The coconut odyssey

the bounteous possibilities of the tree of life

Mike Foale

The coconut odyssey: the bounteous possibilities of the tree of life

The coconut odyssey

the bounteous possibilities of the tree of life

Mike Foale

Australian Centre for International Agricultural Research
Canberra 2003

The Australian Centre for International Agricultural Research (ACIAR) was established in June 1982 by an Act of the Australian Parliament. Its primary mandate is to help identify agricultural problems in developing countries and to commission collaborative research between Australian and developing country researchers in fields where Australia has special competence.

ACIAR MONOGRAPH SERIES

This series contains the results of original research supported by ACIAR, or material deemed relevant to ACIAR's research and development objectives. The series is distributed internationally, with an emphasis on developing countries.

Foale, M. 2003. The coconut odyssey: the bounteous possibilities of the tree of life.
ACIAR Monograph No. 101, 132p.

ISBN 1 86320 369 9 (printed)
ISBN 1 86320 370 2 (online)

Editing and design by Clarus Design, Canberra
Printed by Brown Prior Anderson, Melbourne

Foreword

Coconut is a tree of great versatility. It provides food, drink, clothing and shelter, as well as a source of income from its products. Coconut can grow in fragile environments, on coasts and coral atolls where few other species survive. In extreme weather, the coconut provides refuge and sustenance to coastal and island communities. The health-promoting properties of coconut are increasingly being recognised. Yet coconut is too often seen as a 'sunset crop', with little future, unable to compete in export markets with palm kernel oil and, more recently, with genetically modified rapeseed oil.

This timely publication summarises the case for coconut. It describes ways in which the full potential of coconut and its benefits may be realised for better health, food and the environment. Its publication by ACIAR in 2003 is also noteworthy, in that ACIAR's support for coconut research and development in Asia and the Pacific began in 1983, and was amongst the first areas of activity in ACIAR's portfolio of collaborative research projects. This support continues today, with a new ACIAR coconut project commencing at the University of Queensland.

This publication also comes at a time when the International Coconut Genetic Resources Network (COGENT) is determining its future strategy to ensure the long-term conservation of coconut genetic resources, and their use through a global program of coconut research and development activities.

I congratulate Mike Foale on his efforts in writing this important publication, and in assembling its comprehensive set of illustrations. I commend it to all interested to learn more about the 'tree of life'.

Gabrielle J. Persley
Chair, International Coconut Support Group

Contents

Preface

Few plants are more universally known, admired and acclaimed than the coconut palm, *Cocos nucifera*. Its graceful appearance and bountiful harvest, combined with its environmental resilience even under the stress of cyclonic storms, have led to its pan-tropical establishment and use in moist coastal environments. Hundreds of millions of people consume each day both coconut water and kernel derivatives—especially the milk squeezed from the shredded kernel and the extracted oil.

Long after Portuguese sailors first brought the coconut home to Lisbon from voyages to 'the Indies' at the end of the 15th century, the nut became popular in the temperate markets of Europe and the United States. It became a staple ingredient in cakes and biscuits, and at English fairs, the 'bare' coconut fruit was transformed into a target and prize ('a lovely bunch of coconuts') in a bowling game known as the 'coconut shy'.

So deeply is the coconut immersed in the culture and diet of tropical people of the East and the Pacific islands that it is honoured among them as the Tree of Life. Every part of the palm and fruit is used, especially the milk, oil and flesh of the nut itself. Even the roots provide valuable medication for the relief of dysentery. However, it was the great 19th century surge in demand for fats and oils by industrialising Europe and North America that placed coconut oil centre stage as a global trade commodity. This ushered in an era of industrial cropping of the palm on practically every tract of available fertile land in the moist coastal tropics, between the late 19th and the mid-20th centuries. The Tree of Life of the tropical village became, briefly, the tree of economic life for many investors, traders and processors in the West. A calamitous decline in demand followed.

I include a description of the extraordinary economic situation into which the coconut was forced, a hundred years after it was so enthusiastically embraced by the industrial world. Beginning in the 1950s, the producers of polyunsaturated fats—the market rivals of coconut oil—ran a sustained and highly successful campaign against coconut oil and other saturated fats. I explain how, in this context, coconut oil came to be almost universally considered a dangerous food, in spite of its role as an energy staple in the diet of tropical island and coast dwellers for hundreds of generations.
In particular, the producers of margarine, cooking oil and other derivatives of temperate-zone vegetable oils sought to displace coconut oil as the preferred deep-frying oil.

This book summarises the astonishing course of that displacement, along with evidence that might help restore the coconut to its deserved status as one of nature's most useful and valuable foods and cooking oils. Since the 'food war' began, both knowledge of the role of coconut oil as medicine in traditional cultures and modern biochemical research have pointed to great possibilities for coconut oil as a health food and antibiotic.

I also give guidance for those who want to get the most out of having a coconut palm as a fruit tree, or to profit from growing many palms as a plantation enterprise on any scale. The many possibilities for deriving products, not only from the nut contents but from every part of the palm— frond, growing 'heart', trunk, shell and fibre—are catalogued here.

The remarkable evolution and botanical traits of the coconut palm help to explain its durability, its diversity and its distribution. Characteristics that evolved during the coconut's odyssey 'from Gondwana to Goa and Zamboanga' and beyond enabled it to spread naturally and widely across oceans, and to nurture, over many months, the coconut seedling taking hold on a distant shore. I give special attention to the place of the coconut in Australia, a land of extensive tropical shores that was almost completely devoid of coconut palms before European settlement.

This book presents the coconut as food, crop, and cultural and landscape icon, tracing its evolutionary history and endeavouring to restore its reputation. I put the case for the coconut in the hope that people in developed and developing countries alike can rediscover, for the advancement of their own welfare, the economic, health and culinary possibilities of the coconut palm.

Mike Foale
October 2002
Brisbane, Australia

chapter 1

The coconut odyssey begins

A source of food, oil and milk, the coconut has probably been used by humans and their immediate ancestor species for at least half a million years. Its geographical spread—literally around the globe—was aided by waves of mariners migrating and trading between the coconut's homelands and ever more distant islands, from Asia to the Americas. In tropical climes, where the coconut palm is indeed the Tree of Life, it provides food and work for those who add value to its products.

A symbol of dreamy relaxation, the coconut palm is used to promote romantic, indulgent holidays in the sun for people of the temperate zone. Less attractive is the coconut's sometimes exaggerated ability to cause injury, or even death, when it falls from a great height to injure an unsuspecting seeker of the palm-tree ambience promoted in those glossy tourist brochures.

But let us start at the beginning …

The story of the coconut is part of the saga of the great landmass of the Southern Hemisphere, Gondwana, which began to break up around 80 million years ago. Huge sections of the earth's crust—known as tectonic plates—carried land surfaces that now comprise Australia, some islands to its north and north-east, New Zealand, Madagascar, most of Africa and South America, and most of the landmass of India, Pakistan and Bangladesh. The now Australasian sections of Gondwana drifted generally northwards, lately at a rate of 70–150 kilometres every million years. The Antarctic continent, meanwhile, moved south to become centred over the South Pole. Africa began a little south of where it is now, while the South American landmass had drifted westwards.

The ancestral coconut palm grew on the northern coasts of Gondwana fragments. The tree evolved into its niche on the strand—the narrow strip of land immediately above the high-tide line—where it was lapped by warm oceans. On these coasts, the strand often includes a berm—a flat sandy or gravelly strip formed by the sea and associated with low sand dunes raised by the wind.

The coconut palm spawned a buoyant seed, which could drift back and forth among the shifting lands and which was carried by the seas to many shores of tropical Asia and Oceania long before humans intervened to disperse it further. The large, energy-filled seed provided a nourishing welcome for the first human inhabitants of these coasts.

Humans have probably been using the coconut for around half a million years, although it is very difficult to establish an precise time for its first use. The sea level has fluctuated up and down by one hundred metres and more, many times during that period, 'drowning' much evidence of early relationships between humans and the coconut.

In 1788 (the year of the first European settlement in Australia) and for 60 years afterwards, there were no reports of coconut palms on the thousands of kilometres of Australia's tropical shores. This curious absence was noted by explorers as early as the 18th century. Authorities later theorised that the coconut had been transported to far-flung islands and continents by waves of mariners dating back at least 4000 years to the time of the first Polynesians. More recently, it has been realised that the wild coconut probably reached most of the shores in South-East Asia and the Pacific, where it is now found, many millennia ago and through the agency of its floating seeds. Different forms of the coconut have since been spread by the Polynesians and other seafarers. There is an intriguing story, told below, about this absence from Australia.

The story of the coconut and its presence around the globe is one in which evolution, immigration, trade, other cultural practices and the forces of nature all play a part. If the theories of the palaeogeographers are correct, the shores of northern Australia may have been an important habitat in which the ancient palm evolved over geological time.

Evolution of the coconut

The ocean to the north of the migrating Indian and Australian landmasses and associated islands, 40 to 60 million years ago, is known in retrospect as the Tethys Sea.

Occupying tropical and subtropical latitudes and being accessible to the great equatorial Pacific Ocean current, this vast body of water is likely to have been warm and stormy. The behaviour of the weather in modern warm seas suggests that periodic cyclones battered the coastal vegetation of the islands and large landmasses that were inching across the Tethys Sea on their tectonic plates. Frequent exposure to cyclones would have favoured the evolution of many of the wild coconut palm's critical traits.

One vital adaptation was the development of a flexible trunk that elongates rapidly in the early life of the palm, eventually becoming able to bend without snapping in violent winds. During very strong wind gusts of cyclonic storms, the trunk of the coconut can be seen bent almost to the ground, with a hardy narrow cluster of vertical fronds resisting the wind while the lower fronds are whipped back and forth and finally detached. This has the 'clever' side-effect of easing the pressure on the palm trunk as the crown size diminishes. During the normal growth of a mature palm, the younger fronds push the old fronds outwards at the base, weakening their attachment to the trunk and preparing them to be shed progressively under the stress of a persistent buffeting wind. The overall force of the wind on the palm is reduced as outer fronds are broken away, leaving the central core of fronds to ride out the storm. This reduces the risk of fatal damage to the solitary bud concealed at the centre of the palm crown.

