irrigation of both sides of the tree can increase vigour whilst irrigation of one side can decrease vigour and save water.

Canopy management and tree density

Assuming the maximum canopy depth for light penetration to be 1.5 m from the central trunk of each tree, and a two metre wide alleyway for farm machinery to pass between rows, an optimum tree spacing of 5 m x 3 m and a tree population of around 660 trees/ha is suggested. From year one, trees trained into a central leader shape would intercept more sunlight than umbrella-shaped or vase trees through the increased surface area of the canopy and by less shading of the lower parts of the tree.

Balancing tree vigour and nut production

Trees that are trained correctly to fill their allotted space will do so in a structured and orderly way. Close attention to the size, angle, placement and type of branching creates a specific tree architecture that is uniform throughout the orchard. Pinching, pruning, tying, cincturing, notching, bending, twisting, spreading, and growth regulators are the training tools we have at our disposal. When the desired canopy height of say 4 m (80% of a 5 m row width) is reached, tree training is focussed on reducing vegetative growth and encouraging nut production. Irrigation is managed in strategic ways (RDI, PRD) to reduce vigour without penalising nut quality and yield. The objective is to produce enough vegetative vigour to ensure future bud development and to channel the remaining energy of the tree into nut yield.

Tree establishment

Nursery trees should be high-performing cultivars, genetically uniform, free of pathogens, trained to a nominated style and managed to come into nut production at an early age.

The root system on these trees should be fibrous and dense and handled in such a way as to ensure there is no check in tree growth after transplanting to the orchard. The roots should be treated with beneficial fungi and bacteria to resist root infections and to improve the uptake of water and nutrients by the tree. Trees produced by in-vitro propagation have the potential to supply vigorous, cheap, pathogen-free, clonal stocks at economical prices.

Conclusion

A hypothetical statement of what success might look like is as follows. The future orchard is located on a shallow but highly modified soil that has been hilled and sown down to permanent pasture. Planting stock is virus-free, produced by in-vitro propagation and the roots are inoculated with beneficial organisms. Irrigation is by two laterals supplying water through microjets to both sides of the tree in the first two years, then alternate sides in subsequent years. Trees are planted at 660 trees/ha at a spacing of 5 m x 3 m. Tree training begins with staking in year one followed by an intensive period of training of the tree to a central leader shape using a minimum of pruning. Cropping commences in year three and increases steeply to produce a potential, cumulative yield of 100 t/ha by year fifteen.

References

Adem, H.H., Jerie, P.H. and Borchardt, N. (2000). *High yields and early bearing for walnuts.* RIRDC Publication No 00/100, Project No Dav-73A.

Adem, H.H. (2002). *Canopy management for hedgerow planting of walnuts*. Australian Nutgrower. Jun-Aug. Vol. 16. No.2.

Adem, H.H., Williams, DO., Selman, J. and Loveys, B. (2002). *Water use efficiency in fruit trees through partial rootzone drying*. HAL FR00007. (Final Report, In preparation).

Germain, E., Lespinasse, J.M., Reynet, P. and Bayol, M. (1977) *Orchard training of lateral fruit-bearing walnut varieties*. Assessment of trials carried out in France. Proc. III Int. Walnut Congress. Ed. J.A. Gomes Pereira. Acta Hort. 442. ISHS.

Lopez, J.M. (1999). *Field behaviour of self-rooted walnut trees of different cultivars produced by tissue culture and planted in Murcia (Spain)*. Proceedings of the fourth international walnut symposium. Bordeaux, France.

Mitchell, P.D. and Goodwin, I. (1996). *Micro irrigation of vines and fruit trees*. Ed. Rosalind Hopkins. Pub. by Agmedia, Agriculture Victoria.

Ramos, D.E. (1998). (Ed.) *Walnut production manual*. University of California, Davis.

Ross, N.W., Rizzi, A.D., Aldrich, T.M., Ramos, D.E., (1982). *Training young walnut trees by the modified central leader system*. Cooperative Extension, University of California.

Somerville, W. (1996). *Pruning and training fruit trees*. Inkata Press.

Van den Ende, B. (1997). *Turn wood into profit*, Proceedings of a one-day workshop. NVFA and Goulburn Ovens Institute of TAFE publication.

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A REVIEW OF HYLOCEREUS PRODUCTION IN THE UNITED STATES

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Introduction

Pitaya, pitahaya or dragon fruit grow on a vining epiphytic cactus (*Hylocereus sp.*) native to the tropical forest regions of Mexico and Central and South America (Mizrahi et al. 1997). The plants grow up tree trunks anchored by aerial roots. The fruits have red or pink thornless skins, while the juicy flesh can range from white to magenta. The skin is covered with bracts or "scales", hence the name dragon fruit. The seeds are small and consumed with the fruit. The fruit can weigh up to 900 grams, but the average weight is between 350 and 450 grams. The weight depends on pollination as well as the variety selection. When ripe, the dragon fruit are most often consumed fresh. In some parts of South America, the pulp is used in drinks.

Dragon fruit have been cultivated in Vietnam for over 100 years and much longer in their native locations. Only recently have they received attention from growers in other parts of the world including Israel, Australia, and most recently the United States. They are currently being grown commercially in Nicaragua, Columbia, Vietnam, and Israel, with the Australian and US industries just beginning.

Production in the US is in its infancy, but recent newspaper (Karp, 2002; Smith, 2002) and magazine articles (Seabrook, 2002; Valdivia, 2000) have generated a good deal of consumer interest especially by chefs, high-end restaurants and hotels. Presently the demand far exceeds the supply, although that is bound to change as more and more growers dedicate acreage to dragon fruit.

There are several problems to deal with when adapting these cacti to growing conditions outside of their native environment, but thanks especially to Dr. Mizrahi's group in Israel and Paul Thomson of California; many of the problems have already been worked out.

US Production

Presently, it is believed that there are only 10 to 15 hectares of dragon fruit planted commercially on the US mainland. They are all located in Southern California. The largest planting is 7 hectares, while most plantings are less than one hectare. There are also some commercial plantings in Hawaii. As more growers learn about dragon fruit, and how productive they can be, the acreage planted is bound to increase significantly. South Florida as well as any frost-free areas of the Southern United States will probably be suitable for

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dragon fruit production, but as yet there are no known commercial plantings in these areas.

Hylocereus undatus. From ecocrop.fao.org

Presently the majority of the fruit produced are being sold in Asian communities in Orange and Los Angeles counties, with a small amount going to private chefs. In 2002, prices paid to growers ranged from $13 to $22 per kg. This price will drop as production increases. To open up new markets the price will have to be reduced to encourage consumers unfamiliar with the fruit. Currently, the supply does not come close to meeting the demand from the Asian communities, not to mention the potential new markets throughout the United States. It will be important to implement standards, perhaps through a growers association, in order to ensure that only quality fruit go to market. Fruit that is immature or of poor quality has the potential to turn away consumers and spoil markets.

Pollination

These cacti are night blooming and the hermaphroditic blooms remain open for one night only. They are large, up to 30 cm across, and are adapted to pollination by bats or hawk moths. As is the case in California, one of the main problems with growing these cacti in new regions is that often times these pollinators are absent. Bees are not efficient pollinators of *Hylocereus sp.* flowers (Weiss et al., 1994) due to the large size of the flower and the arrangement of its parts. Bee pollinated fruit were found to be smaller than fruit resulting from hand pollination. The fruit set was also found to be less (Nerd and Mizrahi, 1997).

Many of the varieties are not self-compatible, therefore the flowers need to be cross pollinated with pollen from a different clone or species in order to set fruit. Hand pollination is required with self-incompatible varieties to ensure proper fruit set and weight. This adds a considerable amount to the labour cost of growing these fruit. Whenever possible it is recommended to plant self-compatible (self-fertile) varieties, although there are problems with these, as well.

Many of the varieties from Asia (predominantly *H. undatus*) are self-compatible, and some of these are autogamous and will set fruit without the involvement of a pollen vector. It has been previously reported (Weiss et al. 1994) that Selenicereus megalanthus, the yellow pitaya, is autogamous. The anthers and stigma are at the same height in these flowers and touch as the flower closes. They also found that in their clones of *Hylocereus species* the anthers and stigma were separated by at least 2 cm. This may be the reason why their self-compatible *Hylocereus undatus* clone was not autogamous. Several varieties of *Hylocereus sp.* that have similar flower morphology to the yellow pitaya have been identified in California. If these varieties are self-compatible then they will often set fruit without hand pollination. Most of the autogamous varieties in the *Hylocereus* genus are varieties of *H. undatus* from Asia. A few red-fleshed species from Guatemala are self-compatible and possibly autogamous, although that will need to be tested to rule out bee pollination.

The only disadvantage to autogamous varieties is that the fruit is often smaller than if the flowers were cross-pollinated with pollen from a different clone or different species. This is similar to what has been demonstrated in Israel where self-compatible clones when self-pollinated produced smaller fruit than when cross-pollinated (Nerd and Mizrahi, 1997; Lichtenzveig et al, 2000). Fruit weight is positively correlated with the number of viable seeds (Weiss et al., 1994). The more successful the pollination is, the larger the fruit will be. Several of the autogamous *Hylocereus undatus* clones produce 350 gram fruit on the average when the flower is not hand pollinated. Although these are large enough to go to market, growers will have to determine if it is economically advantageous to hand pollinate flowers in order to increase the fruit weight.

Hand pollination is easily carried out by physically removing anthers from one flower and touching them to the stigma of another or collecting the pollen and using a brush to pollinate multiple flowers. Pollen is most viable at the time of flower opening, but hand pollination was found to be successful well into the evening of the following day (Weiss et al., 1994). Another problem that often occurs is that varieties will bloom when there are no other flowers open from which to obtain pollen. This will often happen early in the season (Metz et al., 2000). The plants bloom in waves during the summer. Two or three waves of flowers per season were reported in Israel, with a similar pattern occurring in California. Often the first wave of flowers will not set fruit due to a lack of cross-pollination. To circumvent these problems Metz et al. (2000) developed a protocol for the long-term storage of pollen. They found that the pollen must be dried to 5-10% moisture content by weight and stored at subfreezing temperatures. Pollen stored in this manner remained viable for at least 9 months. The colder the storage temperature the larger the resulting fruit was after hand pollination. This protocol will enable growers to store pollen over the winter and pollinate the first blooms of the season thus getting an earlier and larger crop.

The flowering season in California is from May through November (Thomson 2002), which is in line with what is reported in other locations (Raveh et al. 1993, Mizrahi and Nerd 1999). Dragon fruit are known to be a long-day plant (Lauders 1999) so controlling bloom initiation with artificial lighting may be a possibility thus extending the season.

Varieties

There are many named varieties of Dragon Fruit. More than 60 have been identified in California alone. Some certainly were started from seed, but most were undoubtedly brought in from Asia and South America as cuttings. Importation of cuttings from outside of the country is difficult since the plants are protected under CITIS regulations even though the majority of the *Hylocereus* species are not endangered.

Quality of the fruit does vary between varieties, but harvest time has a much greater effect on quality than varietal differences. As mentioned previously there are self-compatible and self-incompatible varieties. The majority of the varieties from Asia are self-compatible and

are autogamous, as well. Except for a few varieties from Guatemala, the red-fleshed varieties are self-incompatible. There is considerable variation in fruit size and shape between the varieties. Fruit shape ranges from nearly round to an oblong shape that is typical of the white-fleshed varieties from Vietnam. Much work remains to be done in evaluating existing varieties and in selecting and developing new varieties based on fruit quality, shelf life, and productivity. It would be advantageous to bring in commercial varieties from other countries for evaluation in the US.

Hylocereus undatus. Copyright 2005, Trade Winds Fruit. www.tradewindsfruit.com

Fruit Ripening and Quality

Two groups have looked at the fruit ripening and harvest times of these cactus fruit (To et al., 2002; Nerd et al., 1999). These studies were performed in Vietnam and Israel respectively. Both groups found that the optimal time to harvest *Hylocereus undatus* fruit was 28 to 30 days after flowering at full colour development. These fruit are non-climactic and were found to maintain their quality for at least two weeks when stored at 14∞C (Nerd et al., 1999). They also found that pigment development in red-fleshed varieties paralleled skin colour development.

Brix readings of fruit grown in California have been found to fall between 13 and 16% on average; with the soluble solids percentage increasing the longer the fruit are left on the plant. The highest brix so far recorded was 20% for a red-fleshed variety. Fruit with brix readings at or above 12 or 13% seem to have an acceptable sugar level for most consumers. It will depend somewhat on the variety, but from currently available data; it appears that for fruit grown in California it takes between 40 and 45 days after bloom to reach acceptable sugar levels. If California fruit is picked at 30 days, as recommended in Israel and Vietnam, the fruit will be low in sugar and of poor quality. The temperature and climate of coastal California, as compared to the desert of Israel or the tropics of Vietnam, may be the reason for this difference. More data must be collected, and the shelf life must be considered, before the optimal time between bloom and harvest can be determined for California.

For the most part, fruit from the plants of the *Hylocereus* genus are picked too early in California. As a result many people who have tried these fruit are not overly impressed with the quality. It has been the author's experience that the main part of the fruit reaches full colour development before the sugar content reaches acceptable levels when grown in California. Possibly, as has been suggested by an Asian dragon fruit grower, the bract colour can be used as a scale of maturity, but this will have to be worked out in the future.

Productivity

Unlike the majority of fruit crops, plants of the *Hylocereus* genus begin to produce significant crops two to three years after planting and reach full production after five years (Jacobs 1999). This results in quick returns for farmers who have a high initial setup cost for this type of crop. *Hylocereus polyrhizus* plants gave an estimated 16 tons per hectare in the second year after planting in Israel (Raveh et al., 1997). The plants are very productive with mature Vietnamese orchards producing 30 tons of fruit per hectare (Mizrahi et al., 1997). In Nicaragua plantings yielded 10-12 tons per hectare in the fifth year (Jacobs 1999).

Temperature Limits

The plants are sensitive to extremes in temperature. This should be taken into consideration when selecting a site for a commercial planting. Ideally a frost-free location should be selected. These cacti will show damage at -2∞C and often die at -4∞C (Thomson 2002). The plants will also be damaged at temperatures above 45∞C. It must be remembered that they are an under story cacti originally adapted to a shady environment (Mizrahi and Nerd 1999) and not a desert species. Therefore, they will be better suited to growing in areas along the coast where temperatures are moderated by the ocean influence. There is considerable variation of sensitivity to cold and heat between varieties as well as between species (Thomson 2002). Consequently, there is the potential to develop varieties that can endure higher and lower temperatures through breeding.

Selenicereus megalanthus. From www.moikel.de

Slight temperature damage will show as blistering and cracking of the green fleshy parts of the stem. Moderate damage will cause yellowing and "liquefaction" of areas of the stem, while heavy damage will cause the whole plant to "liquefy" and more than likely the plant will not recover from such severe damage.

Reduced flowering has been demonstrated in areas where temperatures rise to 45∞C (39∞C average) (Mizrahi and Nerd, 1999). Flower production was found to be only 15-20% of levels in areas where average summer temperatures were just 7 degrees cooler.

Pests and diseases

The plants are relatively free from harmful pests and disease. Rarely, aphids will cover a bloom or fruit, but they are easily controlled and not usually a serious problem. Slugs and snails will damage new growth. Rabbits and squirrels will feed on the green parts of the lower stems leaving only the central core. While this type of damage does not usually kill the plant it should be prevented. Chicken wire, a piece of pipe or any suitable material can be placed around the base of the plants to protect them from this sort of damage. Gophers will do extensive damage if they are not kept under control. When gophers are expected to be a problem it is advisable to plant in gopher baskets made of suitable chicken wire or hardware cloth to prevent plant loss. Rats and mice will eat the fruit causing damage to the crop. Blistering and black spots will sometimes develop on the stems, but in California these have been shown to be a physiological response to stress as opposed to a pathogen or disease (Thomson 2002; author's experience). These symptoms seem to develop in response to temperature extremes, sun exposure, poor soil fertility, improper irrigation practices, or other stresses to the plants.