The fruit of the wild coconut palm floats remarkably well because of its thick, low-density husk, which absorbs water very slowly. Fruits

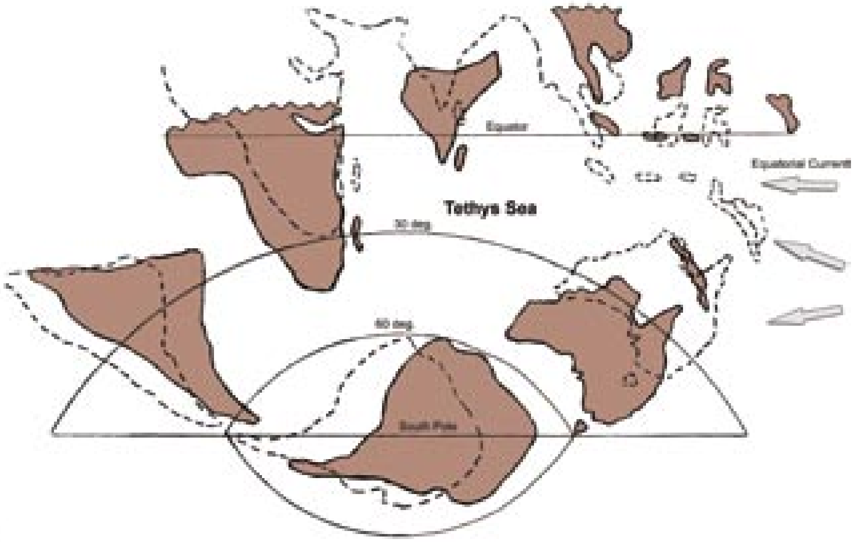

Figure 1-1. Notional position of land fragments (dark brown) around the Tethys sea 40 million years before present (BP) in relation to the present position of those lands (dotted outlines). The great westward-flowing warm equatorial current of the tropical Pacific ocean flowed, in that bygone geological era, into the Tethys Sea, unobstructed by the islands of Papua New Guinea and Indonesia which now divert its flow into both the north and south Pacific.

can float for up to four months on the ocean and still germinate when placed on dry land. Trials in both Hawaii and Solomon Islands have been conducted in which the fruits were floated in cages constructed in calm harbours. Nuts were transferred to the nursery at intervals, to await germination. Even after 120 days floating in the sea, some seeds germinated.

Besides acting as a buoyant container for the coconut seed, the husk is soft enough to cushion the seed inside when it falls onto a rocky spot, but still hard enough to injure any creature, large or small, unlucky enough to stray into its 'flight path'.

The evolution of the palm's hardy floating seed, able to survive months at sea and travel up to many thousands of kilometres depending on the speed of the current, guaranteed the coconut's wide dispersal.

Other adaptations allowed it to sprout in its new home. Imagine the seed arriving, eventually, on a remote shore, pushed up onto a sandy or gravelly spot, perhaps within reach of the king tide—a precarious and harsh environment. Its survival now depends upon the reserve of kernel (endosperm) that it carries to support early growth. Remember that the structure that gave it buoyancy must now be overcome by emerging roots forcing their way through to get a hold on the soil, and by an upthrusting shoot that needs to emerge beyond the husk before it unfolds its first leaf.

So precarious is the perch of the coconut thrown ashore by the ocean, that it has evolved a large seed within its outer husk, containing sufficient kernel (hundreds of grams, in fact) to sustain growth until the roots reach sweet water deep beneath the sand, and until there are five or six young fronds to capture enough solar energy to become independent of the seed's reserve. In some ways, this resembles the reproductive strategy of placental mammals, which nourish their young first in the womb and then from a milk supply after birth.

Figure 1-2. Lower fronds of mature Tall coconut palms being severely flexed by the wind during a cyclone, while the vertical cluster of upper fronds remains firm. Loss of lower fronds in such wind increases the chance of the palm weathering the storm.

In this way, the coconut palm evolved into a well-adapted, widely distributed plant, dwelling on the coastlines of hundreds of islands and some continents. Fossils, likely to be ancestral coconut forms, have been found in both South America and New Zealand. However, there is a compelling case that the modern coconut evolved 'on the move', taking parallel courses in several locations and occasionally exchanging genetic material via drifting fruit, as a number of hospitable shorelines edged their way through the tropical seas.

In clear contrast to the coconut, the oil palm (*Elaeis guineensis*) is a forest-dwelling species with a crown attached to a stout but inflexible trunk, which is shorter and thicker than that of the coconut palm. When longer fronds of the oil palm, which have a greater density of leaflets and a more slender rachis (central stalk), are whipped around and twisted furiously by the wind, they cannot 'self-prune' because of their unyielding attachment to the trunk. As was observed on Guadalcanal (Solomon Islands) following Cyclone Namu in 1986, the oil palm's central cluster of fronds can be fatally damaged by cyclonic wind, while neighbouring coconut palms are left unscathed (Figure 1-3).

Figure 1-3. Crown of an oil-palm (at right) on Guadalcanal with the central growing point fatally damaged by cyclone Namu in 1986. Coconut palms growing nearby were undamaged.

Friendship with a crab

A species of crab (*Birgus latro*), known simply as the 'coconut crab', has long thrived on a coconut-enriched diet and has evolved some deft abilities to get at the nourishing kernel. This crab is reputed to be able to climb the coconut palm, pull the fruit loose, strip off the husk and, with its giant claws, gain entry to the nut by smashing a hole in the shell. The crab is common in many coconut habitats but there is so far no documentary evidence that it can help itself to a coconut meal as easily as the legend claims. The coconut crab's claw is certainly the right shape to be inserted through a 40-mm diameter hole and to scoop out the oil-rich kernel. There is no doubt that the crab often eats coconut kernel, perhaps in some cases by attacking seedlings whose somewhat weathered husk can be easily ripped off to get to the nut.

The coconut crab is often found with a great reserve of coconut-flavoured fat in its tail. This is prized as a delicious high-energy food by indigenous peoples in Melanesia, for example, and offered to tourists as a gourmet dish at some resorts. As the fat is reputed to be chemically very similar to coconut oil, it is a healthy addition to any diet.

The coconut crab inhabits the three great archipelagos of the Philippines, Indonesia and Melanesia—which together might be described as the 'coconut heartland'. The apparent coevolution of crab and coconut has been found to be less complete than once believed, however, as the crab can subsist in places where the coconut is not readily available. For example, the crab is also found in outlying islands as far north as Okinawa (south of Japan in latitude 25 degrees north), where the coconut is present but not widespread.

Figure 1-4. The coconut crab, showing its very powerful claws used to tear the husk from the fruit and gouge out the kernel through a hole it has the power to make in the coconut shell. (C. Schiller)

Coconut diversity and the human factor

In the ancient coconut heartland, variations in the size and shape of the wild coconut palm and its fruit were unlikely because the basic functional traits of the palm had already evolved. The palm's natural home was the strand, the strip of sandy soil on the coastline, and it was already well adapted to this environment.

But there are other, invisible, traits that are important to the palm's survival in various areas. Physiological adaptations to the physical environment (such as seasonally cool periods, drought and different soil traits) and the biotic environment (diseases and pests) would have evolved as responses to the varying latitudes, rainfall zones, and plants, insects and pathogens close enough to the strand to affect the coconut.

Genetic diversity is generally a good indicator of a plant species' prolonged presence in a region—diversity is greatest where the species has been longest—but this rule does not apply in trying to understand the coconut's evolution. The coconut must grow within the reach of king

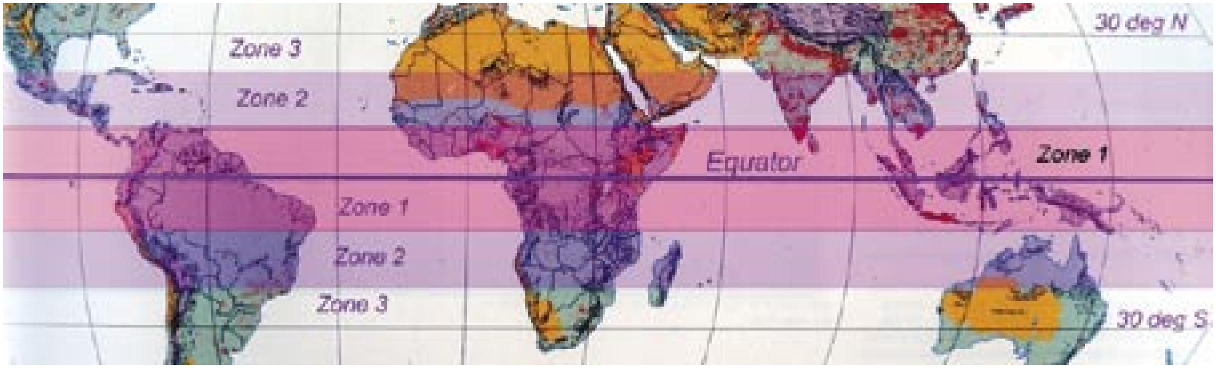

Figure 1-5. Zones of latitude within which any regions of moist coastal environment support the growth of the coconut. Zones 1, 2 and 3 support high, medium and low potential productivity, respectively. The fall in productivity relates to the duration of the cool season which is nil in zone 1 and 6 months at the extreme of zone 3.

tides and tidal surges generated by cyclonic winds, or, more rarely, a few hundred metres further inland, where its seed has been carried by a tsunami (or 'tidal wave').

Nowadays, there are many shape and size variations in the modern coconut palm. The palm shows diversity in tallness and in its rate of increase in height, in the shape and thickness of its trunk, the robustness of its crown, and the size, shape and colour of its fruit. The colour of the fruit ranges from dark brown through light brown to light and dark green, orange and yellow.

However, many of these variations reflect not natural selection but humans' attempts to improve on nature. Producers have bred coconuts for pleasure and for profit, increasing the value of the coconut to their economies. They have selected fruit for its attractive colour and thinner husk (with a consequent increase in the proportion of water and kernel), and for increased nut diameter (see Figures 1-6 and 1-7). A large nut contains two to three times more water and kernel than a small nut, and a palm producing fruit with thin husks produces a great deal more water and kernel from every bunch.

As well as selecting coconut palms that bear large fruit with thin husks, increasing the amount of edible kernel per fruit, producers have cultivated Dwarf varieties, which are easier to harvest (the other main variety is, of course, referred to as the Tall). There are also some varieties that bear fruit earlier than others, another characteristic of the Dwarf and of certain Talls.

The original colonisers of Polynesia took coconuts, possessing some of these 'domestic' traits, to the fringes of the coconut's natural range. Evidence suggests that, 4000 years ago, colonising mariners began moving eastwards from the coast of

Figure 1-6. Wild-type coconut fruit. The thick husk give buoyancy and protection against mechanical shock upon falling from the palm. (Brian Leach)

South-East Asia to the islands of the South Pacific, extending 10 000 kilometres from New Guinea to Tahiti. They carried coconut fruits for food and drink on the voyage and to plant in their new homes.

Perhaps such voyagers are also responsible for the coconut-based menu of southern India and Sri Lanka. More than 2000 years ago, the coconut spread westwards from its heartland to the coasts of the subcontinent, carried by traders returning home from the islands that now form part of Indonesia. Perhaps, in that same era, people who probably originated in Borneo (according to linguistic evidence), took the coconut with them across the Indian Ocean to Madagascar, from where it journeyed on to East Africa. The coconut populations in the regions around the Indian Ocean were, until recently, much less diverse in palm and nut characters than those of the coconut heartland and of Polynesia. It seems likely that the ancestors of the Polynesians had been using the coconut—and modifying it by selection—for countless millennia before they began their great voyages. Just why they set out on such voyages is not clear, but probably there was pressure to escape invaders from North Asia.

Figure 1-7. Domestic-type coconut fruit. The result of human selection, such fruit has less husk and a greater proportion of consumable water and kernel.

Completing the equatorial circle

In more recent times, Portuguese mariners, beginning with Vasco da Gama in 1498, took the coconut from India and East Africa to the tropical eastern Atlantic. From the Portuguese stronghold on the Cape Verde Islands (off the coast of Senegal in West Africa), coconuts were taken in two directions. Westwards, they were a source of food and drink on slave-trading ships bound for Cuba and other islands, with those fruits remaining on arrival being planted in the New World as a foundation food source. Eastwards, they were dispersed from the Cape Verde Islands to the coast of West Africa, from Senegal all the way to Angola.

Before these events in the early 16th century, the coconut was foreign to the indigenous people of West Africa, many of whom used the local oil palm of the forest as a major food source. The ease of planting and management of the much-travelled and adaptable coconut palm led within a few decades to its widespread dispersal in the islands of the Caribbean, on the Caribbean coast of Mexico and Central and South America, and along the coast of West Africa. As coconut palms were already growing on the Pacific coast of Central America and on some nearby islands before the 'discovery' of those places by European mariners, the plantings in the Caribbean actually completed, in the 16th century, the coconut palm's encirclement of the globe. It thereby became, and it remains, the most widespread and widely used palm in the world.

Australia's coconut story: a remarkable absence in precolonial times

Although the coconut was to be found on tropical coasts worldwide before European settlers came to Australia in the late 18th century, it was, remarkably, absent from the tropical coasts of the continent. The reasons for this are still debated, especially because the coconut has become widespread and successful since European settlement began. In many locations on the north-east coast of Queensland, obscure groves thrive without any human management, indicating that the environment of the tropical coast, at least, is hospitable. These groves were probably all initiated with deliberate plantings, but their extension might include some natural dispersal of seeds.

The early European mariners in the Pacific were very 'coconut conscious', having been introduced to the practice of carrying stocks of coconuts for food by the indigenous peoples of tropical islands and southern India. There is, however, not one precolonial mariner who refers in his journal to coconuts on the Australian mainland coast.

The journals from the voyages of the Dutch ships *Hormuzeer* and *Chesterfield* in Torres Strait in 1693, and that of William Dampier, who followed the north-west coast of Western Australia in 1688 and 1699, do not mention the coconut among mainland vegetation—yet the Dutch reported large numbers of coconut palms on several of the Torres Strait Islands.

In 1770, Captain James Cook named Palm Island (near Townsville) after mistakenly believing he saw coconut palms through his telescope. Investigation showed that the palms were not coconut, but a species of the genus *Livistona*, which he referred to as a 'cabbage' palm. This name arises from the use of the heart of *Livistona* palms as food in dire emergency.

Neither Cook nor Matthew Flinders (who circumnavigated the continent in 1801–03), reported other sightings of coconut palms, despite their scrutiny of many parts of the north Australian coast. Flinders did, however, record seeing a piece of 'fresh' coconut shell on Aken Island, three kilometres off the central Queensland coast in south-western Shoalwater Bay. Perhaps it had been discarded by an Aborigine who had opened a nut that drifted ashore.

Were Aborigines consumers but not growers?

There has been much speculation by naturalists as to why the coconut was absent from the Australian mainland. The palm and its products were prominent in the life of the Melanesian and other peoples of the nearby region—including the eastern islands of Indonesia—as well as in Papua New Guinea and the Torres Strait Islands.

It is reported that coconut fruits were traded between Torres Strait islanders and the Aborigines of northern Cape York Peninsula. Why, then, were there no productive palms in Australia? Could it be that the traditional Aborigines, who mainly hunted and gathered their food and did not cultivate food plants, were unaware of the potential of the traded or gathered fruit to grow into a bountiful palm?

I am convinced that a hungry forager would consume a nut washed up on the beach, thankful for the ease of harvesting it, and thereby thwart its potential growth into a palm. There is no doubt that coconut fruit was familiar to the Aborigines along much of the north Queensland coast, as there are specific words for the fruit in local languages: around Cooktown the coconut is *keremande* and at Mackay it is *cooreemboola*.

The scourge of a native rat

A white-tailed rat (*Uromys caudimaculatus*) might have been another player competing for the prized meal of a coconut fruit washed up on an Australian beach. This animal of the north-east coast, the male of which sometimes weighs 1.5 kilograms, is equipped with very strong, sharp teeth and can easily gnaw its way through a coconut's husk and shell to reach the kernel. The rat shows interest only in mature fruits, either on the palm or on the ground (as opposed to the feral rats that have invaded most coconut habitats and prefer to forage on immature fruits).

It seems likely that the consumption of coconut seeds by Aboriginal people and foraging white-tailed rats would have kept the beaches of northern Australia clear of coconut palms. Even a young seedling up to one year old would still yield a quick meal for human or rodent from its residual kernel and spongy 'apple'. The 'apple' is an organ that grows to fill the space inside the nut

Figure 1-8. Mature fruits opened by the white-tailed rat of north-eastern Australia.

Figure 1-9. The white-tailed rat (*Uromys caudimaculata*) showing the distinctive white colour at the tip of its tail. (Queensland Museum)

as the seedling develops. It secretes enzymes that break down the kernel to a liquid form that is absorbed to provide energy to the growing plant attached to the nut. Eventually all the kernel is consumed by the seedling in this way (see Chapter 3). The seedling would be destroyed when the nut was opened.

Loss of coconut seedlings and older palms

The white-tailed rat and some foraging birds, such as the swamp hen, are able to chew through the base of the outer fronds of a robust seedling to get to the tender tissue of the growing bud. Because there is only one vegetative bud in the coconut, such an attack is fatal. In the case several native Australian palm species, such as the *Livistona* group (the cabbage palms), it was common for traditional Aborigines to harvest the succulent growing bud, known as 'heart of palm', from the centre of the crown of older trees. Any coconut palm that had escaped the attention of food gatherers, swamp hens or rats long enough to grow to maturity, perhaps due to its isolation, would most likely have been harvested for heart of palm when it was eventually discovered by the local people.

Coping with sea-level rise

The coconut's colonisation of northern Australian beaches could also have been stalled by a more insidious, long-term factor, more important in Australia than elsewhere because the native people were not cultivators. That factor was climate change.

Following the last ice age, which was at its most intense around 20 000 years ago, the sea level rose gradually by about 140 metres. The sea level peaked at approximately one metre above its present level about 6000 years ago. During those 14 000 years of rising seas, the coastline of north-eastern Australia was relocated, bit by bit, from a position that was originally an average of almost 100 kilometres further east than its modern location. The coconut palm may well have colonised the outlying northern coast from time to time, but successive palm colonies would have been drowned as the sea level rose inexorably at an average rate of 10 metres per millennium. If indigenous hunters and gatherers were active on that coast during that time, it is unlikely that they would have assisted the coconut to survive, since propagating or protecting static crops was not part of their traditions. Farming peoples of the coconut heartlands, on the other hand, would surely have replanted the coconut further inland in response to the advancing ocean.

During this period, the Great Barrier Reef developed parallel to the north-east coast of Australia and in the zone that was once dry land, the coral colonies grew to keep pace with the rising sea level. The reef became a kind of shield against ocean-borne objects, such as coconut seeds, which would have tended to be washed up on inhospitable coral cays and sandbars that were too small to develop a vital 'lens' of fresh water above the saline water table. Rarely would seeds have reached the distant coastline of the main landmass.

Coastal explorers in Australia

Whereas mariners like Dampier, Cook and Flinders did not report sighting any coconut palms, sightings were reported in the mid-19th century by explorers looking more closely at parts of the Queensland coast.

In June 1848, Captain J. MacGillivray of the survey ship *Rattlesnake* noted two clumps, each of several tall and fruitful palms, on Russell Island, southernmost of the Frankland Islands south-east of Cairns. In 1864, an old, isolated palm with an estimated height of 14 metres was recorded by the botanist A. Thozet at Cawarral Creek, south of the modern small town of Emu Park (latitude 23 degrees south) on the central Queensland coast.

Later sightings in the mid-19th century were of palms that could possibly have been planted by passing mariners. On the other hand, once the dispossession of local Aboriginal tribes had begun by the mid-19th century, their regular visiting of the beaches may have declined, increasing the probability that arriving coconut seeds would be left to germinate and survive, especially in areas outside of the habitat of the white-tailed rat.

In 1871, while exploring the coast around the estuary of the Herbert River, the explorers and sugar pioneers, brothers Arthur and Frank Neame, reported finding two productive and tall palms. George Dalrymple, in 1868, noted that there was a palm at Tam O'Shanter Point on Rockingham Bay and another at the mouth of Trebourne (Palm) Creek on Halifax Bay. An 1866 drawing of the bay at Somerset (10 kilometres south-east of the tip of Cape York Peninsula) shows two coconut palms that appear to be 20 years old, a sign of possible planting by an early trader based in the region. There is again the possibility, however, that seaborne seeds had survived as the Aborigines gave up traditional ways in response to contact with European visitors and settlers.

Absence of coconut palms from the west coast of the Gulf of Carpentaria and the north coast of the Northern Territory (known as Arnhem Land) and areas further west might not have depended upon Aboriginal gathering or foraging by rats. The rapid ocean current that flows through Torres Strait from east to west, which made passage through this extremely shallow strait so difficult for Torres in 1606 and Cook in 1770, would probably prevent floating coconut fruits from drifting to shores south of their dictated course.

Planting by Australian colonists

In the late 19th century, soon after the overland telegraph from Cairns to the tip of Cape York was built, coconut palms were planted in clearings near the line's repeater stations. Palms were also planted near homesteads on the developing cattle stations in the region. Besides the obvious ornamental attraction of coconut palms, these plantings were part of a government policy of providing an emergency food supply for the occupants of these isolated outposts.

Early in the 20th century, many coconut plantations, albeit small ones compared to those in the South Pacific islands, were established on the North Queensland coast between the Daintree and Johnstone rivers (latitudes 16–17.5 degrees south). In 1911, an adventurer named Jack McLaren began establishing a small plantation on Simpson's Bay, a few kilometres south-west of the tip of Cape York. At the same time, government agent and trader Frank Jardine planted some thousands of palms at Somerset on the nearby east coast. Christian missionaries encouraged Aboriginal communities at Mapoon and other settlements on the west coast of the Cape to plant coconuts for food.

But there was another motive. During World War I (1914–1918), coconut oil was sold to the armaments industry for the production of glycerine. In common with most vegetable oils, coconut oil is made up of molecules known as triglycerides, which comprise a glycerine molecule and three fatty acid attachments, of which there are a dozen or more varieties. Pure glycerine is obtained by chemically separating the fatty acids. Further processing transforms the glycerine to the powerful explosive, nitroglycerine.