Light Requirements

Due to the fact that that these plants are adapted to growing as an under story plant they need protection from intense sunlight. Near the coast in Southern California they will often thrive in full sun, but the further inland they are planted the more shade they seem to require. Covering plantings with shade cloth is necessary in many areas. When the plants receive too much light they become bleached, their growth is retarded and the plant can be killed (Raveh et al., 1997; Raveh et al., 1993; Mizrahi et al. 1997, Mizrahi and Nerd, 1999; author's own observations). When these plants are grown under heavy shade they become etiolated resulting in narrow stems and elongated growth. The main problem with too much shade is that flowering will be severely reduced and consequently, production will be drastically reduced. To maximize production it is recommended that a minimum amount of shade be used to prevent bleaching out. There are differences between varieties and species as to their shade requirements. The species with a waxy coating on the stems will tolerate more sunlight than the others (Thomson 2002; Raveh et al. 1997). If plants are water stressed their resistance to light intensity and bleaching will be reduced.

Trellis

Plants of the *Hylocereus* genus can reach a very large size. Branches can grow up to 5 metres in a year and mature plants can weigh well over 50 kg. Since their growth pattern is similar to a vine they need some type of support when grown in an orchard. Many trellis designs have been used. In Asia they are most often grown up through a vertical pipe to a height of 1.5 to 2 metres at which point they are allowed to branch and hang down, thus forming a circle of branches all around the pipe. Standard grapevine trellis has been used with centre posts and cross arms. In Israel, they have been grown on a similar trellis, but without the cross arms. Three wires are run down the centre of each row at three different heights. The plants are grown to the top wire with all the side shoots removed and then allowed to branch and hang down from the top. To prevent wind damage and to form a compact hedge the branches are secured to the lower wires. This compact hedge allows for a closer spacing of the rows than when using a standard trellis with cross arms. Any type of trellis that can support the weight of the plants and allow easy access to flower and fruit will work for commercial production.

Spacing depends on the type of trellis used. Numerous spacings have been listed in the literature: 3 by 5 metres in Nicaragua (Jacobs 1999), 2 by 1.7 m (Thomson 2002), in Israel 1.5 by 1.5 m (Weiss et al. 1994), 1.5 by 2.5 m (Nerd et al. 1999), and 1.5 by 3 m (Raveh et al. 1997). The closest spacing used in California with the three wire trellis described above is 2.5 metres between the rows. If the spacing is any closer it becomes difficult to maintain the plants and harvest the fruit. Spacing between the plants within the row varies. If plants are not in short supply, 1.5 meters between plants will give quicker production than a larger spacing. They have been planted 3 or more meters apart. Higher density plantings will produce returns sooner, but the plants will also begin to crowd each other sooner.

Water Requirements

Although these plants are cacti, they take more water than expected for a typical desert cactus. It must be remembered that they come from areas of high precipitation and humidity. Several papers have mentioned amounts of water given, 150 mm of water per year (Mizrahi and Nerd 1999), 4 litres per plant per day (Raveh et al., 1997), 5 litres per plant per week in the hot season and 2 litres in the cool season (Lichtenzveig et al., 2000), and 5 litres per week in the summer and 2.5 litres in the winter (Nerd et al., 1999). Raveh et al. (1997) were attempting to keep the topsoil continuously wet. It has been the author's experience (originally suggested in a personal communication with Dr. Avinoam Nerd) that a small amount of water every day is more beneficial to these plants than a larger amount of water less often. They have a very shallow fibrous root system and seem to respond well when the upper portion of the soil is kept continuously moist. The amount of water will depend on the type of soil, but in a sandy soil (decomposed granite) in Southern California young plants responded well to 1 litre per day by drip irrigation. The optimal amount of water still needs to be worked out and it will vary by location depending on climactic factors as well as soil type. Heavy rains (greater than 1300 mm) will lead to flower drop and fruit rot (Jacobs, 1999), so plantings in heavy summer rainfall areas such as Florida or Hawaii may have reduced yields and crop loss due to rot.

Fertilizer Requirements

These cacti respond well to most fertilizers, although care must be taken not to burn the shallow root system. In Israel small amounts of fertilizer have been applied in the irrigation

water with every watering (Raveh et al., 1997; Nerd et al., 1999; Lichtenzveig et al., 2000, Weiss et al., 1994). It was recommended to add 35 ppm N from 23N-7P-23K fertilizer in the irrigation water (Mizrahi and Nerd 1999). Animal manures and composts have been used in California with much success (Thomson 2002). Very little has been published on fertilization of these plants, and a proper schedule will need to be worked out to increase flowering and fruit production.

Hylocereus undatus. From www.labuznik.com

Propagation

Propagation of dragon fruit by cuttings is the most common and simplest method. The plants are very prolific and, if allowed, will produce many side shoots each year that can be removed and used for propagation. It is often possible to increase plant numbers by at least ten fold in one season by this method. Well-hardened cuttings 15 cm or longer are taken by cutting at a constriction in the stem or branch. Cuttings can also be taken in the middle of a stem. When this is done, it is important to let the cuts callous over for a week before planting to prevent rotting. Although it is not required, dipping the ends in a suitable rooting hormone will accelerate rooting. In areas with cool wet winters, such as Southern California, it is best to propagate these plants in the spring and summer months or in a greenhouse. When propagated in the winter, rotting is more common and the plants often will not begin to grow until temperatures increase in the spring.

Seed viability is very high and germination is quick when using a fine medium such as peat moss. There are several drawbacks to growing these plants from seed. The first is a longer juvenility period than when grown from cuttings. Cutting propagated plants will take two to three years to begin to fruit in California. Seedlings, however, will often take 4 years or longer before their first bloom. In more tropical climates this period will be reduced. The other disadvantage is that there will be much seedling variation affecting fruit quality and production.

Drew and Azimi (2002) have developed a protocol for the micropropagation of these cacti.

If this can be adapted to a large-scale operation and not induce a long juvenile period in the plants it will enable the production of large numbers of plants from a relatively small stock. This will be important since very few nurseries in the US carry *Hylocereus* species. The fruit quality of these plants is usually unknown since they are most commonly grown as an ornamental. So, for now, anyone in the US wanting to plant commercial acreage of dragon fruit has to propagate them themselves or must import cuttings, which can be a large expense.

Conclusion

Fruits of the *Hylocereus* genus have the potential to be a profitable new crop for farmers in the US. With a market already established in the Asian communities and a much larger potential market, commercial plantings can be increased without saturating the market in the short term. Imports from Asia and Mexico are presently prohibited, as the fruit is a host for fruit flies. At least one irradiation facility is being built in Asia, which will allow for the importation of some dragon fruit as well as other exotic fruits. If certain areas of Mexico, where the pitaya are grown, can be certified as free of fruit flies, then this fruit may also be allowed into the US. This has the potential to flood the US market and cause a significant drop in the price of dragon fruit. It will be difficult for US growers to compete since the labour costs are much higher here. Production levels in the US have not yet been proven, except in Hawaii, to be comparable to other areas. This is still a very speculative crop for the majority of the US.

Much work remains to be done. Standards for fruit quality need to be established. Optimal spacing, water requirements, trellising systems, fertilizer regimes, and pruning requirements all need to be worked out. Harvest time and post harvest storage also need to be examined. There is also a need for breeding new varieties in hopes of obtaining a good quality fruit with a long shelf life that is autogamous and sets a large fruit without the need for hand pollination. Attempts should also be made to extend the season whether through breeding or manipulation of growing conditions. The University of California Extension has recently taken an interest and a small planting is in the planning stages.

Overall dragon fruit is a promising crop, but growers should be cautious before dedicating significant amounts of resources to large-scale plantings.

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References

Drew, R.A., M. Azimi. 2002. *Micropropagation of Red Pitaya (Hylocereus undatus)*. Proc. IS on Trop. & Subtrop. Fruits. Acta Hort. 575:93-98, ISHS.

Jacobs, D. 1999. *Pitaya (Hylocereus undatus), a Potential New Crop for Australia*. The Australian New Crops Newsletter 29(16.3).

Karp, D. 2002. *Purple, Spiny and Heading Your Way*. Los Angeles Times September 18. H1.

Lichtenzveig, J., S. Abbo, A. Nerd, N. Tel-Zur, and Y. Mizrahi. 2000. *Cytology and Mating Systems in the Climbing Cacti Hylocereus and Selenicereus*. American Journal of Botany 87(7): 1058-1065.

Luders, L. 1999. *The Pitaya or Dragon Fruit*. Agnote No. 778 D42. Australian Department of Primary Industry and Fisheries.

Metz, C., A. Nerd, and Y. Mizrahi. 2000. *Viability of Pollen of Two Fruit Crop Cacti of the Genus Hylocereus Is Affected by Temperature and Duration of Storage*. HortScience 35(2):199-201.

Mizrahi, Y., and A. Nerd. 1999. *Climbing and Columnar Cacti: New Arid Land Fruit Crops*. p. 358-366. In: J. Janick (ed.), Perspectives on New Crops and New Uses. ASHS Press, Alexandria, VA.

Mizrahi, Y., and A. Nerd. 1996. *New Crops as a Possible Solution for the Troubled Israeli Export Market*. P.37-45. In: J. Janick (ed.), Progress in New Crops. ASHS Press, Alexandria, VA.

Mizrahi, Y., A. Nerd, and P.S. Nobel. 1997. *Cacti as Crops*. Horticultural Reviews. 18:291-320.

Nerd, A., and Y. Mizrahi. 1997. *Reproductive Biology of Cactus Fruit Crops*. Horticultural Reviews. 18:321-346.

Nerd, A., F. Gutman, and Y. Mizrahi. 1999. *Ripening and Post Harvest Behavior of Fruits of Two Hylocereus species (Cactaceae)*. Postharvest Biology and Technology. 17:39-45.

Raveh, E., A. Nerd, and Y. Mizrahi. 1997. *Responses of Two Hemiepiphytic Fruit Crop Cacti to Different Degrees of Shade*. Scientia Horticulturae. 73:151-164.

Raveh, E., J. Weiss, A. Nerd, and Y. Mizrahi. 1993. *Pitayas (Genus Hylocereus): A New Fruit Crop for the Negev Desert of Israel*. P. 491-495. In: J. Janick and J.E. Simon (eds.), New crops. Wiley, New York.

Seabrook, J. 2002. *The Fruit Detective*. The New Yorker. Aug. 19 & 26.

Smith, G. 2002. *Dragon Fruit Lights Fire Among Growers*. San Diego Union Tribune. October 10. C1.

Thomson, P. 2002. *Pitahaya (Hylocereus species) A Promising New Fruit Crop for Southern California*. Bonsall Publications, Bonsall, CA.

To, L.V., N. Ngu, N.D. Duc, and H.T.T. Huong. 2002. *Dragon Fruit Quality and Storage Life: Effect of Harvest Time, Use of Plant Growth Regulators and Modified Atmosphere Packaging*. Proc. IS on Trop. & Subtrop. Fruits. Acta Hort. 575:611-621, ISHS.

Valdivia, E. 2000. *Pitahaya — A Fruit for the Deligent*. The Fruit Gardener. 32(1):12-13.

Weiss, J., A. Nerd, and Y. Mizrahi. 1994. *Flowering Behavior and Pollination Requirements in Climbing Cacti with Fruit Crop Potential*. HortScience 29(12):1487-1492.

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CHINESE OLIVE TREE - *CANARIUM*

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(Editor's Note. Suppliers of Asian foods will sometimes have available packets of olive-size dried fruits labelled 'Chinese Olives'. Although resembling traditional olives in appearance, and perhaps in taste, these come from unrelated trees in the Canarium family, which also embraces Pili and Kenari nuts. The fruit body around the stone and kernel of Kenari nuts is also eaten. Very occasionally, the kernels of Chinese Olives may also be offered, these resemble small pine kernels.)

Chinese Olive is one of the endemic fruits native to the subtropics of Asia and botanically known as *Canarium album* (Lour.) Raersch. and *C. pimela* Leenh. It was first described in some detail in the third and fourth centuries AD.

Chinese Olive is different from European olive, *Olea europaea* L. Olive is an oil plant belonging to the botanical family Oleaceae, and is native to the Mediterranean. Chinese Olive is a plant in the Burseraceae family, and the dried fruits and nuts are edible and also have medicinal uses. Resin from the tree is used for a varnish known as elemi and for printing inks.

The timber of the tree is used for shipbuilding, railway sleepers, and furniture. Trees are commonly planted by the side of a highway, in streets, and in gardens.

Botanical description

Tree, 10-18 m high, trunk and branch with aromatic resin, odd-pinnate compound leaf, alternate; leaflet with petiolule, opposite, entire, papyraceous to coriaceous; slightly concave reticulate veins giving a special smell while twisted; floret unisexual or polygamous; staminate inflorescence thyrsoid, pistillate inflorescence racemose, inflorescences terminal or axillary, corolla white to yellowish white; drupe elliptic to ovate; epicarp thick, yellowish green while mature, putament hard, two ends pointed, trachyspermous; seeds 1-2. Blooms in China from April to May, fruit matures from October to December.

C. album and *C. pimela* are both used as Chinese Olive in China, the above mainly describes the characters of *C. album*. Table 1 lists their distinct characters.

Biological distribution

Chinese Olive trees are found in Fujian, Guangdong, Hainan, Taiwan, Sichuang, Zhejiang, Guangxi, and Yunnan, China, and are also planted in other countries — Vietnam, Japan,

Table 1. Comparison of botanical characters between *C. album* and *C. pimela*

	C. ALBUM	*C. PIMELA*
Length of leaf	15-30 cm	30-60 cm
Number of leaflets	11-15	15-21
Shape of leaflet	lanceolate or elliptical; apex acuminate to cuspidate; base cuneate to rounded and oblique	oval, ovate, or rotund; apex cuspidate; base rounded or wide cuneate
Nerve	obvious on two sides	salient above, smooth below
Leaf fragrancy	weaker	stronger
Inflorescence	shorter than leaf	longer than leaf
Colour of ripe fruit	yellowish green	purplish black
Epicarp	thicker	thinner
Putamen	two ends pointed, transverse section round to hexagonal	two ends obtuse, transverse section hexagonal

Malaysia, etc. The native habitat is in 22°N-26°N. An annual average temperature of 20-22° C is needed, with rainfall of 1200-1400 mm. A minimum temperature of 0° C is tolerated for a short time, one of -3° C will cause frozen shoots. Very moist clay isn't suitable for acceptable growth.

Chemical composition and extracts

Chinese Olive is used mainly in the south of China, particularly in Fujian, Guandong, and Hainan provinces. The flavour is very distinctive and reminiscent of several fruits, the tartness will pucker your mouth, but sweetness is your reward. It is valued by pregnant women and children for its rich nutrients, for example, calcium 146-204 mg and Vitamin C 15-100 mg per 100 g of the sarcocarp. The fresh fruit is crisp, first tastes a little bitter, then tastes fragrant, sour, and sweet after chewed for a longer time. It is used in stir-fry dishes and loved with chicken. It is one of the two most common items used in the making of crack seed. It is also used in varieties of preserved fruits and beverages. Chinese Olive fruit, from *C. album*, is exceptional in being exported to other regions of Southeast Asia and, occasionally, further afield.

In China, the fruit, nut, seed, and root have been used as medicines for a long time. Traditional Chinese Medicines (TCM) regards that Chinese Olive fruit remove heat from the lung, relieve sore throats, promote the production of body fluid and detoxicating, and is used for swollen and sore throat, excessive thirst, hematemesis due to cough, lacillary dysentery, epilepsy, puffer poisoning, alcoholism, etc. Nowadays polyphenols are extracted from the leaf or fruit as food complements or medicines for countering coronary heart disease, arteriosclerosis, hepato-protection, etc.. In Malaysia, oil from the seed is used against cancer.

The fruit for medicinal use, before it is fully ripe, is collected to dry in the sun or shade, or to dry after being soaked with brine.