The high postwar cost of labour and the economic depression of 1929–35 meant that these early plantations were not commercially viable for long. Australian coconut plantations were not the only ones to suffer, as the depression undermined the profitability of coconut plantations worldwide.

The coconut redeployed in an ornamental role

Isolated remnants of some of the early coconut enterprises of European Australians remain, even to this day. But the coconut began to fill a new and completely different role in the later part of the 20th century, as an ornamental palm to beautify parks, streetscapes and tourist resorts throughout coastal northern Australia. It has become the ubiquitous symbol of holidays and relaxation, evoking thoughts of a warm environment, languid waters, romance and generous banquets.

The 'escape' image of the coconut seems to have evolved in Europe because of the contrast between the coconut's lush tropical environment and the industrial cityscapes of so many European cities in the 19th and early 20th centuries. The power of this image was heightened by the writings of authors such as Robert Louis Stevenson, who took up residence in Samoa in the South Pacific. His description of the apparently carefree lifestyle of the indigenous people of this Polynesian island had great appeal. The paintings of Gauguin, working in Tahiti, added to the myth of coconut cultures in an environment of plenty, where no-one needed to be stressed in the course of survival, and where the inhabitants were universally welcoming of visitors who came to share their paradise.

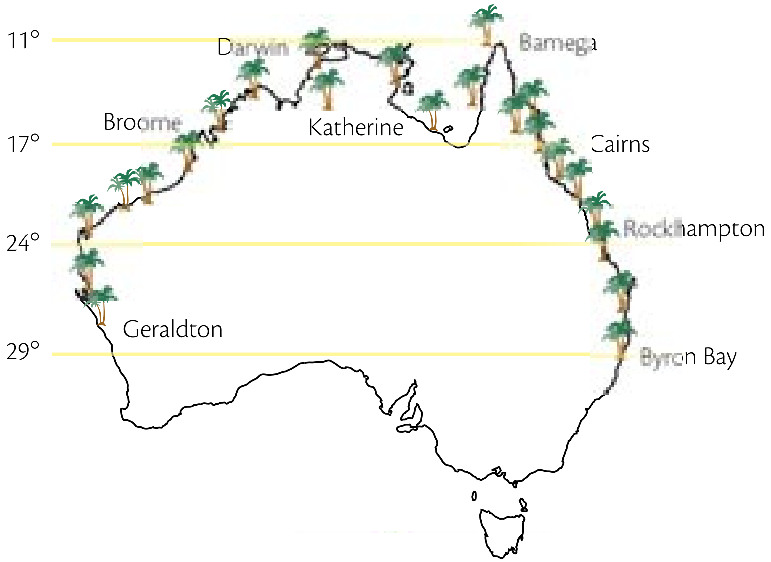

Figure 1-10. Distribution of the coconut palm around the 20 000 km northern coast-line of the Australian mainland, extending south to the 29th parallel of latitude on both the east and the west coasts.

Another popular image among Europeans was the 'desert island' inhabited by a lone marooned person and a coconut palm, suggesting that the person was provided for by fruit falling from the palm.

Figure 1-11. An ancient palm at Mapoon on the east coast of the Gulf of Carpentaria, Australia – 24 m tall and around 100 years old. It was the last survivor (year 2000) of hundreds planted by missionaries in the late 1800s with a view to securing a source of food for the local aboriginal tribes.

There are now many tens of thousands of coconut palms, scattered along 20 000 kilometres of coastline from Geraldton (latitude 29 degrees south) in Western Australia, through the towns of the north-west coast (although much of that coastline is too hot and arid), Darwin, Arnhem Land, the islands and coast of the Gulf of Carpentaria, and in pockets all the way down the east coast from the tip of Cape York to Cape Byron (spanning latitudes 11–29 degrees). This spread of distribution, lying outside the equatorial zone (zone 1 in Figure 1-5) has enabled observation of the effects on coconut palm growth of substantial variations in seasonal cool temperatures (see Figure 1-13 and Chapter 3).

What are the environmental limits for the coconut?

Little information has been gathered about the effect of temperature on the fruit development of the coconut, although there have been descriptions of the effect of severe drought on fruit growth in Africa.

Altitude and temperature combined can limit the range of the coconut palm. In tropical and subtropical latitudes, the temperature is known to decline, on average, 0.6°C for each 100-metre increase in altitude. If the mean temperature at sea level is 27°C, which is not uncommon on tropical coastlines, on adjacent highlands at 1000 metres it will be close to 21°C—the approximate limit for reproductive growth of the coconut. At the higher altitude, the palm may survive and be capable of growing fronds, but not fruit.

Latitude and seasonal temperature also play a part. Although the palm grows attractively on the coast in latitudes as high as 29 degrees, it rarely retains fruit beyond the early developmental stage in latitudes beyond 24 degrees. This fact frequently gives rise to the question, 'Why are there no fruit when the palms look quite healthy?' Fruit will fail to set if the inflorescence (the flower stalk) does not develop properly and, as most kinds of palm need cross-pollination to produce fruit, isolated palms are disadvantaged. The exception is the Dwarf palm, which is able to self-pollinate. Failure can also be induced by three to four months of mean temperatures below 21°C, too low for the palm to achieve the vigour of growth needed for fruit development.

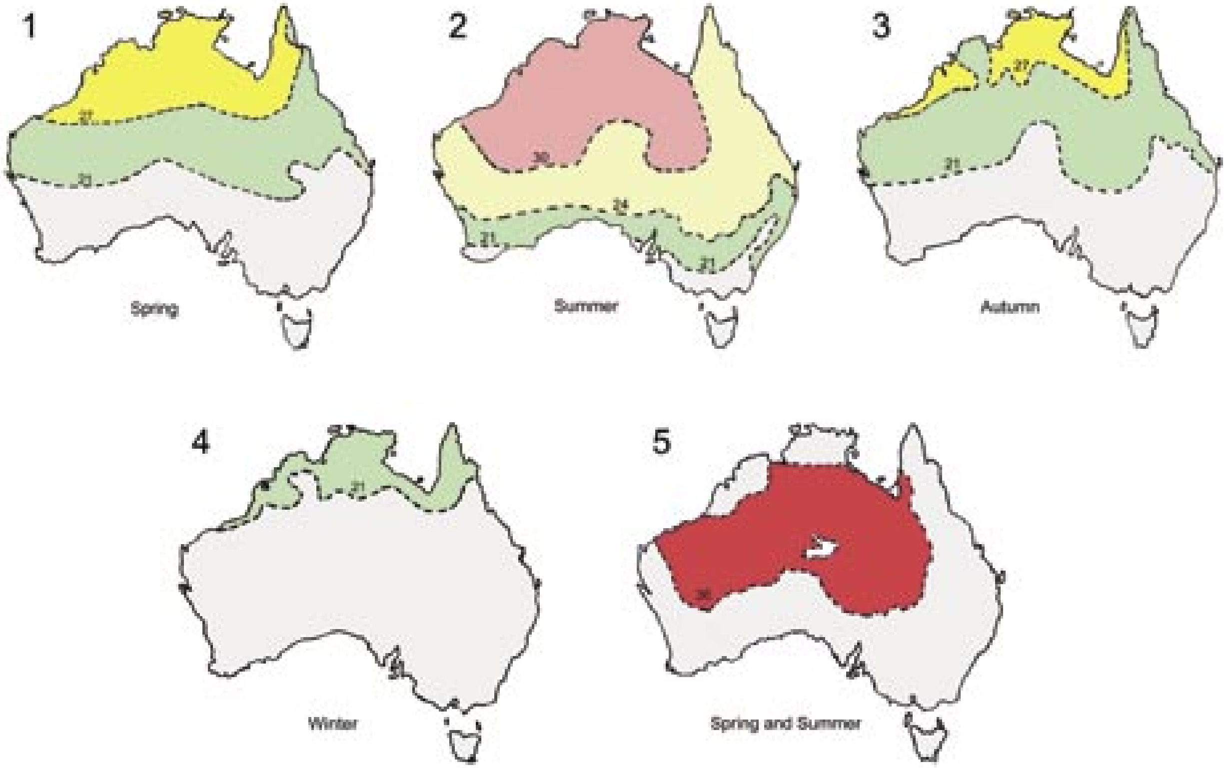

Figure 1-12. Four seasonal mean temperature distribution maps of Australia. Even during winter the entire north coast, and the east coast as far south as Cooktown have an average temperature above 21 degrees, enabling the palm to grow quite well year round in that zone. The southern limit of coconut survival corresponds closely to the position of the 21 degree isotherm in spring and autumn. The map coloured bright red shows those areas where the mean maximum temperature exceeds 36 degrees during both spring and summer. This identifies areas where the coconut would experience damaging stress even when cared for with regular watering. (Based on data of the Bureau of Meteorology, Australia.)

The coconut fruit requires a year-long period, during which the palm is free from severe stress, to grow to maturity.

Natural fruit loss because of cold weather or water stress is a boon for city councils and other organisations managing coconut palms in urban settings. They would normally spend much money removing the fruit so that passers-by are not endangered by falling mature nuts (see Chapter 6), which usually weigh more than one kilogram at maturity. Palms can grow up to 30 metres, but even a five-metre drop would cause serious injury. Tall palms become hazardous very soon after fruiting begins. Those responsible for palms in public places must invest in pruning (denutting) or bunch-caging services to eliminate the risk.

South of Mackay, on the Australian east coast (around latitude 20 degrees south), the fruit reaches full maturity but a small proportion may have incomplete kernel development. This renders the nut incapable of germinating, although the kernel is still good to eat. North of that latitude, most fruits contain a fully developed kernel and have potential value as seeds and as a reliable source of food and drink.

Figure 1-13 shows the shapes of coconut shells in fruit grown in various places in Australia. The annual mean temperature in these locations, and some others, has been graphed in Figure 1-14. A prolonged cool period appears to induce narrowing of the nut within the fruit, giving it an elongated appearance, with some fruit also showing incomplete development of the kernel. In places where there is little seasonal variation in temperature, for example near the tip of Cape York (latitude 11 degrees south), the typical rounded nut shape predominates. In the coconut heartlands of Indonesia, the Philippines and Melanesia, nut shapes vary from spherical to oval or almost cone shaped; the shape found in seasonally cool regions seems always to be elongated or a narrow oval. Shape is not an issue in the marketplace, provided that the kernel is sound, but a narrow nut has a smaller volume and therefore less value than a spherical nut.

Figure 1-13. Fruit and nut shapes that have been affected by different seasonal temperature ranges. Elliott Heads (latitude 25 degrees) is midway between Brisbane and Rockhampton, Seaforth is close to Mackay (latitude 21 degrees) while Cooktown (latitude 15 degrees 30) is on the east coast of Cape York Peninsula.

Extreme latitude: the coconut seedling as an indoor plant

I was once astonished to find coconut seedlings growing in the dining room of a hotel in Pitlochry, Scotland (latitude 57 degrees north). Although it was midwinter, the central heating kept the temperature around 21°C, which was sufficiently warm to support active growth. The nutrient and energy reserves of the kernel are capable of supporting growth well beyond 12 months in this environment. Eventually, however, the reserves will be exhausted and growth will cease unless there is enough light for photosynthesis. Ornamental coconut seedlings for indoor use are distributed widely by nurseries in the Netherlands, and very probably in other temperate countries.

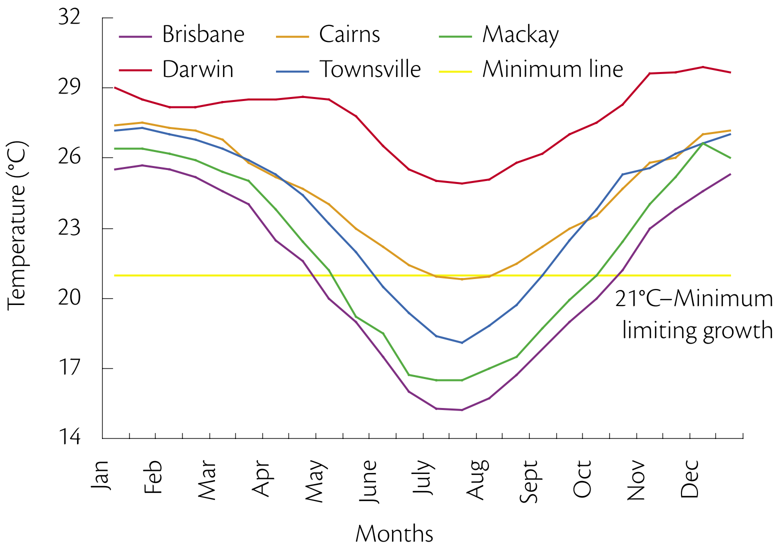

Figure 1-14. Annual daily mean temperature graph for some Australian centres of different latitude. Brisbane is marginal for coconut, having a mean temperature below the 21 degrees critical value for about six months. Fruit always drops before reaching maturity in Brisbane. In Mackay, where the cool season is shorter and less intense, fruit is able to mature successfully. This is the southern limit of consistent production of sound fruit though a proportion of good fruit is produced as far south as Bundaberg. Cairns has a short period close to 21 deg, while in Darwin the daily mean temperature is close to the ideal of 28 degrees for six months and only slightly below for the remainder of the year.

Can the coconut palm be regarded as a native Australian plant?

From time to time in Australia, the question of the coconut's indigenous or 'naturalised' status is raised, especially in relation to the management of coastal national parks. The coconut was very scarce indeed when the European colonists arrived, but it was not entirely absent, as shown above. It is obvious to anyone who walks the beaches, particularly of the east coast, that coconut seeds arrive fairly frequently, and that some of these seeds are capable of establishing palms. Their arrival is not surprising, because the dominant ocean current off the Queensland coast flows through the islands to the east of Papua New Guinea, where the coconut grows prolifically. The Australian coast shares many other species of strand plants with Melanesia, such as the casuarina (or 'sheoak'), the goats-foot morning glory, and the leguminous creeper *Vigna marina*.

It seems clear to me that, but for the presence of Aboriginal food-gatherers and the foraging white-tailed rat, the coconut would have been well established on at least the

Figure 1-15. The author holding an ornamental coconut seedling indoors at Pitlochry in Scotland. After one year or so, when the supply of kernel supporting growth is exhausted, indoor palms die due to lack of sufficient sunlight.

most favourable tropical shores of the Australian north-east before European settlement. It is a potential coloniser of the Australian coast, and quite possibly has established itself on some northern beaches since the dislocation of the Aboriginal tribes, and perhaps also the local decline in numbers of the white-tailed rat, during the 19th century.

There is no clear proof either way about its establishment during that time, but given the palm's known tenacity in colonising remote strands, and some circumstantial evidence that it actually did so on the Australian coast, I suggest that it be accepted as a native Australian plant. The coconut palm's 'native' habitat is a very restricted niche on the strand. It cannot establish itself naturally anywhere else, because dispersal is solely by water—which counters any argument for its acceptance in natural heritage areas away from the strand.

chapter 2

Surprising diversity among coconuts

adaptations to new environments and to human demands

The two main groups of the coconut palm are the Talls and the Dwarfs. The Tall group contains much diversity, in spite of its origins on the narrow strand, and includes scores of varieties recognised globally and many that have not yet been classified.

There are great differences in the thickness, shape and rate of growth of the trunk; the length of frond of the mature palm; the colour, shape, size and flavour of fruit; adaptation of the palm's growth to physical variables, particularly nutrient supply, seasonal temperature cycles and water deficit (drought); and tolerance to damage by some pests and diseases.

Tall and Dwarf palms show great physical contrast, and are usually separated by village people for convenience: the Dwarf is found close to settlements because it is more ornamental and more accessible as a source of coconut juice.

How many varieties of coconut are there?

Despite the first impressions of visitors to coconut country, not all coconut palms look alike. The coconut 'kingdom' is divided into two main groups, called 'Talls' and 'Dwarfs'. There is a great deal of variation in fruit colour and size within these two groups, but usually the Tall has a thicker trunk, a larger crown and larger fruit.

Talls mostly cross-breed, while Dwarfs mostly inbreed. One result of this difference in breeding behaviour is that a group of Talls might appear fairly 'mixed', particularly in the diverse shapes and colours of the fruit. Cross-breeding, or outbreeding as it is sometimes called, is the consequence of the male and female flowers on each flowering branch (inflorescence) being active at different times (see Chapter 3 for a full description of flowering). The female flowers are mostly fertilised by pollen from other nearby palms, but sometimes the durable, waxy, coconut pollen can be carried many kilometres by insects or wind before it reaches a receptive flower. The diversity, or heterozygosity, arising from this high frequency of crossing means that no two Tall palms have the same genetic makeup, even though their ancestors might have been confined for generations to the same small island or beachfront.

Apart from usually small differences in appearance (fruit size, shape and colour; trunk thickness; length of fronds etc.) between all the members of a group of Tall palms, their different gene combinations influence their adaptation to the environment. If the group experiences an attack by a disease organism, for example, some members might cope better with the disease because of their particular combinations of genes. While those members will continue to produce seeds, natural selection will work against the others. Eventually, the surviving descendants of the group will be more likely to carry the effective combinations of genes and cope with the particular disease.

A group or family of Dwarfs, on the other hand, shows very little variation and does not adapt as well to a changing environment. Dwarfs are physically less robust than Talls (Figure 2-1) and do not acquire the flexibility that enables older Tall palms to yield to the wind without breaking. The Dwarf trunk at any age is inclined to snap in severe cyclonic wind, and its small circumference at the base makes it vulnerable to breakage of the root attachments. The broader base of the Tall carries more roots and suffers less 'leverage' force when the upper trunk is flexed sideways. The only advantages of Dwarfs over Talls, in the matter of survival, are their earlier fruiting and higher number of fruit per bunch.

It is common practice to refer to a Tall population according to its location, either regional (such as West Coast Tall, from the western coastline of southern India) or, in the case of small countries, by the country's name (such as Solomon Islands Tall). Palms will have become adapted to the particular ecological conditions of the place, such as climate, soil and biological influences, and especially insect and disease pressure. This applies particularly in south and south-east Asia and the Pacific islands, where adaptation has come about through natural selection acting upon hundreds of generations of palms. A group of Tall palms associated with a location in this way is referred to as a variety or 'ecotype'.

Dwarfs have far fewer varieties than Talls, both because of their inbreeding and because their seeds cannot survive a long period floating on the ocean. This inability stems from the characteristically thin husk of the Dwarf nut, which acts against the preservation of the seed within.

Dwarfs are regarded as the likely result of mutations that made female flowers ready for pollination whilst the male flowers of the same inflorescence were releasing their pollen, resulting in a high frequency of self-pollination. The names of Dwarf varieties usually refer to the country or region of origin and the colour, such as Sri Lanka Green, Nias Orange, Malayan Yellow and New Guinea Brown (see Figure 2-2).

Telling the difference between a Tall and a Dwarf palm

The differences in trunk thickness and the size of the crown allow almost instant recognition of a palm as Tall or Dwarf, except for hybrids of the two, which are intermediate in trunk thickness (see Figure 2-1).

Figure 2-1. Contrasting thickness and shape of the base of the trunk of a Tall (left), a Dwarf (right), and an intermediate hybrid, type of palm — all three adjusted to the same scale.

The Dwarf palm does not develop a bole or enlarged base on the trunk, as most Tall varieties do. The Dwarf trunk has very nearly the same diameter at ground level as it does along its full length, except for very slight tapering as it gains height. Dwarf palms are of course much shorter than Talls of the same age (less than half the trunk height), and their shorter fronds result in a smaller crown. The Dwarf begins to flower and bear fruit two or three years earlier than the Tall (from the age of three years under really favourable conditions), and because its trunk extends only slowly, fruit bunches are carried close to the ground at first and remain within reach of the human hand for several years.

Talls, on the other hand, usually bear their first bunches out of reach, and they rapidly grow to a height at which harvesting requires a long-handled cutting tool, an extension ladder or climbing skills.

Within the Tall group, it is fairly easy to recognise two major subgroups on the basis of size and shape of the fruits. A large, roundish fruit having a thinner husk is referred to as the 'domesticated' form (Figure 2-3, right). It has evolved as

Figure 2-2. Four common fruit colours, light brown, orange, yellow and pale green, found especially on Dwarf palms. Many other shades of green and brown are found on Tall fruit but the recessive orange and yellow colours shown here are almost exclusive to Dwarf palms, which display the same colours on the frond petiole and also have pale leaflets. (Roland Bourdeix, Centre for International Cooperation in Agricultural Research for Development (CIRAD), France)

a result of selection by humans over many millennia for greater water content, providing a convenient water supply for drinking where fresh water is scarce, especially on sea voyages.

The 'wild' form of the Tall coconut, on the other hand, is found wherever the palm has spread naturally, and has remained genetically unchanged in its proportions of husk and nut. The wild-type fruit is smaller than the domesticated fruit and has a higher proportion of husk, which enables it to float on the ocean for a long time, and a correspondingly lower volume of nut-water. Intermediate-sized fruits, showing great diversity between palms, are found in many coconut populations. This is especially so on some of the long-occupied Pacific islands, indicating that an original wild coconut palm population, which predated the arrival of human colonisers, has been blending for some time with introduced larger-fruited varieties.

A few very remote islands, such as North Keeling in the Cocos Islands of the Indian Ocean, show truly wild-type fruit with no trace of introduced forms.