Phytochemical studies showed Chinese Olive contains urs-12-ene-3,16-diol, olean-12-ene-3,16-diols, 3-epi-amyrins, scoparone, scopoletin, (E)-3,3'-dihydroxy-4,4'-dimethoxystilbene, gallic acid, brevifolin, hyperin, ellagic acid, and 3,3'-di-O-methylellagic acid, etc.

Chinese Olive tree (Wulan, Canarium pimela). This and next photo by Dr Liang Zhitao, School of Chinese Medicine, Hong Kong Baptist University. Tree location: Heba, Bahe (village), Shengjiang (town), Luoding (city), Guangdong Province

Propagation and Planting

Seed is picked for planting at the end of autumn, and drilled or scattered at a line and row spacing of 12-15 cm to 18-21 cm in the following February. The gaps are filled after the leaves come out. After hardening, seedlings can be transplanted to a hole fertilized with organic manure with a volume of about 1 cubic metre at a line and row spacing of 6-8 m (sometimes 4 m x 4 m). Usually Chinese Olive starts bearing fruit from the 7th year. After then, it needs fertilizing two to three times a year, before bloom and around fruit harvest time.

Nowadays most Chinese Olive orchards have intercrops or interplants of legumes, sweet potato, etc. These crops not only increase the fertility of soil as a green manure, but also increase soil cover to retain moisture and nutrient. However, they should be not too near the tree. The management aims for Chinese Olive tree include dwarf trees, higher density,earlier

Foliage of Chinese Olive. Note intercrop plants

bearing, and higher yields. Techniques used include grafting, growing in high-nutrient bags, pruning at appropriate times, developing extensive and strong leaf cover, and choosing selected cultivars with higher yield. The stem should be pruned at 80 cm, branches at 40-50 cm, cutting out too-close, water-, dead, thin, and side shoots regularly.

Stress needs to be placed on the pruning of Chinese Olives. Propagation from seed gives very varied offspring: about 10% of trees don't bear fruit, 30% trees bear abnormally, so it is necessary in Chinese Olives to use selected cultivars to get better horticultural characters. The usual pruning times are all feasible for Chinese Olives, however, tannins contained in the trunk and twig will have a marked influence on the survival, so autumn is better as there is less sap leakage than in spring. Of course, practical skill is also essential to keep survival high.

Cultivars

1. Tanxiang

Fruit smaller, oval to oblong, each about 8 gram weight; peak pointed rounded, base rounded; pericarp deep green, glabrous; sarcocarp sallow, crisp, fibre less, tartness less, smell fragrant, aftertaste sweet and refreshing. It is one of the best cultivars for fresh edibility. Produced in Minqing, Minhou, Fujian Province. Inflorescence starts in April, buds open in May, flowering lasts for about 35 days. The fruit matures in November.

Packet of Ka Po, "Preserved Honey Olive", with fruit and fruit stones.
Photos: David Noel

2. Huiyuan

Fruit bigger, ovoid, each about 20 gram weight; peak rounded, base retuse; pericarp green, glabrous; sarcocarp thick, light white, soft and tender, fibre little, tarter, fragrance thin. It is one of the best cultivars for processing. Produced in Minqing, Minhou, Fujian Province. Inflorescence starts and buds open in May, flowering lasts for about 24 days, fruit matures in November.

3. Changying

The size of fruit varies, each of 6-16 gram weight, shape longer, the total length of 7 Changying fruits, of one strain, is 30-33 cm; pointed at two ends; sarcocarp with texture, tartness a little. It is the most used for processing. Produced in Minqing and Minhou, Fujian Province. Fruit matures in November.

4. Xiaxiben

Fruit smaller, slight, shape rhombic, each 7 gram weight; peak acute, base muticous, pericarp wax yellow; sarcocarp yellow, with texture, tartness a little, smell fragrant, aftertaste sweet. It can be used for eating fresh or processing. Produced in Putian, Fujian Province. Fruit matures in October -November.

5. Zhuyaolan

Fruit slight, and retuse in the middle, looks like kidney of pig (Zhuyao); pericarp deep green with ebony macula; sarcocarp fine, crisp and sweet. Mature fruit doesn't easily drop off. It is one of the best cultivars in Guangzhou for eating fresh.

6. Chashulan

Fruit shorter; pericarp deep green with ebony macula; sarcocarp fine, tartness little, aftertaste sweet. Its yield is higher. It is one of the best cultivars in Guangzhou for eating fresh.

7. Liqiu Wulan

Fruit oblong, pericarp greyish black with ebony black macula of stylar relic, base with 4 furrows, peak round, red; single fruit about 11 gram; sarcocarp sweet and fragrant, fibre less. Matures in the first ten days of August. Common in the suburbs of Guangzhou.

8. Huangzhuang Wulan

Fruit oblong, pericarp greyish black with ebony macula of stylar relic, base reddish yellow; sarcocarp thick, sweet, crisp, and fragrant. Matures in October. Distributed in Zengxian, Guangdong province.

In fact, the cultivars of Chinese Olive are much more extensive than the above. Chinese Olive has a rich cultivar resource. Since it reproduces from seed, its variance is large and brings about many local cultivars after natural selection and manual cultivation for long time, some suitable as fresh fruit, some for processing, some only as rootstock for propagation.

Detail of fruit and stones. Note typical 3-chambered Canarium nut

Chinese Olive kernels. Note scribble patterns on kernels

Gathering, Storage, and Process

The date of fruit collection varies with different purpose for fresh eating, for processing or medicinal use. Harvesting starts from August, for fresh fruit in October-December till the frost comes once or two times. The later the fruit is picked, the stronger the flavour is, and the better the fruit is judges. However, the outcome is that the yield decreases markedly in the next year, for shoots bearing fruits can't germinate in the autumn.

The fruit is manually picked, or collected by shaking branches to drop after spraying 300 ppm ethylene solution at 3-4 days.

After storage, the fruit tastes better, feels crisper, smells pleasant; the content of organic acids and chlorophyll decrease, of monose is steady, of carotenoid increases. In the past, farmers usually stored a little in gallipot for 4-5 months, in cannikin or bamboo basket for 2-3 months. Now it is stored in a plastic bag for 4-5 months, or in coolstore with modern equipment keeping moderate temperature, moisture, and gas level. A coating reagent is also used to lengthen storage life.

Storage life varies with cultivar, ripeness, method of collection, and storage conditions. Among the cultivars of Chinese Olive, Bailan, Tanxiang is suitable for storage for it has a thick and even cuticle in pericarp, more mechanical tissue in mesocarp, cell lignified, and large resin cavity distributed thickly along pericarp. In contrast, Changying, Huiyuan, etc. are not. About 90% ripeness and manual picking is needed for storage. 6-10° is the optimum temperature.

To date, Chinese Olive has been processed into types of preserved fruits, beverages, jams, wine, etc. However, preserved fruits are the most common product. Here are two processes for preserving fruits.

Salt Ganlan

5% common salt is added to the fresh fruit and stirred 6-7 min by the Chalan Machine (a special machine for cutting off the pericarp of Chinese Olive) to the flesh peeled off the nut, then washed with water and dripped. The fruit was immersed into 10-20% brine for 24-48 hr, then extracted and dried in the sun till 85% of the water evaporates. This salt Chinese Olive is Salt Ganlan for eating as is or reprocessing.

Heshun ganlan

Proportion: 1 kg Salt Ganlan, 0.7 kg white sugar, 0.13 kg licorice (Glycyrrhiza uralensis), 8 g vanillin.

Salt Ganlan is washed with water till there is little or no salt taste. White sugar is added into the extract solution of licorice and heated, then poured it into the container with the treated Salt Ganlan. After the sugar solution is fully absorbed, the fruit is dried in an oven or over a fire.

The product is sweet and refreshing, with a fresh fruit flavour. It contains 25-30% water, 55- 65% total sugar, 0.2% - 0.8% total acids.

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THE GRANNY SMITH APPLE AND TATURA TRELLIS

BAS VAN DEN ENDE

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The high productivity of Granny Smith on Tatura-type trellises is one of the most successful achievements of modern-day intensive orcharding.

The woman responsible for the Granny Smith apple never received much appreciation for giving the world the fruit that bears her name.

Maria Ann (Granny) Smith was the wife of Thomas Smith. The Smiths emigrated from Sussex, England, in 1839 and developed a 2-ha orchard in the Sydney suburb of Ryde.

One morning in the year 868, Mrs. Smith asked E.H. Small, a successful orchardist, to look at a seedling apple that was growing in her orchard and to express an opinion about it. His son, Tom Small, then a 2-year-old, went along with him.

The tree was growing among ferns and grass and had a few fine specimens of green apples on it. Mr Small tested it critically and remarked that he assumed it would be a good cooking apple, and might be worth grafting from, even though Mobb's Royal and several other cookers seemed to fill the demand at that time. Tom, however, remarked that it was also a good eating apple as he sampled it.

French Crabs to Granny Smith (?)

Mr. Small asked "Granny" how the apple tree came there. She replied that she had brought some gin cases back from the Sydney markets, which had contained some Tasmanian apples, that were rotting. She said she had thrown them out at the site where the original seedling tree grew.

It is thought that Mrs. Smith mentioned that the remains in the cases were of French Crabs. The greasy skin and keeping qualities of the "Granny Smith" point to this being correct.

From grafting to planting

Mrs. Smith grafted a few of her trees and not long afterward Edward Gallard, another member of the family, planted out a fairly large block of these "Grannys", and is credited as being the first commercial grower of this new variety.

Early tests in the Bathurst district, west of Sydney, were completed shortly after the turn of the century. After its excellent storage ability was established, the fame of the variety spread far and wide. Granny Smith had met the full test:

- It was a grower's apple
- It satisfied the packer and marketer
- It stood up well in the markets
- And finally, the consumer liked it and asked for more.

Maria Ann Smith and her eldest son Thomas (photo from the City of Ryde website, used with permission)

Several spur-type mutations were found in Australia, the USA, South Africa and Chile. However, the standard Granny withstood the test of time because the production and quality were far superior to any of these mutations. Granny Smith did not gain success in the world market until after 1950.

Despite the problems of blind wood in the early years of its growth, and sunburn of the fruit, the Granny Smith has remained popular for more than 50 years and may outlast Red Delicious and Golden Delicious. Granny Smith is a multi-purpose apple that can be harvested over more than 6 weeks. It is still planted in large quantities in countries with long hot summers.

Tatura Trellis for growing Granny

The Tatura Trellis appears to be well suited for growing Granny Smith apples. High early production of fruit of high quality is an important feature of the Tatura system.

By carefully managing the trees (e.g. delay-heading and taking steps to manage certain natural hormones in the tree), orchardists can avoid blind wood. Managing the canopy in summer prevents sunburn to a large degree. Lately, some orchardists have discovered that overhead netting resulted in high pack-outs of fruit with excellent skin-finish.

Preferred. rootstock MM106

Many new plantings of Granny Smith are on Open Tatura at densities ranging from 1600 to 2900 trees per hectare. The most preferred rootstock is MM106. This rootstock combines resistance to woolly apple aphid, adequate vigour to provide good foliage cover and precocity. Planting 2-year-old nursery trees of high quality is a prerequisite for early bearing and high, sustained production.

In an orchard at Ardmona, near Shepparton, a Tatura Trellis block of fully mature Granny

Smith trees on MM106 at 1000 trees/ha produced an average annual yield of 81.5 tonne/ha. In the same orchard, Granny Smith trees on MM106 were planted in 1998 as bench-grafts. This 2.5-hectare planting (1333 trees/ha) has already produced 3 crops totalling 77.5 t/ha (figure 1).

At another orchard in Ardmona, a 3-year-old Open Tatura planting of 1.83 ha of Granny Smith trees on MM106 (2964 trees/ha) has already produced 20.8 t/ha (figure 2). A young Granny Smith planting on M26 at Bunbartha (1646 trees/ha) produced a total of 16.5 t/ha when only 3 years old. These yields compare favourably with the marketable yields of high density orchards in Australia.

It is doubtful if anyone buying Granny Smith apples in the supermarket realises that this variety was discovered in Australia 136 years ago by sheer luck. Intensive orcharding in the 21st century, which involves high tree densities, support structures, and emphasis on tree training and canopy management, will ensure continued profitability and popularity of Granny Smith.

Mrs. Maria Ann Smith and her family deserve posthumous adulation for discovering and commercialising this green apple, called Granny Smith.

Fig.1. Granny Smith trees were planted as bench-grafts in 998 on Tatura Trellis and produced a total of 77.5 tonne/ha when 5 years old

Fig, 2, Granny Smith on MM106, 22 months after planting (2964 trees/ha). The trees were planted as rods of about 1.5 m long. Trees were scored and plucked to promote side shoots. After 3 years in the orchard, this 1.83 ha planting had produced a total of 20.8 t/ha.

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[Based on an article in the Northern Victoria Fruitgrowers' Association Technical Bulletin, March 2004].

PHYSALIS: GROUND CHERRIES

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Introduction

The genus *Physalis* consists of some 80 annuals and perennials, characterised by their very distinctive papery sacs (lanterns or calyces) which completely surround the fruits. Originating from North and South America, Asia and Europe, several species have edible fruit, a few well known such as the cape gooseberry and tomatillo. Some of the perennial types are considered weedy in some climates. This article considers the edible species and other species of use.

Warning: Physalis species are part of the nightshade family (Solanaceae), and all foliage and the unripe fruits of most species is poisonous, containing solanine and other alkaloids (tomato and potato foliage is toxic too, of course). Only the ripe fruits of the species described as a edible in this article should be eaten. Do not eat if allergic to potatoes or tomatoes. There are occasional reports of stock being poisoned from eating the foliage, however animals usually avoid it and only eat the fruits.

The common names for these species are often a source of confusion, many being shared by several species. The Latin names, too, are sometimes a nightmare with numerous synonyms!

General description

Plants are often much branched and spreading at the top. Leaves are alternate and simple; flowers are whitish-yellow or whitish-violet. The fruit is a round yellow, green, red, purple, or blue-black berry surrounded by a papery sac. The fruit contains numerous seeds. Ripe fruits of some species are edible, generally considered at their finest when cooked in sauces or preserves. Several species have been used medicinally in the past but the powerful toxins in all parts (except ripe fruits) make this inadvisable in terms of herbal medicine. The spreading perennials can be used for ground cover.

Cultivation

All species like a well-drained soil and sun or light shade.

The less hardy annuals, grown from seed, should be started under cover and transplanted out when robust enough; they can be treated like outdoor tomatoes. Hardier annuals can be sown outside and will self-seed if allowed. The hardier perennials, once established, may require division every few years, else they will stop flowering.

§ Member, WANATCA

Physalis alkekengi. From www.meb.uni-bonn.de/giftzentrale/pflanzen

Flowering and fruiting is best in soils that are not too fertile. Pollination is via wind and insects, including bees.

Fruits can be harvested quickly by shaking plants over a net or cloth; ripe berries in husks will drop. Fruit picked green may ripen but never with as good a flavour.

Weedy perennial species can be controlled by spading out underground runners in autumn.

Plants are susceptible to many of the same diseases and pests as tomatoes (though not potato blight). New growth is susceptible to slug damage in spring.

Most species are grown from seed, which germinates easily.

The Species

***Physalis acutifolia.* Sharpleaf ground cherry, Wright ground cherry.**
Annual from the SW of North America.

Uses: The ripe fruits are edible.

***Physalis alkekengi.* Chinese lantern, Winter cherry, Bladder cherry, Strawberry ground cherry.**

A perennial growing to 60 cm high with a creeping branched rhizome. Bears yellow-cream flowers and orange sacs (calyces) up to 5 cm long, within which are round edible scarlet fruits, 17-20 mm across, red to scarlet, ripening in summer. Native to southern and central Europe and Asia to Japan. Hardy to zone 6 (about -18°C).

Varieties: 'Bunyardii' — compact, free flowering.

'Franchettii' — vigorous plant. Sacs are huge, to 70 mm long, with larger fruits.

Gigantea' ('Monstrosa') — bears large fruit.

Uses: The fruits are edible but lack much flavour. The plant is valued for floristry, the stems are cut as the sacs change colour and dried.