Drought tolerance

Apart from their recognisable fruit characters (size, shape, dominant colour), different Tall populations can also be distinguished, when compared within a location, through their differences in adaptation.

Environmental variables (such as the regular occurrence of a dry season, seasonal variations in temperature, or attacks by pest and disease organisms) induce tolerance through natural selection. For example, coconut palms from Kerala, in south-west India where the dry season is pronounced, withstand the seasonal drought well at home.

They are also notably better adapted than palms from South-East Asia or the South Pacific when these are all compared, regardless of whether they are grown in India or in other seasonally dry environments, such as in parts of Africa and the Caribbean.

Tolerance of low temperature

Hainan Island, off southern China (latitude 19 degrees north), has a pronounced cool season. The indigenous coconut population tolerates the spasmodic occurrence, during the cool season, of short periods (a few days) of near-freezing air that moves in from mainland China. Exotic varieties, on the other hand, are severely damaged or killed by such weather.

In subcoastal north-eastern Australia, young palms succumb to frost, which occurs rarely on the northern Atherton Tableland (latitude 16 degrees south, altitude 400 metres) and with increasing frequency at inland locations progressively further south. If there is not a fatal frost for five or six years following germination, a young Tall palm can grow tall enough to survive spasmodic frosts, because its increase in height raises its fronds and growing point above the level of the layer of freezing air.

Figure 2-3. Contrasting fruit size and proportion of husk and nut of wild (left) and domesticated palms. The images have been adjusted to the same scale.

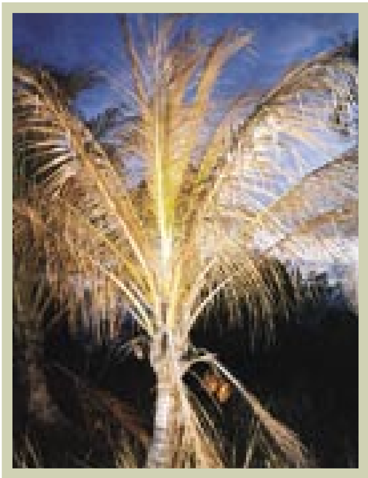

Figure 2-4. A young Dwarf palm killed by a rare frost on the Atherton Tableland (latitude 17 degrees S., altitude 400 m) in north-eastern Australia

In Queensland, there are plenty of healthy irrigated palms at Charters Towers (latitude 19 degrees south, 130 kilometres inland), for example, and an isolated healthy 30-year-old palm at Moura (latitude 24.5 degrees, 180 kilometres inland). South of Moura, the coconut does not survive inland. It would be very interesting, however, to test the survival of the Hainan variety in such areas of occasional overnight frost.

Tolerance of insect and disease attack

Natural selection has led to the development, in Tall populations scattered around the coconut world, of resistance or tolerance to attack by particular insects or diseases. Many examples can be found of palms somewhat resistant to specific insects, such as the Melanesian coconut leaf beetle (Brontispa longissima), in Papua New Guinea and Solomon Islands. This leaf-miner does little damage to young, adapted palms growing in its habitat, but it can be very destructive of young palms brought from regions where it is absent. The beetle can also be very destructive if it invades a new region. For example, a coconut variety brought, because of its large fruit, from Malaya to Solomon Islands in the 1920s suffered very severe damage from the local Brontispa beetle. Conversely, when the beetle entered Australia's Cape York Peninsula recently as a new arrival, it wreaked extensive damage on coconuts and some ornamental palms.

Coconut palms also exist that are resistant or tolerant to bud rot and lethal yellowing disease—both serious scourges of coconuts in many parts of the world (see Chapter 4 for a more detailed description of diseases and pests of the palm).

One of the most interesting examples of invisible tolerance to a disease was discovered in Vanuatu during the 1960s, when many varieties of coconut were imported for research. Many of these exotic coconut palms died, and local people accused the researchers of importing a dangerous disease along with the palms. It turned out, however, that there was a viral pathogen present in the local palms, which were so tolerant of it that they showed no symptoms. Exotic varieties, on the other hand, had no tolerance and began to succumb to the virus, later found to be confined to Vanuatu. The discovery was a blow to the research project because there had been hopes of breeding new hybrids for export to neighbouring countries, but export was now too risky.

Molecular tools show promise of becoming useful in the long term in identifying, at moderate cost, populations with tolerance to a particular species or strain of attacker, or to an environmental stress. This approach might render unnecessary large field trials designed to compare the tolerance of populations. Such trials are costly and subject to uncertainty about the intensity of exposure to the hostile organism.

The strand posed few biohazards

Throughout its long evolution in its natural environment on the strand, the coconut has not been exposed to particularly strong selection pressure from pests and diseases. This is because many small-island environments do not carry complex populations of plants whose associated insects and pathogenic microorganisms would prey upon or invade neighbouring coconut palms.

The palm planted elsewhere faces more threats. Its foliage is palatable not only to many insects but to all herbivorous animals. Where the palm coexists with horses, cattle, buffalo, sheep, goats or the like, the foliage must be protected for several years until it is out of their reach. Many nonselective pests—such as stick insects, locusts, the palm-dart caterpillar, scale insects and whitefly—inflict foliar damage on coconut palms episodically, especially in a monoculture (plantation) situation (see Chapter 5). The soft tissue of the central bud, particularly in the palm seedling, also attracts creatures ranging from beetles, birds and pigs to elephants!

Diversity among Dwarfs

Three main subgroups can conveniently be identified among the Dwarfs: the 'stumpy' or compact Dwarf of the South Pacific (named Niu Leka or Niu Leha in Polynesian languages); the 'village' Dwarf, found scattered in villages throughout the Pacific; and the Malayan or Nias Dwarf. The last two types are fairly uniform, especially the highly inbreeding (self-pollinating) village Dwarf, whereas the stumpy Niu Leka is mostly an outbreeder.

The Niu Leka produces many intermediate forms by crossing with the Tall, and with the village Dwarf.

The benchmark type of Niu Leka has a short, dense frond, resulting in a very compact crown. The bunch stem is also short, and the dominant fruit colour is green. The trunk is of similar thickness to that of the Tall but the rate of height increase is the slowest among coconut varieties, allowing easy access to the fruit from the ground for a longer period than with other Dwarfs. The fruit is medium-sized with moderately thick husk, so the nut is fairly small. The Niu Leka tends to be low-yielding and has been used commercially for copra-making only once (on the Fijian island of Taveuni), but it provides a more easily harvested source of drinking nuts than does a Tall of the same age.

The village Dwarf has the thinnest trunk of all coconut varieties and bears small orange fruit. Fruit can have a very light green colour when immature and darken to a definite yellow before drying to brownish grey at maturity. The fruit of the village Dwarf is small and elongated, and the mature nut is pear-shaped and very small indeed. Any progeny of a village Dwarf that does not bear orange (or yellow) fruit is a hybrid (from cross-pollination with a Tall). The orange colour is the product of a recessive gene and is suppressed in all the dominant green and brown variants of Tall palms.

The Malayan or Nias Dwarf embraces a large group of variants, long found in Indonesia (particularly on the island of Nias off Sumatra) and in Malaysia, which have become widespread and popular for various reasons. In contrast to the village Dwarf with its tiny fruit, these have small to medium-sized fruit and a more robust, though still distinctly straight-sided lower trunk. The fruit is easily distinguished from that of Talls by size and colour, which might be dark to light green, dark to light orange, yellow or brown.

Most Dwarfs are up to 90% self-pollinating, with the principal exception of the thick-trunked 'stumpy' Niu Leka Dwarf. Dwarfs generally 'breed true' and retain the fruit colour of the mother (which is also the father) palm. The orange and yellow colours are each produced by a recessive gene, and self-pollination allows these colours to be expressed because a 'pure' palm has two genes for the colour. In palms in which either of these genes is paired with a single brown or green gene, the recessive orange and yellow colour genes are not expressed because brown and green colours are dominant. This allows convenient identification of both hybrid and Dwarf seedlings emerging from Dwarf seed-nuts. If hybrid seedlings are being selected, green and brown colour on the petiole (leaf stalk) identifies them; if Dwarfs are sought, orange and yellow petioles provide verification.

Some members of this third group of Dwarfs have been used in plantations, particularly the Malayan orange, yellow and green cultivars. However, they have less kernel per nut than Talls with similarly sized nuts, and their kernel has a lower oil content and a less-developed coconut flavour. Early fruit production, and the associated ease of harvesting, are attractive traits in the Dwarf, but its use in plantations has not persisted. Small nuts are more costly to process per unit of oil produced and the kernel is softer that of the Tall, is harder to separate from the shell, and contains less oil.

Some Dwarf populations in the Caribbean and Africa have shown traits that are particularly interesting for security of production, such

Diversity among palms introduced into Australia

As we have seen, Australia lacked significant numbers of coconut palms until the late 19th and early 20th centuries, when small investments were made in plantations on the coast north of the Johnstone River (which flows through Innisfail at latitude 17 degrees south), and at the tip of Cape York (12 degrees south), using 'copra' palms of the type also being planted widely at the time in New Guinea and the South Pacific islands (copra is the kernel of the nut, dried to about 6% moisture content). Seed for planting these areas would probably have come from the Torres Strait Islands and the Papuan coast and islands, where many trading boats and trading posts were active in that era.

Remnants of the Queensland plantations remained until at least the 1980s, and an occasional very ancient palm (probably around 100 years old) can still be seen, even though copra-making did not continue in Australia beyond the depression of the 1930s. The old plantations continued to produce fruit that provided food for domestic and wild pigs. In some areas, the native white-tailed rat population proliferated in response to the constant supply of unused fallen coconuts.

A few copra-type Tall palms were also planted in the late 19th century around Darwin, and on coastal mission stations in the Northern Territory and on the north-west coast of Western Australia—for example, at the Catholic mission at Kalumburu, and around Broome (latitude 18 degrees south). Many seednuts, probably from Timor, were imported to Darwin in the 1860s in a vessel named the *Gulnare*, and there are records of imports from Thailand and from the Federated Malay States (now West Malaysia).

In North Queensland during the 1970s, interest grew in the use of yellow and orange small-fruited Dwarf palms as ornamentals in real estate developments and resorts, and on city streets. This is perhaps the first example in Australia of a purely ornamental use of the coconut, although the palm had long been appreciated in holiday resorts for the way it helps to create a relaxing, tropical ambience. In the late 1990s, several distinct Dwarf varieties were introduced from Solomon Islands by the Townsville City Council, for ornamental use in parks. Some may be found in the magnificent Townsville Palmetum in the suburb of Aitkenvale, along with a great range of other palm species. Interest in Dwarf varieties continues to increase, as managers of holiday resorts, public parks and city streetscapes become concerned about liability for injury from any source, including falling coconut fruit.

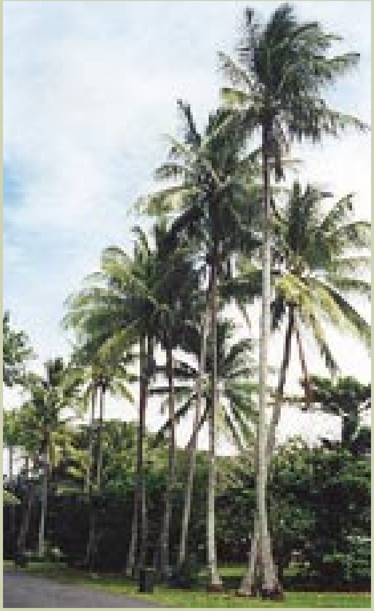

Figure 2-5. Ancient palms at Wonga Beach north of Cairns, Australia (latitude 16 degrees 30 min S) planted in the early 20th century.

Figure 2-6. Aerial view of North Keeling atoll (latitude 12 degrees S, longitude 96 degrees E), which is host to a 'wild' coconut woodland.

Figure 2-7. Coconut palms planted on a 'high' island overlooking coral reefs — typical of many coastlines of the south Pacific and Torres Strait. (Simon Foale)

The Australian external territory of the Cocos–Keeling Islands, comprising one large and one small atoll, has a very interesting coconut history. Situated south-west of Java, these islands had already been colonised by the coconut palm when they were settled by a Scottish family early in the 19th century. Coconut plantations operated for 150 years. The plantations on Main Atoll, the larger of the islands, have been abandoned as a commercial enterprise and, while they meet the small needs of the few hundred descendants of the earlier labouring families, they have reverted to overcrowded coconut woodlands. There seems never to have been any settlement on the smaller atoll, North Keeling, and this gives rise to the possibility that this island is home to the last truly wild-type coconut population in the world.

as resistance to lethal yellowing disease and related pathogens. Others show better tolerance of drought, for example the Sri Lanka, Cameroon and Brazil Green Dwarf (a molecular study has shown these to be very closely related). As noted above, the fruit and nut of the Dwarf are smaller than those of the Tall used in plantations, which makes a larger-fruited Dwarf variant more attractive. Unfortunately, two otherwise suitable large-fruited Dwarf varieties, Malayan Green and New Guinea Brown, have poor drought tolerance.

Other variations in both Dwarf and Tall palms include the non-branching fruit bunch, or Spicata type, which has a greatly reduced number of male flowers, while the female flowers are all crowded on a single flower stem. In a rare type of palm in the Philippines, the Makapuno type, the kernel is replaced by a gelatinous mass with a strong coconut flavour; this type fetches a premium price for use in ice-cream. A similar trait is known in India, Indonesia and Sri Lanka, and an isolated mutant of this type has been observed in Solomon Islands.

Thailand has a prized type, Aromatic Green Dwarf, with an attractive aroma in the immature husk. Keeping rats away from this variety is a problem, as it is with 'edible husk' fruit found occasionally in several countries.

There are many reports of particular palms producing fruit of exceptional medicinal value, especially in their nut water (the coconut juice), but it is hard to find proof of such claims.

Exploiting diversity with hybrids

Hybrids between Tall and Dwarf types have attracted much interest among producers seeking high productivity, especially of kernel and oil. These hybrids, for which the Tall parent has usually been chosen because of its large fruit and local adaptation, grow more vigorously and flower sooner than the Tall parent. They exhibit intermediate trunk thickness and a moderate rate of height increase, and are usually more productive of kernel and oil than either parent type.

It is not yet known if they will sustain production throughout a long life, as large-scale planting of hybrids began only in the 1970s, but in the first 20 years they have produced up to 30% more than the related Tall in the same environment. One theory proposes that the high yield of the hybrid is based in part on its low rate of trunk growth, which allows more of the plant's resources to be allocated to fruit production.

Hybrids usually also have a higher proportion of kernel in the fruit than either parent does, because both the shell and the husk are thinner than those of the Tall parent, while the nut is larger than that of the Dwarf parent. It is interesting to note that the highest-yielding hybrids are those with a large number of smallish fruit.

chapter 3

The life story of a palm

from seed to first fruit

Here we follow the stages in the life of a palm, from the germination of the giant seed (the nut), through the consumption by the seedling of the energy reserve in the kernel, to its gradual 'weaning' onto its own photosynthetic energy supply as leaves emerge.

The young palm reaches full independence from the seed at about 12 months. After three or four years, the first inflorescence emerges and fruiting begins.

The effects of different environments on the partitioning of energy between the fronds, trunk and fruits affect productivity.

Starting with the seed ...

The coconut fruit, which develops on the palm for 12 months (a little longer where there is a cool season), becomes a mature seed when its husk dries out and loses the fresh, bright colours of immaturity.

The coconut seed is the second largest in the plant kingdom, and weighs from one to four kilograms. It is exceeded in size only by the 20–50-kilogram seed of the extremely rare 'coco-de-mer' or double coconut (*Loidicea seychellarum*), native to the Seychelles Islands in the north-west Indian Ocean) and on view in a few botanical gardens in the tropical world, notably Peredeniya in Sri Lanka and the Townsville Palmetum in Australia.

The husk of the ripe coconut seed (the fruit) loses moisture by evaporation to achieve the buoyancy it needs for its natural dispersal across oceans. The seed of the wild-type palm passes through a period of enforced dormancy, which is extended while it is floating on the ocean or being held in dry storage. Remoistening with fresh water breaks this dormancy and stimulates germination.

In contrast, the domesticated coconut fruit, whose natural behaviour has been much altered by human selection, often germinates while hanging on the bunch. Such a sprouted fruit, when it eventually falls to the ground, has no chance of being dispersed on the ocean because immersion of the emerged seedling in salt water is fatal. Fruit from a domesticated population therefore has less chance of natural dispersal than wild fruit.

Whatever the delay before germination, the process thereafter is the same. The inner part of the coconut seed, within the husk, is the hard 'nut' familiar in trade worldwide, but only those who have visited productive palm locations or nearby markets are aware of the thick body of fibrous husk surrounding the nut. This is almost always partly or completely removed before delivery to distant food markets.

Figure 3-1 The coconut embryo, which generally measures 8 mm long by 5 mm diameter (right), the 'socket' that it occupies in the kernel (middle), and an outside view (left) of the surface of the kernel, separated from the shell and with its thin brown coat also removed, showing the outer end of the embryo awaiting the stimulus needed to germinate. (Simon Foale)

The embryo of the seed is concealed beneath the 'soft eye' at the top of the nut (distinguishable from the other two 'blind eyes'), and its emergence from the soft eye signals germination. In a tropical environment with a mean daily temperature around 28°C, early growth following germination is concealed by the husk for 30–40 days. A dehusked nut is also capable of germination when surrounded by a vapour-saturated atmosphere (for example, within a plastic bag that contains a source of moisture), and this has made possible detailed observation of early development.

Figure 3-2. Section through a germinated coconut fruit showing the expanded haustorium (referred to in Melanesia as the 'egg') occupying most of the cavity, and also the shoot, aged about 3 months. The haustorium eventually fills the whole cavity, absorbing all the kernel.

The first growth after germination takes the form of a soft, expanding, white lump of tissue, which shows no change of shape for two weeks. At the same time, the embryo develops an organ of spongy tissue (technically, the haustorium) that expands rapidly into the cavity of the nut, usually filling it completely within four months, although in a large nut this would take a little longer.

A parallel can be drawn between the function of the haustorium and that of the placenta of mammals, including humans. The haustorium provides a conduit for the supply of nutrients between the 'mother' (in this case the large mass of kernel concealed within the nut) and the new organism. The supply is sustained for many months, until the new organism is sturdy and capable of detachment and independent growth.

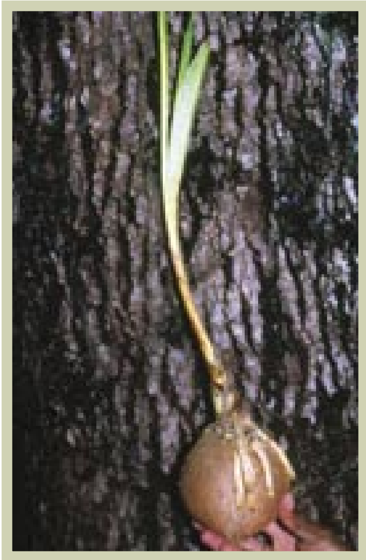

Figure 3-3. A coconut seedling with the husk removed showing its attachment to the nut, from which it is drawing sustenance, and its developing roots.

The husk hides the very young seedling

The external growth, which is attractive to chewing insects, would be very vulnerable without the protection of the husk. After two weeks, it hardens a little and then begins to form the first root on the underside, followed by the shoot on the upper side. A fruit placed in a nursery should not be rolled over during this concealed phase of germination, as the direction the roots and shoot would become distorted and their growth would be retarded. The shoot tip requires two to four weeks to elongate sufficiently to appear through the husk, depending on its vigour and on the thickness of the husk. Slicing off a section of husk immediately above the soft eye hastens emergence.

In the purposeful management of the seedling, the early phase is called the 'pre-nursery'. It is followed by the planting of the developing seedling into a large polybag, by which time the roots have probably emerged from the underside of the husk, sometimes struggling to force their tips through the thin, but rather tough, outer layer. This layer is best sliced away to encourage rapid root emergence. If the nut is large, more of the husk might need to be sliced off to fit it more readily into the polybag, submerged to half its depth in the potting soil.

The seedling 'sponges' from the kernel

The haustorium—the soft, spongy internal organ expanding within the nut—is often referred to as the 'egg' or 'apple'. Progressively, the haustorium makes contact with the entire inner surface of the kernel (except in very large nuts), releasing softening enzymes as it does so. It rapidly absorbs the nut water, and from the kernel it takes nutrients at an increasing rate to provide substance and energy for the growth of the seedling.

In the three-month gap between germination and the expansion of the first green leaf, the seedling depends solely on the kernel for its energy supply. There follows a period of gradual 'weaning' as the young seedling expands a series of leaves, each larger than the one before. Each new leaf supplies a greater share of the energy needs of the seedling, which thereby becomes less and less reliant on the diminishing kernel to sustain its accelerating growth.

The rich nutrient and energy mixture derived from the kernel is delivered by the haustorium to the developing seedling for at least 12 months, although sooner or later a proportion of seeds suffers invasion by fungi or bacteria that disable the haustorium. While the seedling is able to survive this loss of access to the kernel, it suffers a

Figure 3-4. Polybag seedlings in a large plantation nursery in Mozambique (1992). The seedlings will be transplanted to the field without any significant setback after developing three or four more leaves.

noticeable setback to growth, the severity of which is related to the timing of the loss.

At 12 months of age, with the kernel nearly exhausted and the fully independent young palm displaying seven or eight leaves, the seedling is ready to be transplanted into the field or garden.