***Physalis angulata*. Cut leaf ground cherry, Wild Tomato, Winter Cherry.**

A perennial often grown as an annual, to 90 cm high. Bears small yellow-orange edible fruit. Native to South America.

Uses: The fruits are similar to cape gooseberries, with a sweetish flavour, and are used in the same ways, raw or cooked.

Physalis angulata. From http://botany.cs.tamu.edu

***Physalis angustifolia.* Coastal ground cherry**

Perennial from SE North America, found on sand dunes.

Uses: The ripe fruits are edible.

***Physalis arenicola.* Cypresshead ground cherry**

Perennial from SE North America (Florida).

Uses: The ripe fruits are edible.

***Physalis carpenteri.* Carpenter's ground cherry**

Annual from SE North America.

Uses: The ripe fruits are edible.

***Physalis caudella.* Southwestern ground cherry**

Perennial from southern North America.

Uses: The ripe fruits are edible.

***Physalis crassifolia.* Thickleaf ground cherry**

Perennial from SW North America, growing 30 cm high.

Uses: The ripe fruits are edible.

Physalis divaricata

Annual growing to 1 m high from Asia (Nepal, Pakistan, Afghanistan).

Uses: The ripe fruits are edible.

Physalis alkekengi fruit capsules. From www.amg.gda.pl

***Physalis foetens.* Tropical ground cherry**

Annual from southern North America.

Uses: The ripe fruits are edible.

***Physalis hederifolia*. Ivyleaf ground cherry**

Perennial from SW North America, growing 30 cm high.

Uses: The ripe fruits are edible.

***Physalis heterophylla*. Clammy ground cherry**

A rhizomatous perennial to 90 cm high, densely hairy and sticky. Yellow flowers are followed by a greenish-brown sac. The fruit inside ripens yellow in summer-autumn and is edible. Native to the SE USA; hardy to zone 8 (about -10°C).

Uses: The fruits are edible with a sweet distinctive flavour. They are ripe when the sac turns brown and the berry inside turns yellowish.

Physalis crassifolia. From http://tolweb.org

***Physalis ixocarpa*. Tomatillo, Jamberry, Mexican husk tomato**

An annual growing to 120 cm high, with spreading branched stems. Yellowish-purple flowers are followed by greenish sacs, inside which are edible sticky green fruits, 2-6 cm across, ripening to yellow or violet. Native to Mexico and the southern USA in areas hardy to zone 8 (about -10°C). Sometimes included in *P. philadelphica*, this may have derived from it through cultivation.

Flower of Physalis heterophylla. From http://sanangelo.tamu.edu

Varieties: 'Indian' — fast maturing.
'Large Green' — large fruit.
'Purple' — purple fruit, slightly sharper.
'Purple Husk' — has purple husks.
'Rendidora' — large fruits, fast maturing.
'Tome Verde' fast maturing, large fruits.
'Verde Puebla' — large fruits.

Uses: The fruits are used in their green state (presumably they do not contain toxins) when they have a tart flavour, something like green apples with a hint of tomato. The best flavour is when they are still deep green and when the husk has changed from green to tan. They are used raw or cooked and traditionally used in many ways in Mexican cooking in salads, tacos, sandwiches and sauces, especially salsas. The green fruits keep for months in a cool well ventilated location. For longer preservation they are sometimes canned.

If allowed to ripen the sacs split and fruits turn yellow or purple and develop a sweet bland taste, when they are sometimes used in pies and preserves.

***Physalis latiphysa.* Broadleaf ground cherry**

Native to S. North America.

Uses: The ripe fruits are edible.

***Physalis longifolia subglabrata.* Smooth ground cherry, Bladder ground cherry**

Perennial to 120 cm high. Yellowish-purple flowers are followed by sacs containing reddish-purple edible fruits in summer and autumn. Native to Eastern North America, hardy to zone 5 (-23°C).

Uses: The ripe fruits are edible.

***Physalis minima.* Pygmy ground cherry**

Annual from Eastern Asia.

Uses: The ripe fruits are edible.

Tomatillo (Physalis ixocarpa) showing the green fruits (berries) enclosed in a papery, inflated calyx. From waynesword.palomar.edu

***Physalis missouriensis* — Missouri ground cherry**

Annual from S. North America, growing to 1 m high.

Uses: The ripe fruits (to 20 mm across) are edible.

***Physalis mollis*. Field ground cherry**

Native to S North America.

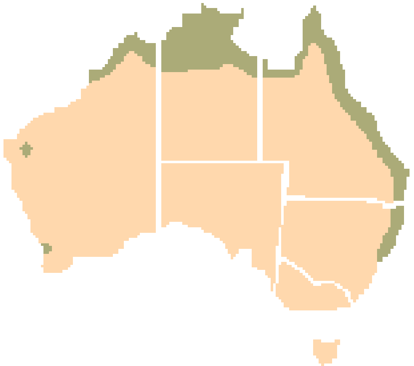
Uses: The ripe fruits are edible.

***Physalis peruviana.* Cape gooseberry, Purple ground cherry, Peruvian ground cherry**

An erect perennial growing to 1 m high, sometimes grown as an annual. Whitish-yellow flowers are followed by greenish-brown sacs, inside which are edible purplish or golden fruits to 2 cm across, ripening in summer. Native to tropical south America, hardy to zone 8 (about -7°C).

The plant is widely grown throughout the world. In India it is often interplanted with vegetables.

Physalis minima. From http://www.nparks.gov.sg



Australian distribution of Physalis minima. From www.rumbalara-e.schools.nsw.edu.au

Varieties: 'Giallo Grosso' ('Large Golden Italian') — fruits large.

'Giant' — very large fruit, needs a long season.

'Golden Nugget' — small fruits, sweet.

'Goldenberry' — fruits large, sweet, golden.

Uses: The fruits are edible with a very nice distinctive sweet grape-pineapple-tomato flavour. Used like tomatoes, raw in salads and desserts or (more commonly) cooked in jams, jellies, pies etc. They are high in pectin. The fruits can also be dried. A single plant can yield up to 300 fruits. The food value of the fruits per (100 g) is approximately:

Fat	0.16 g	Calcium	8.0 mg	Carotene	1.61 mg
Protein	0.05 g	Phosphorus	55.3 mg	Thiamine	0.1 mg
Fibre	4.9 g	Iron	1.23 mg	Riboflavin	0.03 mg
Niacin	1.73 mg	Vitamin C	43.0 mg		

***Physalis philadelphica.* Purple ground cherry, Jamberry, Tomatillo, Mexican ground cherry, Miltomate**

An annual growing to 60 cm high. Yellowish-violet flowers are followed by green sacs, veined violet; inside is an edible yellow to purple fruit. Native to Mexico but naturalised in eastern North America in areas hardy to zone 7 (-15°C).

Varieties: 'Purple de Milpa' — fruit small, purple tinged, sharp flavoured, keeps well.

'Tepehuan' — Mexican variety.

'Zuni' — prolific cropper.

Uses: The fruits are edible raw or cooked.

Cape gooseberry (Physalis peruviana) fruits. From http://jardin-mundani.com

***Physalis pubescens.* Ground cherry, husk tomato, strawberry tomato, Downy ground cherry**

An annual growing to 90 cm high. Yellow-purple flowers are followed by green sacs containing yellow edible fruits to 1.5 cm across in summer and autumn. Native to the Americas in areas hardy to zone 7 (-15°C). *P. pubescens integrifolia* has the synonym *P. pruinosa* and is known as the dwarf cape gooseberry; it grows only 34 cm high and is native to Eastern North America in areas hardy to zone 5 (-23°C).

Varieties: 'Aunt Molly's' — very sweet and tangy fruit, tangerine flavour.

'Cossack Pineapple' — fruit small, yellow, pineapple flavour.

'Eden' — fruits small, yellow, sweet.

'Goldie' fruit medium sized, good flavour, plants prolific.

'Huberschmidt' — heirloom variety from Pennsylvania.

'New Hanover — fruits small, yellow, good flavour.

'Sweet Amber' — small orange fruits, good flavour.

Uses: The ripe fruits (15 mm across) are edible. When ripe, the tight-fitting husk turns brown, peels back and the fruit drops from the plant. If left in the husk it will keep for several weeks. Yields are typically 500 g per plant. The flavour is distinctive and pleasant, resembling

Section through fruit of Physalis philadelphica. From http://toptropicals.com

apples, and fruits are used raw in cocktails or as a dessert; and cooked in jams, pies and sauces.

***Physalis pumila.* Dwarf ground cherry**

Perennial from SE North America, growing 30 cm high.

Uses: The ripe fruits are edible.

***Physalis subulata.* Chihuahuan ground cherry.**

Uses: The ripe fruits are edible.

***Physalis virginiana.* Virginia ground cherry**

Perennial to 120 cm high with hairy stems. Yellowish-purple flowers are followed by sacs containing reddish-purple edible fruits in summer and autumn. Native to Eastern North America, hardy to zone 5 (-23°C).

Uses: The ripe fruits are edible.

Common synonyms

P. edulis = P. peruviana
P. subglabrata = P. longifolia subglabrata
P. greenei = P. crassifolia
P. variovestia = P. mollis variovestia
P. lanceolata = P. virginiana
P. virginiana sonorae = P. longifolia longifolia
P. macrophysa = P. longifolia subglabrata
P. wrightii = P. acutifolia
P. pruinosa = P. pubescens integrifolia

Physalis pubescens. From http://uk.geocities.com

***Physalis viscosa.* Grape ground cherry, Prairie ground cherry**

Perennial growing to 60 cm high with creeping roots, forming colonies. Flowers yellowish-green, fruits (in papery husks) turning purple when mature, sticky. Tolerates drought, shade and trampling. Native to California.

Uses: Ripe fruits are edible.

References

Crawford, M: *A.R.T species database*, 2005.
Dremann, C: *Ground Cherries, Husk Tomatoes and Tomatilloes*. Redwood City Seed Co, 1985.
Facciola, S: *Cornucopia II*. Kampong Publications, 1998.
Huxley, A: *The New RHS Dictionary of Gardening*. Macmillan Reference, 1999.
ITIS (Integrated Taxonomic Information System) at www.itis.usda.gov.
Manandhar, N: *Plants and People of Nepal*. Timber Press, 2002.
Moerman, D: *Native American Ethnobotany*. Timber Press, 1998.
Morton, J: *Fruits of Warm Climates*. 1987.
Munier, I: *Physalis, adorable amour en cage*. Fruits Oublies No. 2 -2002.
University of Minnesota Extension Service, Yard & Garden Brief: *Physalis*. 2005.

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GROWTH PERFORMANCE OF INDIAN SANDALWOOD *(SANTALUM ALBUM)* WITH DIFFERENT HOST SPECIES

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Abstract

The Sandal or Indian Sandalwood tree (*Santalum album* L) is a partial root parasite on several host plants. It shows a preference to certain host species and grows well with these. In the present study, *Pongamia pinnata* and *Casuarina equisetifolia* best supported the sandal plants, yielding robust growth, whereas some hosts like *Artocarpus integrifolia, Acacia auriculiformis* and *Swietenia mahogani* hindered the growth of sandal. Understanding the dynamics of parasitism may help in raising successful multispecies plantations of sandal along with other valuable timber species.

Introduction

Sandal *(Santalum album L.)* has gained importance world over for its scented heartwood and essential oil, which is used in perfume, medicine, incense material, carving and other handicrafts of curious interest.

Sandal is a hemiparasite and was first reported by Scott in 1871. Barber (1906 &1907) observed the absence of root hairs and presence of actively absorbing haustoria in the rhizosphere of sandal plants; this hemiparasitic nature led them to believe that sandal plants depend on hosts for certain nutrients.

Sandal can be a parasite on over 300 species of plants found in nature, from grasses to other sandal. But Sandal shows different growth patterns with different host species. Lack of understanding of the complex host-parasite interaction has been the cause of failure of sandal plantations in the past.

Limited studies conducted earlier in pot culture experiments on the influence of hosts on sandal have shown that certain hosts have promoted better growth (Parthasarathi et al, 1974; Venkata Rao, 1938; and Ananthapadmanabha et al, 1988). In these pot culture studies, plants had a restricted rhizosphere, inadequate for the proper growth of both sandal and the host plants. It is likely that some of the same hosts may behave differently in the field condition because of the wider root zone.

The information on growth performance of sandal plants with different host species in the

Trunk and foliage of Santalum album. From http://herb.daegu.go.kr

field condition is not adequate. Hence, this study was undertaken to understand comparative growth performance in both pot and field conditions.

Materials and Methods

Studies were conducted as a World Bank project during the year 1998-99. Experiments were established in both the nursery and in the field.

Nursery experiment

Studies were conducted under nursery conditions in earthen pots, 40 cm x 30 cm (holding 8-10 kg of soil). The potting mixture consisted of sand, soil and farmyard manure in the ratio of 2:1:1. Based on earlier studies, nine tree species were regarded as poor, medium, and good hosts (Ananthapadmanabha, et al, 1988; Parthasarathi et al, 1974) for the experiment. Seedlings of each host species and sandal plants of known seed origin were raised separately in nursery beds.

Subsequently, uniform sandal seedlings were maintained in polybags along with the primary host, *Cajanus cajan*. After 6 months in the polybag, each sandal seedling and its primary host were transferred to a pot, with one selected host species. One week after planting, the primary host was trimmed at the base. One set of plants without a host served as the control. The following were the different host plant treatments:

1. *Wrightia tinctoria*
2. *Casuarina equisetifolia*
3. *Pongamia pinnata*
4. *Tectona grandis*
5. *Azadirachta indica*
6. *Eucalyptus camaldulensis*
7. *Acacia auriculiformis*
8. *Artocarpus integrifolia*
9. *Swietenia mahogani*
10. Control (without host)

The experiment was laid out as a random block design with four blocks and five replications in each block.

Indian Sandalwood tree. From www.skinbiology.com

Field experiment

The field experiment was conducted in Gottipura, a field station of IWST, 40 km from Bangalore. This was a parallel experiment established in the field with the same host species as for the pot culture experiment.

The sandal plants were transferred to the field along with their selected host species. There were four sandal plants in each block along with hosts in the same pit and also three host plants planted in quincunx pattern.

It has been observed that the quincunx pattern of hosts helps the sandal to parasitise at a later stage and grow without overshading each other (Ananthapadmanabha et al, 1984). Subsequently, the host in the same pit can be removed.

Three replications were kept for each treatment (hosts) and the seedlings were planted in a completely randomized design of row planting with alternate hosts, at a ratio of 4:3, with 3 m between sandal and host, and 6 m between two sandal plants. Each block was 6 m long, including trenches in the middle of the block. Total area of the experiment was 5130 sq m. The land was plain without any undulation or slope. Soil work was done periodically and weeded regularly.

Botanical drawing for Santalum album. From www.payer.de

Experiments were closely monitored for a year in both the pot and the field. Soil working, watering and weeding were done regularly in both experiments. In the pot experiment, hosts were periodically pruned. Mortality of the sandal plants was noted and infilling was carried out for the first month. Plant height was recorded at monthly intervals for 12 months.

Different growth parameters, like survival percentage, collar diameter, fresh and dry weight of shoot and root by the oven dry method (for pot studies only), chlorophyll content (Sadasivarn and Manickam, 1991), leaf area by using the instrument CI-203 (leaf area meter) and nitrate reductase activity (Sadasivam and Manickam, 1991) were recorded after 12 months. Seedling quality index was calculated with the following formula (Dickson et al, 1960) for the pot culture plants.

Seedling quality index = Total dry weight / (Height/collar diameter + Shoot dry wt./Root dry weight)

Statistical analysis

The data was analysed statistically and the significance of the difference between the treatment means was tested at 5% probability using 'F' and 'T' tests.

Results and Discussion

Tables 1 and 2 show the results of the experiments after 12 months. Analysis of the parameters presented in the tables shows that the results are significant at the 5% level.

The height and collar diameter measurements revealed that sandal plants with *Pongamia* were significantly superior, followed by *Casuarina, Wrightia, Tectona, Azadirachta.* and *Eucalyptus.* Plant height and collar diameter in sandal plants with *Pongamia* and *Casuarina* increased by about 200-260% over the control, and other poor hosts such as *Acacia, Artocarpus, and Swietenia.* The sandal plants in association with *Wrightia, Azadirachta* and *Eucalyptus* as host showed height and collar diameter increases of around 150 % (medium hosts).

Table 1. Parameters of Sandal plants with different hosts in pots

Host treatments	Height (cm)	Collar diam. (mm)	Total biomass	Chlorophyll a	b	Total	Nitrate reductase activity	Seedling quality index
Pongamia pinnata	57.94d	5.64d	30.12d	1.21h	0.46g	1.66h	0.24d	0.2952d
Casuarina equisetifolia	44.78c	4.15c	21.13c	0.87g	0.37f	1.24g	0.27d	0.1962c
Wrightia tinctoria	37.16c	3.79c	7.48b	0.44d	0.24d	0.67d	0.2d	0.0808b
Tectona grandis	33.37b	3.17b	1.28a	0.62f	0.29e	0.9f	0.12c	0.0117a
Azadirachta indica	33.81b	3.14b	2.14a	0.5e	0.28e	0.78e	0.13c	0.0196a
Eucalyptus camaldulensis	32b	3.8c	3.46a	0.27b	0.19c	0.46c	0.06b	0.0335a
Acacia auriculiformis	18.42a	1.97a	0.89a	0.23b	0.15b	0.38b	0.04a	0.0058a
Artocarpus integrifolia	19.81a	1.7a	0.76a	0.14a	0.16b	0.31a	0.02a	0.0022a
Swietenia mahagoni	20.6a	1.95a	0.76a	0.23b	0.16b	0.39b	0.02a	0.0069a
Control (no host)	22.43a	2.19a	0.78a	0.23b	0.14a	0.37b	0.06b	0.0079a

Note: In each column values followed by a common letter indicate they were on par at P= 0.05.

Table 2. Parameters of Sandal plants with different hosts in the field.

Host treatments	Height (cm)	Collar diam. (mm)	Total biomass	Chlorophyll a	b	Total	Nitrate reductase activity	Seedling quality index
Pongamia pinnata	187d	29.29c	1.03f	0.28d	1.31g	0.2c	187d	29.29c
Casuarina equisetifolia	183d	25.08c	1.45h	0.38f	1.82i	0.22c	1.83d	25.08c
Wrightia tinctoria	156c	25.04c	0.88d	0.3e	1.18f	0.19c	156c	25.04c
Tectona grandis	148c	20.88b	0.86d	0.22c	1.08e	0.12b	148c	20.88b
Azadirachta indica	163d	25.52c	1.08g	0.37f	l.44h	0.13b	163d	25.52c
Eucalyptus camaldulensis	136c	20.59b	0.63b	0.l5a	0.78a	0.12b	136c	20.59b
Acacia auriculiformis	114b	12.39a	0.89c	0.19b	1.08e	0.02a	114b	12.39a
Artocarpus integrifolia	125b	19.67b	0.82c	0.14a	0.96c	0.02a	125b	19.67b
Swietenia mahagoni	80a	13.86a	0.6b	0.21c	0.81b	0.02a	80a	13.86a
Control (no host)	110b	18 86b	0.86d	0.14a	0.99d	0.02a	110b	18.86b

Note: In each column values followed by a common letter indicate they were on par at P= 0.05.

The results of the total biomass in the pot culture experiment show that biomass in sandal plants with *Pongamia* and *Casuarina* as hosts were discernibly higher, and the increase was 3000-3500 % compared to the control. Whereas near *Wrightia, Tectona, Azadirachta* and *Eucalyptus,* sandal biomass increase was 200-600 % compared to the control and poor hosts such as *Acacia, Artocarpus* and *Swietenia.*

Data obtained on chlorophyll content were also significant when compared with the control, in line with the other growth parameters. Although the order of performance is the same as in other growth parameters, each treatment falls under a different group.

Seedling quality index of sandal plants with *Pongamia* and *Casuarina* as the host was very significant when compared to sandal plants without a host (control). The increase in growth is more than 2000 %, and it is a clear indicator of growth performance and order of ranking.

Sandal plants associated with *Pongamia* and *Casuarina* did not show any mortality, whereas the medium hosts like *Wrightia, Tectona, Azadirachta* and *Eucalyptus* had mortality rates of up to 10 %. Mortality rate of sandal plants was very high (up to 60 %) in the control, and near *Acacia, Artocarpus* and *Swietenia.*

Mortality rate in sandal plants was a little less in the field experiment compared to that of the pot experiment, though the trend remained the same as in the case of pot culture. This may be due to the unrestricted rhizosphere zone in field conditions.

The result of nitrate reductase activity of sandal plants was quite significant and shows that the activity is directly proportional to the growth parameters of the plants. Nitrate reductase activity in sandal plants with good hosts was more than 1000 % compared to poor hosts and the control.

Poorly grown sandal plants showed low nitrate reductase activity. This activity may be taken as an index for the growth and biomass performance. Based on these studies and performance of growth parameters of sandal plants, hosts can be classified into three distinct groups; viz, good, medium and poor. 'These results support the findings of Ananthapadmanabha et al (1988), who classified three groups of hosts based on different physiological activity with sandal.

Section through a sandalwood log. From www.righteouswoods.net

Pokhriyal et al (1993) recorded that the major source of nitrogen available in the soil is nitrate, and that it has to be reduced before assimilation in the metabolic processes, and this nitrate reductase activity has a direct effect on biomass production.

Leaf area was more in sandal plants that were growing with *Pongamia* and *Casuarina* than with the other hosts in the pot culture. In the field, leaf area was more in sandal plants that were grown with *Pongamia* and *Casuarina, while* leaf area near *Tectona, Azadirachta,* and *Eucalyptus* was also good, if not statistically significant.

The present study showed that there are some variations in growth and other parameters between different host treatments. But in both the pot and field experiments, *Pongamia* and *Casuarina* as hosts supported maximum growth and biomass, whereas association of sandal plants with *Wrightia, Tectona, Azadirachta* and *Eucalyptus* as hosts resulted in moderate growth performance. *Acacia, Artocarpus* and *Swietenia* as hosts did not support good growth of the sandal plants. It was observed that the poor hosts hindered the growth of sandal plants to some extent even when compared to that of the control. This may be due to the fast growth of the hosts and over shadowing of the sandal plants by a thick canopy, which might have slowed growth.

The field study showed that the medium hosts also supported good growth for sandal compared to the pot experiment, though the order of performance remains the same as that of the pot experiment. This may be due to the wide root zone where negative stress of interaction between the host and the parasite may be reduced, unlike in potted plants with a narrow root zone. The results of this field experiment emphasis the need for further studies to understand

the process of heartwood formation with different hosts. *Santalum album* planted with multiple hosts in the field has shown to be successful in plantations in Kununurra, Western Australia (Radomiljac et al, 1998) and similar information may be obtained from continuing this field experiment. Further work in this direction will help in establishing a farm forestry system or multispecies plantation of sandal along with other valuable timber species.

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References

Ananthapadmanabha, H S, Rangaswamy, C R, Sarma, C R, Nagaveni,SH, Jain, H C, and Krishnappa, H P (1984). *Host requirement of sandal*. Ind. For. 110:26468.

Ananthapadmanabha, H S, Nagaveni, H C, and Rai, S N (1988). *Influence of host plants on the growth of sandal*. Myforest, 24 :154-60.

Barber, C A (1906). Studies of root parasitism —*The haustorium of Santalum album L.* 1. *Early stages up to penetration*. Mem. Dept. Agri. Ind, Bot, Ser. l. Pt 1: l-30.

Barber, C.A. (1907). Studies of root parasitism —*The haustorium of Santalum album L.* 2. *The mature haustorium*. Mem. Dept. Agri., Ind, Bot, Ser. 1 Pt 2: 1-58

Dickson, A, Leaf, A L, and Honser, J F (1960). *Quality appraisal of white spruce and white pine seedling stock in nurseries*. For. Chron. 36: 10-13.

Parthasarathi, K, Gupta, S K, and Rao, P S (1974). *Differential response in the cation exchange capacity of the host plants on parasitization on sandal (Santalum album)*. Curr. Sci. 43: 20.

Pokhriyal, T C, Chaukiyal,S P, Singh, U, and Bist, G S (1993). *Effects of nitrogen treatments on in vivo nitrate reductase activity and biomass production in Eucalyptus seedling*s. Ind. For. 1(2): 141-47.

Radomiljac, A M, Shea, S R, McKinnel, F H, and McComb, A (1998). *Potential irrigated tropical forestry in northern Western Australia*. Aust. For. 61 (2): 70-75.

Sadasivam, S and Manickam, A (1991). *Biochemical methods*. New Age International (P) Ltd Publishers, New Delhi. Pp 102-03 & 190-91.

Scott, J. (1871). *Notes of horticulture in Bengal. No.2, Loranthaceae, mistletoe order, their germination and mode of attachment*, J. Royal. Horti. Soc. India, 2: 287.

Venkata Rao, M G (1938). *The influence of host plants on sandal and spike disease*. Ind. For. 64(11), 656-669,

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DNA FINGERPRINTING OF FIG (*FICUS CARICA*) VARIETIES USING THE AFLP TECHNIQUE

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Introduction

The identification of varieties of the fig (*Ficus carica*) based on morphology is clouded and confused because of a very long history of breeding (Hart 2001). Previous attempts at discrimination of the varieties have used morphological characters such as leaf type (palmate, three-lobed, five-lobed and seven lobed), leaf texture (glossy, shiny, dull), dimensions of leaf laminas (width and length of blade, length) and colour and shape of fig skin and flesh (green/yellow, bronze/copper/violet, dark violet/purplish black). However, often these characters varied within varieties or failed to discriminate between varieties (Hart 2001). Thus most efforts at using morphology to describe an accurate system for identifying fig varieties have met with limited success (Hart 2001).

Genetic markers provide a powerful alternative to morphology for the accurate characterisation of the genetic relationships among varieties. One of the most powerful genetic markers for varietal identification is Amplified Fragment Length Polymorphism (AFLP). Cabrita et al (2001) contrasted the performance of isozymes, RAPD and AFLP to assess genetic differences and relatedness among fig (*Ficus carica* L.) clones. AFLP proved to be superior, clearly distinguishing between 11 Sarilop clones (Cabrita et al 2001).

In early 2002, BGPA conducted a preliminary study for WANATCA to assess the feasibility of AFLP for the genetic discrimination of fig varieties held at Hillside Farm. The fig varieties "Adam" and "Calimyrna" (plants 22 and 23 respectively) were genotyped with AFLP, and polymorphism detected. On the basis of this result, WANATCA commissioned BGPA to conduct an assessment of genetic discrimination and relatedness for a wider collection of fig varieties from Hillside Farm. This report presents the results of this study.

Methods

Silica dried plant material (leaf) from fifteen fig varieties from Hillside Farm (Table 1) were collected fresh and delivered to BGPA by Alex Hart in November 2003.

DNA was extracted from 15 silica dried leaf samples using SDS method (Jobes *et al*. 1995) supplemented with Qiagen DNasy, Plant Mini Kit. The procedure involved:

- 1ml extraction buffer (100mM NaAcetate pH4.8, 100mM EDTA pH8,500mM NaCl, 10mM DTT, 2%PVP) and 1 ul proteinase-K (20ug/ul) was added to 2ml tube containing dry plant material and two 5mm glass beads.
- The sample was shaken at speed 5.0 for 2x40s (FastPrep FP120) and incubated at 55°C for 30-60 min.
- 20% SDS was added to a final concentration of 2%, shaken for 10s and incubated for a further 1-2 hrs at 65°C.
- The extract was purified with chloroform.
- DNA was precipitated with 2/3 volume of isopropanol, resuspended in 400ul of Buffer AP1 (Qiagen) and 4ul RNAse A, and incubated for 10 min. at 65°C.
- Proteins and polysaccharides were precipitated out of the sample by adding 130ul AP2 buffer (Qiagen), and purifying through a spin column and centrifuging at maximum speed for 2 min.
- Pour off the liquid collected in the collection tube into a new 1.5ml tube
- DNA was precipitated with 1.5 volumes of Buffer AP3/E mix (Qiagen), washed in wash buffer AW (Qiagen) and resuspended in 50-100 ul of AE.

The concentration and quality of DNA was assessed by 1% agarose gel electrophoresis (Fig. 1).

Table 1. Fig varieties collected from Hillside Farm by Alex Hart and delivered to BGPA for genetic analysis by AFLP

Variety	***Sample Number***	***Comment***
Good	T4	Nearest the fence
Deanne	T6	3rd tree from E end of row
Skoss 1	T10	3rd tree from E end of row
Excel	T16	
Other Williams	T20	
Williams 5	T21	Ex Mrs M.Beck Cannington
Calimyrna	T22	
Adam	T23	
Skoss 4	T25	
Tena	T27	
Panache	T88	
Aechipal	T91	
Ex Red Hill Tip	T102	J. Dawson
Pink Jerusalem	T103	
Black Adam	T104	16/8/01

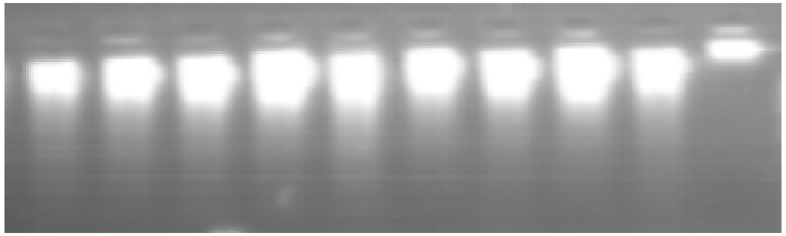

Figure 1. An example of DNA extracted from figs. The last column represents a 100ng standard.

Each sample was then assessed by AFLP according to the method outlined in Zawko et al, 2002 using the fluorescently labelled primer pairs m-cac/e-act, m-cac/e-agg, and m-cac/e-acc. Resulting DNA fingerprints were visualised and scored using GeneScan™ Software. The genetic differentiation between varieties was determined by a count of the number of markers with different states (ie presence/absence). A dissimilarity matrix using Manhatten distance between each pair of samples was constructed. The dissimilarity matrix was summarised for all samples by a UPGMA cluster analysis.

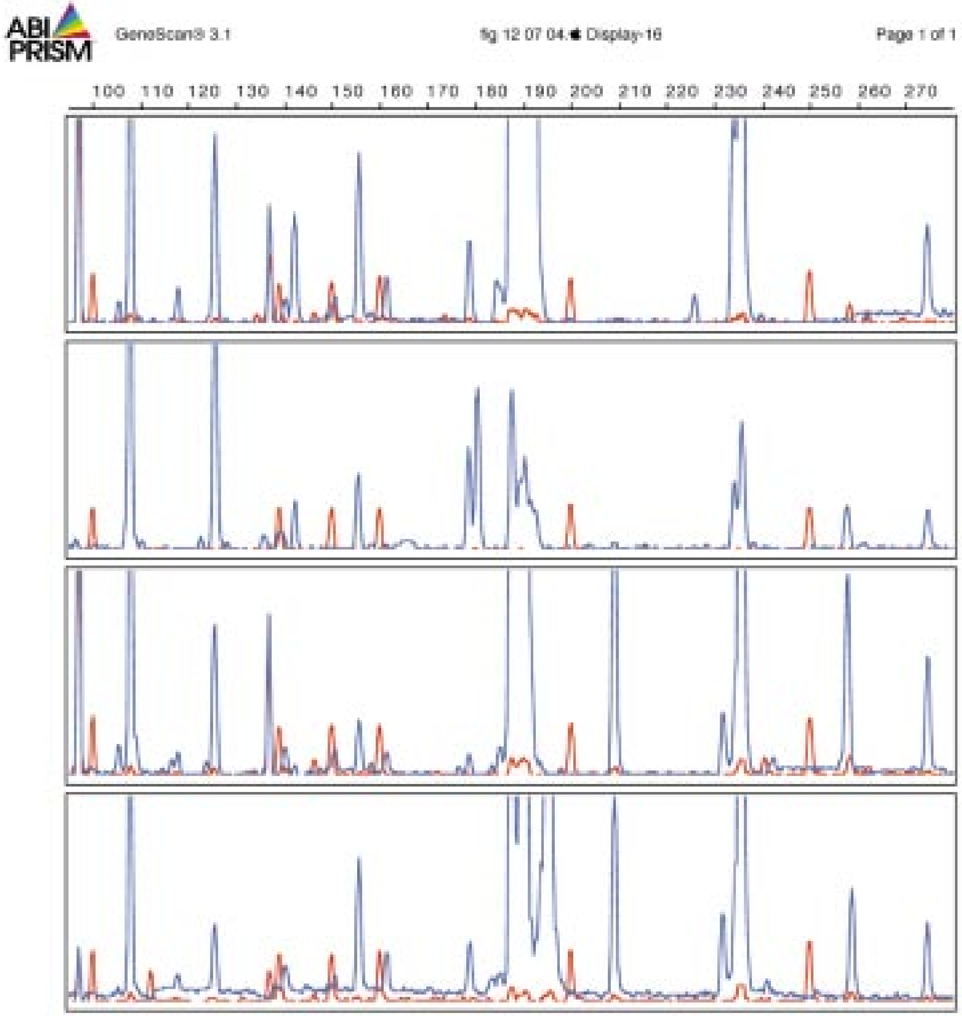

Figure 2. Partial DNA fingerprints (in blue) generated for 4 fig varieties by the AFLP primer pair m-cac/e-act. Each peak indicates the presence of a fragment of DNA of a particular size. Red peaks are internal size standards.

Results

Three AFLP primer pairs generated 42 markers, of which 33 (79%) were polymorphic. Unique DNA fingerprints were generated for each of the 15 varieties of fig assessed (Fig.2; Table 2). Genetic dissimilarity varied from 1 marker difference for the variety pairs Adam/Williams, Calimyrna/ Williams, Deanne/Williams and Skoss4/Calimyrna through to a number of variety pairs with 19 marker differences (Table 3).

Eight markers were unique for the varieties assessed, present in only one variety. These were all generated by the primer pair m-cac/e-act, and included Archipal (103 base pair (bp), 132bp, 144bp), Black Adam (149bp), Excel (102bp), Pink Jerusalem (169bp) and Tena (173bp. 215bp) (Table 2). The primer pairs m-cac/e-agg and m-cac/ e-acc were more conserved.

UPGMA clustering of the AFLP data generated a major bifurcation, made up of [Good, Panache, Pink Jerusalem, Ex Red Hill Tip, Tena and Archipal] in one cluster and [Deanne, Williams 5, Adam, Skose 4, Calimyrna, Skose 1, Other Williams, Excel and Black Adam] in the 2nd cluster. Within these clusters, varieties within the 2nd cluster were

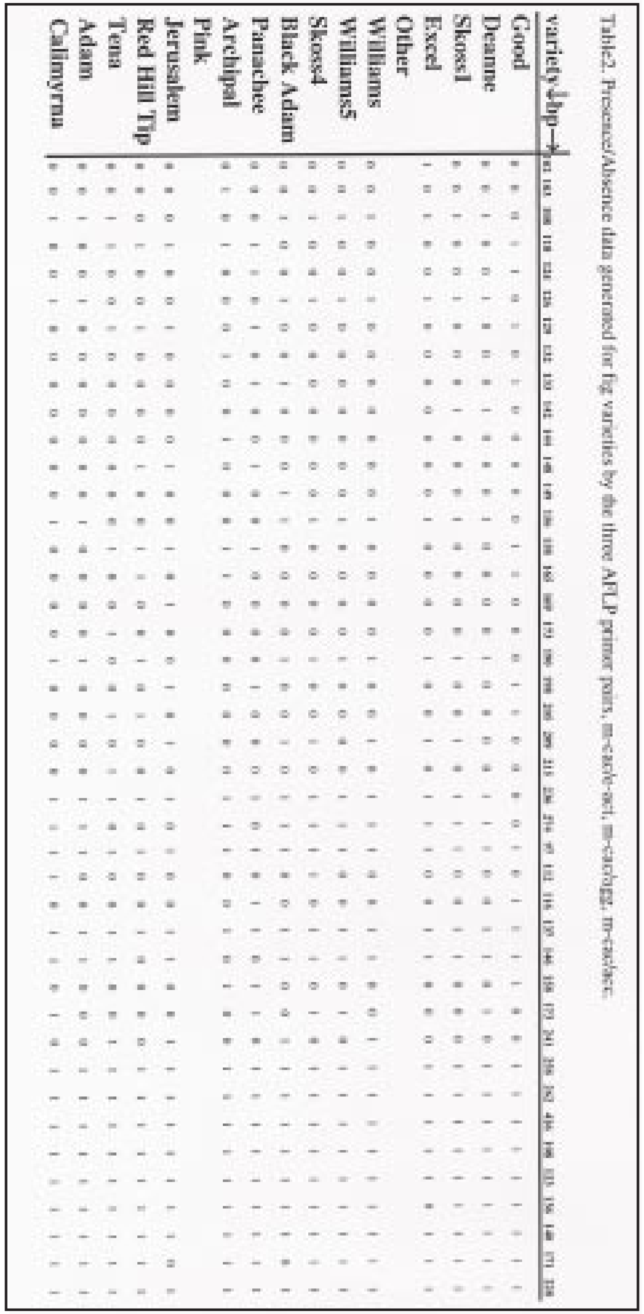

Table2. Presence/Absence data generated for fig varieties by the three AFLP primer pairs, m-cac/e-act, m-cac/e-agg, m-cac/e-acc.

variety↓ bp→	[illegible]
Good	[illegible]
Deanne	[illegible]
Skose1	[illegible]
Excel	[illegible]
Other	[illegible]
Williams	[illegible]
Williams5	[illegible]
Skoss4	[illegible]
Black Adam	[illegible]
Panachee	[illegible]
Archipal	[illegible]
Pink Jerusalem	[illegible]
Red Hill Tip	[illegible]
Tena	[illegible]
Adam	[illegible]
Calimyrna	[illegible]

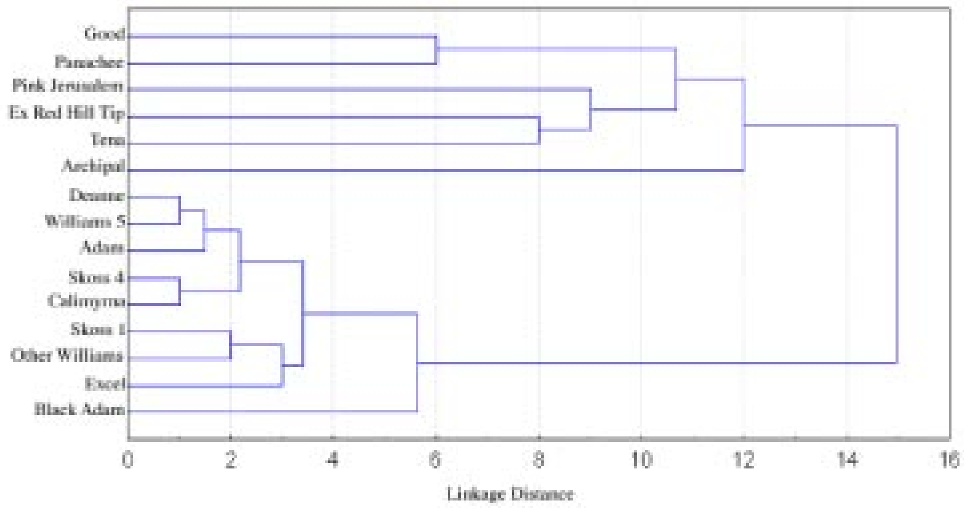

Figure 3. Dendrogram of AFLP data generated by UPGMA clustering of the Manhatten distance matrix showing the genetic similarity among fig varieties. Linkage distance indicates the number of markers different among samples.

more genetically similar to each other than varieties within the 1st cluster were to each other. That is, the 2nd cluster is a relatively tight genetic grouping (showing less genetic variation), while the 1st cluster is a relatively lose genetic grouping (showing more genetic variation).

These genetic results appear to show little similarity to classifications based on morphology as described by Hart (2001). Cabrita et al (2001) drew a similar conclusion for AFLP results compared to results from morphological traits (such as quality, dried fruit yield, transpiration and photosynthesis rates) for Sarilop clones.

In summary, AFLP is a powerful tool for the genetic identification, and the assessment of the genetic similarity, of fig varieties. The development of microsatellite primers (Khadari et al 2001) for *F. carica* presents an opportunity to apply an independent molecular marker for greater genetic resolution and more confident identification of genetic similarities among fig varieties.

References

Cabrita L F et al (2001). *Suitability of isozyme, RAPD, and AFLP markers to assess genetic differences and relatedness among fig (Ficus carica L.) clones*. Scientia Horticulturae 87:261-273.

Hart A (2001). *Problems identifying fig varieties*. (http://aoi.com.au/acotanc/Papers/Hart-1/Author-n-Text.htm)

Khadari et al. (2001) *Identification and characterisation of microsatellite loci in the common fig (Ficus carica L.) and representative species of the genus Ficus*. Molecular Ecology Notes 1:191-193.

Zawko G et al. (2001) *Conservation genetics of the rare and endangered Leucopogon obtectus (Ericaceae)*. Molecular Ecology, 10**,** 2389-2396.

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Table 3: Dissimilarity matrix for fig varieties by the three AFLP primer pairs, m-cacfe-act, m-cac/agg, m-cac/acc.

	GOOD	DEANNE	SKOSS1	EXCEL	OTHER_WI	WILLIAMS	SKOSS4	BLACK_AD	PANACHEE	ARCHIPAL	PINK_JER	R_HILL_T	TENA	ADAM	CALIMYRN
GOOD	0														
DEANNE	18	0													
SKOSS1	18	2	0												
EXCEL	19	5	3	0											
OTHER_WI	18	4	2	3	0										
WILLIAMS	17	1	3	4	3	0									
SKOSS4	19	3	3	4	3	2	0								
BLACK_AD	19	7	5	6	3	6	6	0							
PANACHEE	6	16	18	19	18	15	17	19	0						
ARCHIPAL	12	14	14	15	14	13	15	17	12	0					
PINK_JER	12	16	14	15	12	15	15	13	10	14	0				
R_HILL_T	9	13	13	14	13	12	14	16	9	9	9	0			
TENA	11	13	13	14	11	12	14	14	13	13	9	8	0		
ADAM	16	2	2	3	2	1	3	5	16	12	14	11	11	0	
CALIMYRN	18	2	4	5	4	1	1	7	16	14	16	13	13	2	0

THE AVOCADO — AN ARCHAIC ANOMALY

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The avocado is an archaic anomaly. The skin isn't great, but the heart is pure gold. Botanically and popularly regarded as a fruit, it is typically used as a vegetable. It can hang on the tree for 16 months or more — roughly the gestation period of a rhinoceros — but ripens only after picking, when its reptilian hide belies the buttery flesh within. Indeed, scientists theorize that this extravagantly rich pulp evolved to entice megafauna like mastodons and ground sloths to swallow the fruit whole and disperse the giant seeds.

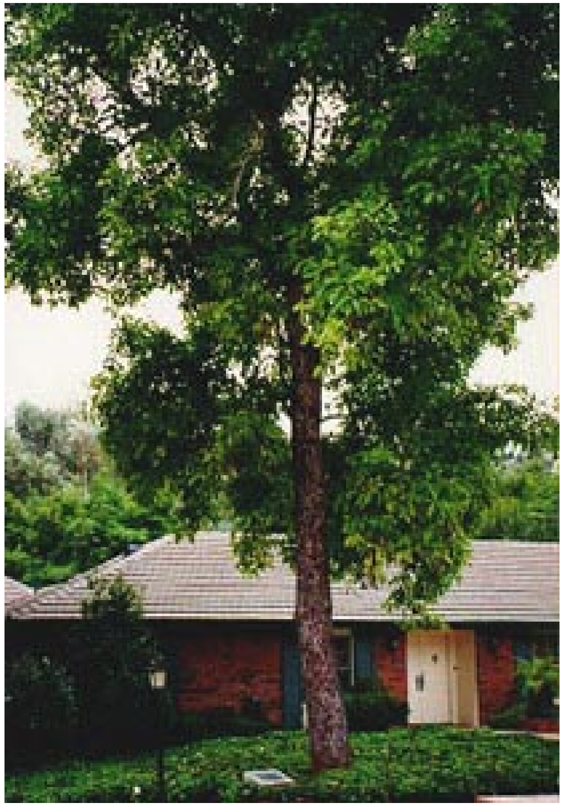
With the increase in America's Hispanic population and in the taste for Latin foods, per capita consumption of avocados has doubled in 25 years, to 2.3 pounds annually. One avocado variety, Hass, predominates, though it ranges bafflingly from sublime to insipid. Much has changed in the last decade, and choosing a top-quality fruit requires a bit of savvy, as I found on a recent tour of California's avocado belt, a 300-mile swath from San Diego north to Morro Bay that produces nearly 90 percent of the nation's crop. Here avocados are diverse and iconic, the objects of passionate study and debate among growers, experts and gardeners.

One of the people most familiar with the full range of avocado shapes, sizes, colours and flavours is Julie Frink, a piano teacher who volunteers at the University of California's orchard in Irvine, 40 miles southeast of Los Angeles. On a recent morning she walked through trees that bore 157 different varieties, exclaiming about favourites like Julia ("It tastes just like ice cream") and Sharwil ("Hands off — we eat them all ourselves").

Avocados. Photo: David Karp

"I'm very particular about the avocados I eat," Ms. Frink said. She showed trees of the three main subspecies of avocados: Guatemalan (typically bearing large, round fruit like Reed), Mexican and West Indian. Some of the finest and most distinctive varieties are Mexican. Long used for cold-hardy rootstock, the trees typically bear pear-shaped or oval fruit that ripen in fall. They are too delicate to ship but are much appreciated by home garden connoisseurs, with their small size; their thin, glossy, purple-black skin; and their spicy, anise-flavoured pulp. The fresh and dried leaves, also anise-scented, are used to flavour barbecued meats in Mexican cooking.

§ Member, WANATCA



Hass avocado tree in California. From www.loe.org

Pure West Indian varieties, adapted to tropical conditions, don't do well in California, but a ripe fruit specimen from a hybrid named Collinred that Ms. Frink found on the ground was typical of that type: a large, light-green fruit with mild, sweet flesh, and much lower in oil than California varieties. Some find such avocados, which Florida produces from June to February, to be watery, but people from the Caribbean relish their lighter, more fruitlike flavour and use them in drinks and ice cream. Florida shippers, seizing every advantage, market them as "Slimcados."

In Fallbrook, the centre of a leading avocado district about 30 miles southeast of Irvine, a traditional Hass grove farmed by the McDaniel Fruit Company seemed a surreal mix of gothic cathedral and jungle on a misty May morning. A thick carpet of moist leaves turned the steep hillside into a trampoline, while in the dark canopy 30 feet overhead, workers on ladders used long clipping poles to snip the oval green fruit into canvas bags. As a radio blared Mexican ballads, they filled their satchels, then descended to release a torrent of avocados into wooden field bins holding 900 pounds each.

Introduced to California in the mid-19th century, avocados were grown on only a small scale until about 1910, when agricultural explorers sent back the best varieties from Mexico and Guatemala, notably Fuerte, a green-skinned, pear-shaped fruit with excellent flavour that matured in winter. As part of a boom in new subtropical crops, nurserymen and real estate developers promoted avocados as the next big thing — "Health fruit possessing unusual Vitalizing and Rejuvenating properties," as one pamphlet put it. Lured by dreams of green gold and a bucolic life, well-to-do enthusiasts planted thousands of acres, mostly in small groves.

"The avocado is rich and nutty, and so are those who grow it," one farmer observed dryly in the 1920's.

As production increased, growers established a cooperative, Calavo, to develop a market. Prices were high, 50 to 85 cents apiece, and advertisements in Vogue and The New Yorker pitched avocados as the "aristocrat of salad fruits," to be served to impress guests on special occasions. The first shipment of California avocados reached New York in 1926, though for several decades fruit from Florida and Cuba continued to dominate Eastern markets.

In the same year, a Pasadena postal carrier, Rudolph Hass (rhymes with pass), planted seedling avocado rootstock in La Habra Heights, 20 miles east of Los Angeles, and grafted the Fuerte variety onto it. On one tree, grafts failed three times, and Hass might have ripped it out, but his sons tasted the fruit from the rootstock and begged him to try it.

Hass liked it so much he named it after himself and patented it. Besides its creamy texture and nutty flavour, it had thick and pebbly but easily peeled skin that typically turned purplish black when the fruit ripened, serving both as an indication of readiness and as a mask for bruises or decay. The new variety bore more steadily than Fuerte, and hung on the tree well into summer, giving growers a long season for sales.

At first, markets did not readily accept the dark-skinned fruit. "They'd be turned down because they appeared to be spoiled," Jack Shepherd, 90, who retired as Calavo's president in 1978, said in an interview at his home in Pasadena. He started working at the cooperative in 1934.

But the Hass caught on in the 1950's, and surpassed Fuerte in volume by 1972. Over the next decade plantings more than tripled, driven by syndicators and tax shelters. This surge led to a glut and a fall in prices. Meanwhile, many novice growers faced ruin due to root rot, a fungal disease; high winds, which could knock most of the fruit to the ground; and skyrocketing water costs.

Even so, with the increase in demand, the roller coaster of Hass prices currently rides high — $2 a pound wholesale, $1.29 to $3 for a half-pound fruit at retail — explaining why the California acreage in avocados is holding steady at 58,000 despite pressure from suburban development.

Although most growers give the nod to Fuerte for flavour, the durable, productive Hass has swept aside all competing varieties. It now represents 92 percent of California's crop — a virtual monoculture that leads to fears that a new pest or disease could devastate the industry.

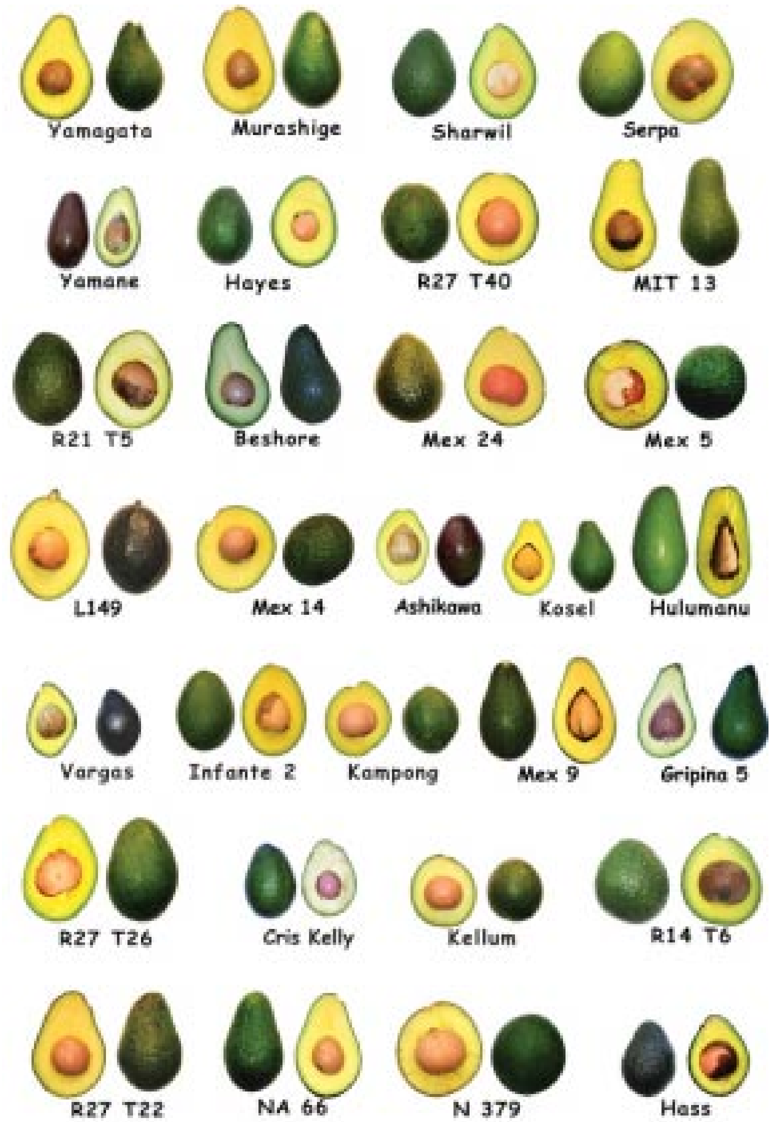
One omnipresent threat is avocado rustlers, who sneak into groves at night and strip the trees or drive off with a field bin. "We call it 'grand theft avo'," said Nile Peterson, a manager for Calavo. "It's a constant problem, especially when prices are high. I've heard of thieves so bold they tell the workers, `We're coming to steal these avo–cados, and if you don't like it we'll kill you.' "

Avocado flowering. From www.spacerad.com

Old-fashioned avocado groves look like over-grown forests, but growers have started shifting to closely packed smaller trees, pruned short, hoping to increase yields and decrease harvest costs. A leading advocate of this practice is Reuben Hofshi, an Israeli-born packer and researcher who dreamed 30 years ago in an Ecuadorean jungle that his life's work lay in avocados.

"Picking with ladders and poles is an absurdity that we got away with when land and labour were cheaper," he said, showing a group of Chilean growers an orchard of six-foot-tall avocado bushes, their trunks painted white to protect them from the sun.

Hass trees are not suited for such plantings because they spread naturally, so Mr. Hofshi



Avocado types. From www.hawaiifruit.net favours Reed, an upright grower that produces green-skinned fruit the size and shape of a softball, with a shell-like rind. In its prime season, July through September, Reed offers extraordinarily rich, sweet flavour, as good as that of Hass, or even better, many growers agree.

Such green-skinned varieties, including Fuerte and Pinkerton (a long-necked late-winter fruit), are often the best choices in season, but are increasingly rare because they lack the Hass's shelf life. The most likely sources for them are farmers' markets in California and organic stores.

In New York, fruit from Florida is available in season, just occasionally at mainstream stores but quite commonly at markets catering to Caribbean and Central American customers. Florida ships several dozen varieties, each for a month to six weeks, though they are rarely identified by name at the store.

Hass, a Guatemalan-Mexican cross that is mostly Guatemalan, is available year round, but its quality varies greatly depending on the season and source.

Early fruit, harvested in December and January in California, can be low in oil, bland and grassy, and sometime shrivels without ever ripening. Midseason fruit has the best flavour and texture.

Each area peaks in quality at a different time, moving north: San Diego County from April to June and Ventura County (the second-biggest avocado district, northwest of Los Angeles) a month later. In Santa Barbara and San Luis Obispo Counties, cool sea breezes let the fruit hang in good condition well into fall.

Late in the season and after prolonged hot spells, avocados ripen very quickly and can turn pasty and rancid.

The Reed avocado. From http://tfphotos.ifas.ufl.edu

Adding to and complicating consumers' choices, imported avocados, mostly Hass from Chile and Mexico, have surged in number, now making up 36 percent of the supply, as against 13 percent a decade ago. In September 2004 a federal requirement to label produce with its country of origin will become mandatory. Chilean Hass peaks from November to January, though it suffers from the three weeks it has to spend in cold storage on its way to the United States. Avocados from Mexico, the world's largest producer, are best from December to February, when they are often cheaper and tastier than those from California.

Avocados should be ripened at room temperature, and refrigerated only when necessary to keep them from spoiling. Not all Hass turn from green to black when ripe; some early fruit remains green when soft, while in summer most turns dark on the tree, while it

is still hard. For all varieties, the best indication of ripeness is a tendency to yield slightly to gentle pressure. The ideal fruit has firm but creamy flesh, yellow in the centre, shading to green near the peel.

Ripening a rock-hard avocado takes time — up to two weeks in early season. So to encourage impulse purchases, markets increasingly offer preripened fruit. Large avocado packers commonly hasten ripening with ethylene, as they do for bananas.

Getting a ripe but an unbruised avocado at the store can still be tricky. Stickers or signs saying "ripe" lead consumers to pinch the fruit, which leaves little spoiled spots that are hard to detect beneath the black rind of a Hass.

Lamb Hass avocados, which are larger and blockier than the original Hass variety, growing in an orchard in Ventura County in California. Photo: David Karp

Dr. Mary Lu Arpaia, a University of California postharvest specialist, demonstrated the problem at a supermarket in Santa Paula, the avocado centre of Ventura County. She bought eight ripe fruit at random and sliced them open in the parking lot. Two were actually overripe, and three of the six others suffered from the "squeeze syndrome."

"The approach I'd take is to buy fruit a few days from ripe, to get them home without bruising," she said.

On the same morning Dr. Arpaia, who directs the university's avocado breeding program, visited a nearby test orchard of new varieties. She showed off the most successful recent introduction, Lamb Hass, a great-grandchild of Hass — larger, blockier and later-ripening — and a promising experimental prospect, nicknamed Gem in testing, with pulp as rich as egg custard.

The Hass dynasty might seem set to continue indefinitely, but in San Luis Obispo County, at the northern end of the avocado's range, a potential usurper looms: a large, seedless avocado, discovered by William Martony on a surfing trip to Costa Rica. He and his partners patented the prodigy as "Fruta De Oro" and are hoping for their first crop this year. The time may be ripe, since there aren't any giant ground sloths around anymore to disperse avocado seeds.

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[Based on an article appearing originally in the The New York Times for June 25, 2003]

MACADAMIA: DOMESTICATION AND COMMERCIALISATION

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The macadamia is considered one of the world's finest gourmet nuts because of its unique, delicate flavour, its fine crunchy texture, and rich creamy colour. Nuts from wild macadamia trees provided a source of food for the aboriginals in the Australian subcontinent, but Australian farmers were slow to appreciate the commercial potential of this fine nut.

Origin

The macadamia nut is the only commercial food crop indigenous to Australia, originating along the fringes of rainforests in coastal southeast Queensland and northeast New South Wales (25 to 32°S latitude). The tree has several features suggesting adaptation to harsh environments, including sclerophyllous leaves and dense clusters of fine, proteoid roots that develop to enhance nutrient uptake from poor soils, particularly those low in phosphorus.

Of the four southern species of macadamia, only two are edible, the smooth-shelled *Macadamia integrifolia* and the rough-shelled *M. tetraphylla*. Only the former has been developed commercially. The latter, grown on moderate scale in California and New Zealand, produces a raw kernel of excellent eating qua XXXity but contains a higher percentage of sugar that may caramelise on roasting, thus detracting from its appearance and reducing its effective shelf life. The wild *M. ternifolia* produces a small, unpalatable, bitter kernel. *M. jansenii* was first discovered in 1982 and there are less than 100 known individuals surviving in the wild. It has small inedible fruit.

Botany

The evergreen macadamia tree is medium to large, attaining a height of up to 20 m and a spread of up to 15 m. In *M. integrifolia*, the leaves are arranged in whorls of three and often have spiny, dentate margins, and short (5-15 mm) petioles. Multiple branches (or inflorescences) may be produced from each node. The pendulous racemes, up to 15 cm long and bearing approximately 200 creamy, white flowers, are borne on hardened wood. Less than 5% of flowers set fruit and the nuts take 6 months to mature, after which they abscise naturally.

The fruit is a globose follicle in which con of two ovules develops. As the husk dries, it splits along a single suture to release the nut, consisting of a hard, thick, stony, light-tan shell (the seed coat) that encloses the kernel.

The leaves of *M. tetraphylla* are sessile and are arranged in whorls of four. The margins

are more serrated, with up to 40 spines on each each side and, whereas new leaf growth of *M. integrifolia* is pale green in colour, young *M. tetraphylla* leaves are an attractive pink to red colour. Racemes are longer (up to 30 cm) and bear up 500 reddish-pink flowers.

Small nuts of Macadamia ternifolia *compared with the larger commercial nuts of* M. integrifolia

History

A German explorer, Ludwig Leichhardt, was the first person to collect macadamia. Some time later, in 1857, Ferdinand von Mueller, the Director of the Royal Botanical Gardens in Melbourne, and Walter Hill, the superintendent of the Brisbane Botanical Gardens, discovered a macadamia tree on the banks of the Pine River, 30 km north of Brisbane. Von Mueller described the specimen and named it after his good friend, Dr John Macadam.

One of the earliest macadamia orchards in Australia was established at Rous Mill, near Lismore, in the early 1880s and it is still producing nuts today. Other small blocks were planted throughout New South Wales and Southeast Queensland, but the total area prior to 1960 was less than 100 ha with annual production of less than 50 tonnes (t) of nut-in-shell.

Although the macadamia is native to Australia, large-scale commercial development first occurred in Hawaii after trees were imported by William Purvis, also in the early 1880s. It was not, however, until the early 1920s that the first developmental macadamia orchards were established in Hawaii. A major breakthrough to commercialisation was the development of efficient cracking machines. The first truly commercial orchards were established by Castle and Cooke at Keauhou on the island of Hawaii in 1948.

Research in Hawaii

The development of the macadamia industry was supported by research at the Hawaii Agricultural Experiment Station at the University of Hawaii. An early achievement was the discovery of the importance of starch accumulation above girdled branches for successful grafting, resulting in true-to-type trees that commenced bearing earlier, and produced much higher yields than seedling trees. J H Beaumont and R H Moltzau initiated a cultivar selection program in 1936 and William Storey released the first 5 cultivars from 20,00 bearing trees in 1948, two of which ('Keauhou'=HAES 246 and 'Kakea'=HAES 501) were the basis for early commercial orchards in Hawaii, and later in Australia and other parts of the world. Cultivar trials using grafted trees were established on all the major islands of Hawaii.

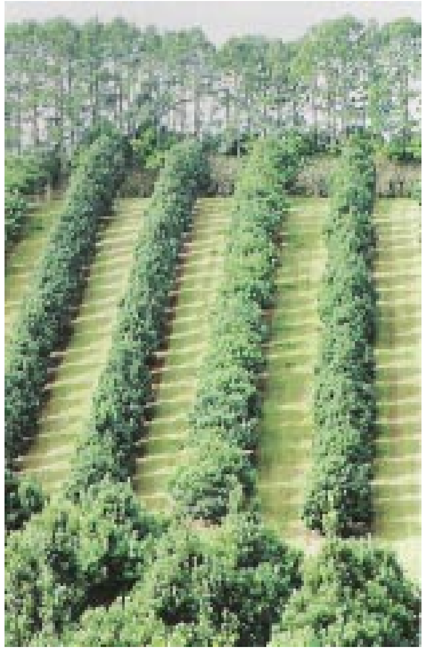
Other important cultivars released were 'Ilaika' (HAES 333) , 'Kau' (HAES 344), 'Keaau' (HAES 660), Mauka' (HAES 741) and 'Makai (HAES 800). In 1960, Storey visited Australia and collected additional new germplasm for evaluation in Hawaii. Richard Hamilton enthusiastically promoted the development of the macadamia industry and continued the variety selection work, as did his student, Phil Ito.

The importance of maintaining high quality standards in the developing Hawaiian industry

Flowers of Macadamia integrifolia *(left) and M.* tetraphylla *(right)*

was acknowledged by J C Ripperton, R H Maltzau and D W Edwards, who developed effective quality assessment procedures for factories. Their simple and convenient flotation test for maturity was widely adopted. Kernels that float on tap water have at least 72% oil and are considered mature.

They also developed the concept of kernel recovery (the percentage of kernel within the nut), an important quality feature, particularly in those early days when many orchards were based on variable seedling trees that produced nuts with thick shells. More recently, Cathy Cavaletto's postharvest research at the University of Hawaii has underpinned the high quality of macadamias in the marketplace.



An Australian macadamia orchard in northern New South Wales bounded by tall windbreak trees

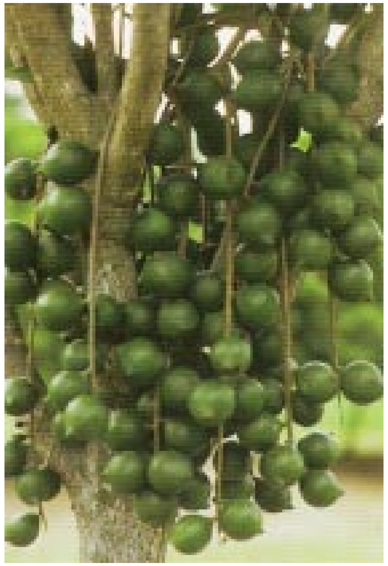
From the early 1950s to the 1970s, research was carried out by B J Cooil, G T Shigeura, R M Warner, R L Fox and coworkers to overcome nutritional constraints to productivity in Hawaiian macadamia orchards and to develop leaf analysis standards for optimum production and quality.

Yields were enhanced by applying phosphorus fertilizer to lava and phosphorus-fixing soils. Excess phosphorus (leaf P greater than 0.1 %), however, resulted in the formation of insoluble iron phosphates in the soil, and consequently, leaf chlorosis. This work provided the basis for the development of macadamia orchards not only in Hawaii, but also in Australia and other parts of the world.

Macadamias in Australia

It was not until the early 1960s, when the Hawaiian macadamia industry was already well established, that efforts were made to develop the indigenous macadamia as a commercial crop in Australia.

Colonial Sugar Refiners (CSR) imported superior selections and technical expertise from Hawaii. Other large commercial operations were soon established, with income-tax incentives for investment in the industry. Although CSR imported the best varieties from Hawaii, it became obvious their performance was often disappointing and they were not necessarily well adapted to Australian conditions. It was widely acknowledged that local research was needed to select varieties better adapted to Australian conditions, and to similarly modify the Hawaiian cultural technology.



Bunches of macadamia nuts

As in Hawaii, the Australian macadamia industry was fortunate in having a large number of enthusiasts and innovators who contributed to the improvement of the industry. The most prominent of these was Norm Greber, widely regarded as the founding father of the Australian macadamia industry. He was the first Australian to successfully graft macadamia and was engaged by CSR to help develop their macadamia nursery. Norm also propagated many trees in his back yard and selected superior cultivars, including 'Own Choice, 'Own Venture', 'Renown', 'Ebony' and 'Greber Hybrid'. He received life membership of both the Australian and the Californian Macadamia Societies for his contribution to the development of the macadamia industry and became patron of the Australian Macadamia Society.

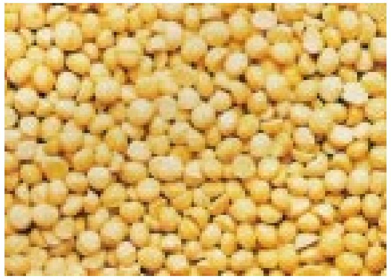
Stan Henry, the CSR nursery manager, subsequently developed a novel punch budding technique using a modified, spent 0.303 brass bullet shell to remove an oval patch of bark from the rootstock that was replaced with a patch containing a single bud from the commercial scion.

This rapid, effective technique gave CSR a considerable advantage over nurseries employing conventional grafting techniques. The success of punch budding was largely due to careful selection of budwood with bark that lifted readily. The CSR nursery supplied all the trees for the first large-scale commercial orchards at Baffle Creek, north of Bundaberg, Maleny, Peachester, Mt Bauple, and Rockhampton, totalling over 1,000 ha.

In the 1970s, the first commercial processing plant was established by CSR. Soon after, other factories were established by Suncoast Gold Macadamias and by the Macadamia Processing Co and Macadamia Plantations of Australia. Today, there are about 10 factories operating in Australia.

The Australian Macadamia Society

The macadamia industry in Australia is particularly fortunate in having forged a strong and effective organisation, the Australian Macadamia Society Limited (AMS). It was established in 1974 by a small group of enthusiasts eager to share the benefits of their experience and their innovative ideas. Ever since, it has responded to needs and opportunities across the whole industry. It fosters the dissemination of information through its bimonthly News Bulletin, website, MacGroup meetings, field days, and annual conferences. These very effective and powerful extension functions complement services provided by State Departments of Agriculture.



Premium macadamia kernels

Perhaps the most significant initiative of AMS was the active encouragement of research into production, processing and promotion of the crop. Initially, research was funded from a voluntary levy. In 1993, a production levy, attracting a subsidy from the Commonwealth Government, was introduced. This intensified research activity and flow-on benefits to the industry. The industry levy is currently 25.21 cents/kg total kernel of which 17.4 c/kg is for product promotion and marketing, amounting to an annual budget of about A$2 million. A further A$2 million is invested in research each year, half of which comes from the Commonwealth Government as a matching dollar for dollar subsidy. Part of the levy is also used for regular chemical residue testing to maintain Australia's reputation for producing high quality, quality-assured kernel.

Research in Australia

One of the great challenges was the selection of genetic material better adapted to Australian environments. In Hawaii, over 100,000 trees were screened to select the commercial cultivars that are widely used today, whereas in Australia, fewer than 20,000 seedlings have been screened. Two of Henry Bell's Hidden Valley cultivars (A4 and A16) are registered under Plant Breeders Rights legislation and widely grown commercially, together with subsequent releases.

A macadamia fingerwheel harvester significantly reduces harvesting cost

The AMS currently funds a major plant breeding program to develop superior cultivars for Australia. To assist in the search for, and development of, better adapted cultivars, the AMS has also provided funds to conserve a wide range of germplasm from native rainforests before they are lost forever by land clearing.

Early macadamia yields in Australia were generally quite low compared with those reported from Hawaii, although some trees approached the Hawaiian yield standard of 45 kg nut-in-shell. Yields of 30 kg are more common and productivity continues to improve steadily with better technology. It seems that one of the factors contributing to lower yields in Australia, and many other countries, is harsher environments with larger diurnal and seasonal variations in temperature than in the mild, equable climate of Hawaii.

Understanding the influence of environment on macadamia growth and production was an essential objective of early macadamia research (and management). The mature macadamia is capable of withstanding mild frosts to as low as -6 °C for short periods, but extended periods or lower temperatures may severely damage or kill mature trees.

Even where trees survive, frosts may burn off inflorescences and thus seriously reduce cropping. Optimum temperature for tree growth and photosynthesis is about 26 °C. Temperature is a major factor influencing vegetative flushing, which, in turn, influences floral initiation, nut growth, yield and quality.

Most genera of Proteaceae grow only in climates where there is a long dry season. Drought, however, limits yield and results in small nuts with undeveloped kernels. Research at the Maroochy Research Station in a through-draining lysimeter showed that even mild stress during nut development, particularly the oil accumulation stage, adversely affected both yield and quality.

Fortunately, the macadamia has few serious ease problems and when these occur they tend to be localised. An example is a husk spot fungus (*Pseudocercospora*), which induces nuts drop early in the harvest season before they fully mature.

In Australia, its place of origin, the macadamia is attacked by more than 150 pest species, although parasites and predators usually provide considerable control. Insects that commonly reduce yields include macadamia flower caterpillar (*Homoeosoma vagella*), fruit spotting bug (*Amblypelta nitida)*, banana spotting bug (*AmbIypeIta lutescens*), macadamia nutborer (*Crytophlebia ombrodelta*) and macadamia felted coccid (*Eriococcus ironsidei*).

Any of these has the capacity, during severe infestations, to destroy the crop. An integrated pest management system for insect pest control has been adopted.

Mechanical pruning of a high density macadamia orchard

Pest population levels are monitored in the orchard by pest scouts and chemical sprays are only applied when threshold pest population levels are reached. This approach maximizes the contribution of natural enemies in suppressing pest populations below economic threshold levels. PM has contributed to the profitability of macadamia growing.

Early nutrition work in Australia refined the Hawaiian standards to suit Australian conditions. It was found that small, frequent applications of nitrogen, for example, effectively restricted tree growth but actually increased yield and quality of nuts. Many of the soils on which macadamias are grown in Australia are low in boron, and foliar boron sprays improve both yield and quality (kernel recovery). As in Hawaii, phosphorus deficiency limited yields on phosphorus-fixing ferrosol soils.

Because of the long break-even period (10-12 years) for a net return on money invested in macadamias, the Australian industry moved towards high-density plantings to increase early cash flow. Mechanical pruning is used to maintain hedgerows and allow normal orchard operations such as spraying and harvesting.

The AMS responded to indifferent quality by adopting stringent quality standards and financial incentives to encourage growers to sort poor quality nuts from their consignments. This significant step has enhanced Australia's

Health Benefits

Macadamias, like other nut crops, have a high oil content (>72%) and for a long time were considered by nutritionists to be less desirable in healthy diets. Research, dietary trials and population studies, however, demonstrate that macadamias contain a range of nutritious and health promoting constituents. These include monounsaturated fats, proteins, dietary fibre, minerals, vitamins, and phytochemicals.

The composition of both raw, dried and roasted macadamias typically contain:

• Natural oils: 75%; • Moisture: 1.5%; • Protein: 9.4%; • Dietary fibre: 7.7%; • Carbohydrates: 4.7%; • Mineral matter: 1.6% including Potassium, Phosphorus, Magnesium, Calcium, Selenium, Zinc, Copper and Iron; • Vitamins: Vit. B1, 82, B5, B6, Vit, E, plus niacin and folate; • Phytochemicals: Antioxidants including polyphenols, amino acids, selenium and flavanols plus plant sterols; • Energy value: 3000 kilojoules per 100 g (727 calories)

Macadamias contain no cholesterol or trans-fatty acids. They do contain a higher percentage of monounsaturated oils than any other natural product. Macadamia oil is similar to olive oil in composition and use. Macadamias are low in damaging saturated fats and in polyunsaturated fats that oxidize readily. Diets containing moderate fat levels promote satiety and have been shown to be sustainable and enjoyable in the long term. The desirable Mediterranean Health Pyramid diet has 40% of the food energy from fat.

Separate dietary trials with macadamias in Australia and Hawaii have demonstrated a significant reduction in total cholesterol, total triglycerides and the undesirable low-density cholesterol, but little or no effect on the desirable high-density cholesterol. They, like many tree nuts, have been shown to lower blood pressure in hypertensive people and reduce the risk of heart disease, Current research includes a full biochemical analysis and nutritional profiling of macadamias and, in the USA, a phytochemical analysis is close to completion.

Table 1. World macadamia production and exports. Sources: Australian Macadamia Society (www.macadamias.org); Australian Bureau of Statistics; US Embassy, Canberra; Hawaii Agricultural Statistics Service, July 12 2004; World round-up reports (Proceedings of the Second International Macadamia Symposium, Tweed Heads, Australia, 2003).

Country or region	Area (ha)	Trees (000)	2003 production (t) NIS+	2003 production (t) Kernel	% Kernel recovery	Kernel exports (t)
Australia	15,000	5,000	30,000	9,100	32	7,460§
Central America	8,700	-	17,000	3,100	18	3,100
USA (Hawaii)	7,284	1,350	27,240	4,500	25	200
South Africa	7,000	3,073	12,500	3,400	28	2,975
Kenya	6,500	1,000*	8,800	1,000	16	1,000
Brazil	6,000	-	3,000	600	17	ca 540
Malawi	5,112	1,022	4,000	1,000	25	1,000
Zimbabwe	-	-	900	120	-	120

** Estimate +Nut-in-shell § 6,400 t of Australia's production was exported as nut-in-shell in 2002-2003.*

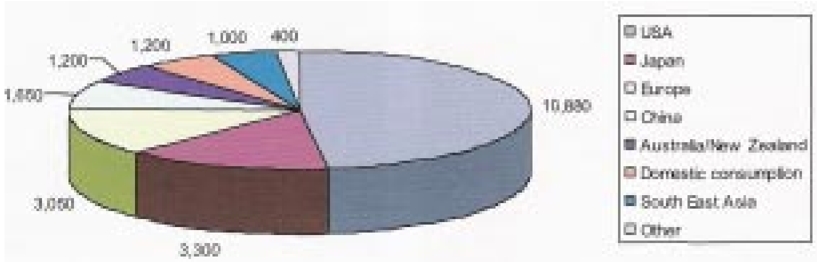
reputation on world markets as a supplier of consistently high quality kernel. The industry places a lot of importance on maintaining this reputation. It has developed a 'Code of Sound Orchard Practices' to help achieve this.

Commercialisation

World consumption of macadamias accounts for only about 2-3% of all tree nuts. For example, only 23,000 t of macadamia kernels is consumed compared with 650,000 t of almonds, 370,000 t of walnuts, 330,000 t of hazelnuts, 250,000 t of cashews, 200,000 t of pistachios and 110,000 t of pecans. There is, therefore, considerable scope for expanding world markets.

The USA is still the largest market for macadamias, which are particularly popular in cookies (Fig. 1). Bakery products account for about 40% of world production. Another 35% is used as snacks, 22% is coated in chocolate, mainly for the Japanese market, and about 3%

Figure 1. World macadamia consumption (t) (2003). Source: Australian Macadamia Society (www.macadamias.org); US Embassy, Canberra; Hargreaves (2004).



used in ice cream. The Australian industry is actively investing in promotion of macadamias to diversify its markets, particularly into Japan, Europe and Asia.

Although Australia's production of macadamias was only about 25% of that of Hawaii's in 1987, Table 1 shows that it is now greater, particularly the production of kernel. Australia has a considerable advantage due to a higher kernel recovery. Nearly half the world's macadamia exports come from Australia. Massive expansion of plantings continues, particularly in Australia and South Africa. There are now over 5 million trees planted on 15,000 ha in Australia, with production valued at around A$150 M, at the farm gate.

The Future

Macadamia plantations require a large capital investment and take several years to commence bearing. There is also the risk of declining prices with increasing world production, although this has not occurred yet. The industry's investment in promotion and marketing will secure a sound future, despite competition from countries like Brazil with low production costs. The Australian industry has developed advantages in cultural technology through its investment in research. This investment will continue to help overcome remaining constraints to productivity and profitability. The future success of the Australian macadamia industry is assured by the enthusiasm, cohesion and innovative spirit of all those who are involved in this young, dynamic industry.

Further reading

Gallagher, E C, O'Hare, P J, Stephenson, R. A, Waite, G, and Vock, N. 2003. *Macadamia problem solver and bug identifier*. Field Guide. Queensland Department of Primary Industries, Brisbane.

Hargreaves, G. 2004. *Growth of the macadamia industry: From bush tucker to the king of nuts*. Australian Nutgrower, 18: 26-29.

Ironside, D A. 1981. *Insect pests of macadamia in Queensland*, Queensland Department of Primary Industries, Brisbane.

Nagao, M A and Hirae, H H. 1992. *Macadamia: Cultivation and Physiology*. Critical Reviews in Plant Sciences 10:441-470.

O'Hare, P J, Quinlan, K, Stephenson, R A, Vock, N et al. 2004. *Macadamia grower's handbook*. Growing Guide, Queensland Department of Primary Industries and Fisheries, Brisbane, 2l4 p.

Power, J. 1982. *Macadamia power*. Tudor Press, Brisbane p. 6-44.

Shigeura, G T and Ooka, H. 1984. *Macadamia nuts in Hawaii: History and production*. Univ. Hawaii, College of Tropical Agr. & Human Resources, Res. Ext. Ser. 039.

Stephenson, R A. 1990. *The macadamia : From novelty crop to new industry*. Agri. Sc. NS 3: 38-43.

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Submission of Articles

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

Articles would be gladly received from any source — there is no requirement to be a member of WANATCA. If the text is available on a computer or word-processor disc, this is greatly appreciated. Text and enquiries can also be sent by fax or e-mail.

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