The early leaves are 'entire', which means that each has a single large blade comprising leaflets that are joined at the edges. Later leaves display separated lower leaflets, while the upper ones remain joined. Before long, a leaf emerges on which all the leaflets are separated, and this form of leaf is referred to as a frond. The earliness of the appearance of the first true frond varies considerably between varieties, and is another means of identification of genetic subgroups within the Tall group of coconut varieties.

Growth of the independent seedling

Under ideal conditions of plentiful water supply, a mean temperature around 27°C and fertile soil, the transplanted coconut seedling will grow very rapidly, each new frond emerging six weeks after the previous one. The fronds become progressively longer and quicker to emerge during this phase, so that by the age of five years they are approaching the maximum length of around seven metres on Tall palms (three to five metres on Dwarfs) and are emerging every 25–30 days. A slower growth rate is brought about by prolonged dry weather, poor soil nutrient supply, insect damage or markedly cool seasonal weather, such as occurs in most inhabited coastal areas in northern Australia other than the extreme north of Cape York.

Flowering begins

The Tall palm begins to flower between four and 10 years of age, while some Dwarf types flower earlier. The flower, referred to as an inflorescence or flower bunch (because it has many branches bearing male flowers on the upper part of their length and female flowers lower down), is encased in a robust, spear-like sheath protruding up to one metre from the inner side of the base of its accompanying frond. The tough 'skin' or casing of the fully extended sheath splits and shrinks back somewhat, leaving the multibranched inflorescence openly displayed.

The newest inflorescence appears associated with the frond that has reached the 10th to 12th position down from the youngest emerging frond.

The tiny male flowers at the tips of the many inflorescence branches begin shedding their pollen immediately upon exposure, and those below them on each branch gradually follow suit over about three weeks. A few days after all pollen-shedding is complete, the female flowers become 'pollen-ready' and will

Figure 3-5. Newly emerged inflorescence featuring small 'knob-like' female flower-buds close to the near end of some branches, and numerous tiny male flowers attached along the length of each branch. (Asia Pacific Coconut Community)

usually be pollinated from another palm by either insect-borne or wind-borne pollen. A Tall palm growing in isolation is unlikely to set many fruit because of the usual poor 'click' or coincidence of its male and female flower activity. It has been noticed, however, that in midsummer in Australia (mean temperature around 27–30°C), and also quite commonly among domesticated palms in wet season conditions in the tropics, the rate of emergence of new flowers is more rapid. This generates an overlap, so that pollen from the following inflorescence sometimes reaches the pollen-ready female flowers of the previous inflorescence, allowing up to 60% self-pollinated fruit to set.

In contrast to the high rate of cross-pollination in Talls, most Dwarfs self-pollinate up to 90% of the time, because the male and female phases are active at the same time within each inflorescence. Such palms readily set fruit in isolation.

What gives the palm crown its great shape?

The crown of the palm is made up of 20–35 fronds, depending on how favourable the growing environment is. The fronds emerging in sequence from the central bud of the palm conform to a set geometrical pattern of angular separation around the circumference of the palm trunk. It is convenient to use the navigation term 'azimuth' to refer to this angle of separation of fronds, as if they were all attached to the centre of a horizontal circle surrounding the trunk.

If frond 1 in a series is given the azimuth angle of zero degrees, frond 2 will be located at plus or minus 140 degrees, frond 3 at 280 degrees, frond 4 past the starting angle at 60 degrees on the second circuit, frond 5 at 200 degrees and frond 6 at 340 degrees, 20 degrees short of

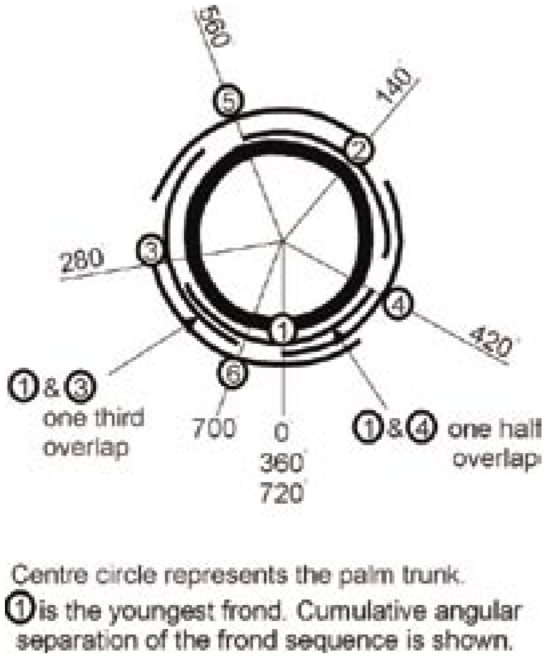

Figure 3-6. Diagram illustrating the location of successive semi-circular frond base attachments to the trunk of the coconut palm. The circled numbers show that the fifth frond either up or down from frond 1 is only 20 degrees of angle short of being on a line directly above or below frond 1. Cumulative degrees of angle anti-clockwise from frond 1 are shown on the lines radiating from the centre of the trunk.

completing the second full circle. The result of this spiral pattern is that the 6th frond is located 20 degrees short of being directly above frond 1. This pattern of angular relation between the fronds of the coconut is referred to as a '2/5 phyllotaxis' (phyllotaxis is a Latin word for 'leaf arrangement').

The location of frond 6, almost directly above frond 1 (or below, if the counting begins at the top rather than the bottom of the crown), allows for rapid counting of the number of fronds on the palm. Simply locate the oldest green frond on the palm; look just above it and either slightly to the right or left for frond 6, then above that again for frond 11, and so on. Observing total frond number a useful way to judge the relative vigour of palms.

That fronds 6, 11, 16 and so on are on either a left-hand or right-hand path above the starting point is because the fronds of half the palms in a group will spiral clockwise and those of the other half will spiral anticlockwise. One researcher claimed to have proof that clockwise and anticlockwise palms differed in yield potential, but others were sceptical.

It is unusual for a palm to have any fronds near to each other that are aligned at the same azimuth angle.

This natural separation reduces in some measure the shading of lower fronds by those above when the sun is overhead.

Crown shape responds to age

During the course of about 30 years following planting, the shape of the palm crown evolves from an early 'feather duster' shape, through an 'upright' hemispherical form in which the older fronds have a horizontal attitude, to one in which the fronds are 'loose' and displayed in a range of positions, depending on their age, between upright and drooping. The combination of young fronds pointing upwards and older ones in progressively more drooping positions gives an overall open character and spherical shape to the crown.

This evolution begins at the transition from a juvenile to a productive palm at the age of five to ten years (earlier in the Dwarf) and continues because of the increasing priority that the palm gives to fruit production during the early years, and the consequent decreasing importance of trunk growth. If the palm has an exceptionally high fruit load, or is stressed by drought, more fronds may be found hanging low; a period of low production allows more fronds to retain a more erect attitude.

The influence on the shape of the palm crown of the change in partitioning of resources as flowers and fruit develop has an interesting effect. In a young palm, where all the energy from photosynthesis flows into the development of new fronds

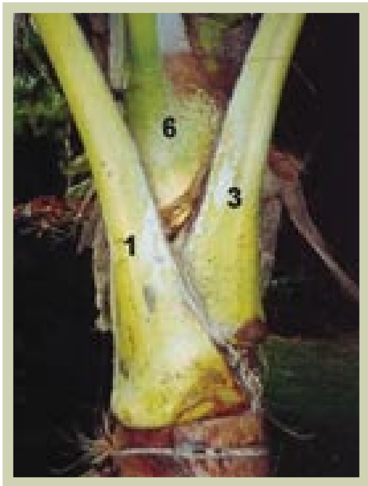

Figure 3-7. This young palm has well-separated frond bases, that are attached to the trunk at intervals more than 50 mm apart, providing ample space to 'cling' closely to the trunk. Frond numbering here is done 'upwards', placing frond 6 almost directly above frond 1, as shown in Figure 3-6.

and of trunk, there is sufficient energy to generate a long vertical gap, or 'internode', between fronds on the trunk (100 mm or so). Because each frond then has a substantial portion of trunk to itself, the lower stem (petiole) of the frond maintains a position closely hugging the trunk, free of any contact with fronds higher up. There is a gentle curving out or drooping of the top ends of these fronds, under the influence of gravity. The overall shape of the crown is that of an inverted cone, which achieves high and efficient light interception, and therefore rapid growth.

Fruiting begins: a competition for resources

Once fruiting begins, the energy need of fruit growth is met at the expense of the trunk, resulting over a few years in a significant shortening of the internodes. As the internode space decreases, the base of each frond is subjected to increasing outward pressure from the thick basal part of the two fronds immediately above it, tending to force it away from the trunk and weakening its attachment or 'grip' on the trunk. The base of each frond also experiences the increasing weight of its bunch of fruit, which also tends to pull it away from the trunk.

The result is that the attitude, or angle of display (in a vertical plane), of each frond evolves gradually from vertical upon first emergence through 45 degrees around 10 months of age, 100 degrees (horizontal) at 18 months and 135 degrees (pointing somewhat downwards) when the frond is two years of age or older. The combined effect of 20 or more fronds, each angled a little further from the vertical than its next, younger neighbour, is a spherical shape in the palm crown—a shape that is typical of Tall palms older than 20–30 years (and Dwarf palms older than 10 years), and which constitutes the classical 'loose, languid and relaxed' image of the coconut palm.

A palm crown with this spherical display of fronds intercepts less light than it did with a similar number of fronds in a more hemispherical or inverted conical shape. Downward hanging fronds receive little light, while only a few fronds are held in the horizontal position to intercept the maximum available. The productivity of the ageing palm gradually diminishes, because of the reduction in photosynthesis that goes with reduced light interception. There is often some compensation apparent, however: fruit yield can be sustained by allocating fewer resources to the growth of the trunk. In turn, this increases the crowding of the fronds on the trunk and the length of the fronds themselves also begins to diminish, contributing to a further decline in light interception.

Palms can live to 100 years and more, but at that age the crown is very small, the trunk has tapered to a 'pencil point', and nut production is close to nil.

Figure 3-8. Crowded frond bases of a mature palm, which has developed a spherical crown shape. The internode space on the trunk here is only 5 to 10 mm compared with 50 mm in Figure 3-7 above. (Simon Foale)

Why does the palm on the strand lean towards the water?

An attractive feature of Tall palms on the strand is their graceful angle over the beach towards the water. This occurs because the reflected light from the surface of the water is more intense than light coming from 'inland'. All plants respond to uneven light by growing towards the stronger source, achieved by generating a growth hormone that elongates the growth of the stem on the side of weaker illumination. Once the crown of the coconut palm reaches the tilt angle that distributes the incoming light more or less evenly, that angle is sustained, and the trunk extends in that direction, leaning towards the water.

Palms have a greater lean on a strand aligned north to south. In such a location, the water is on either the east side or the west side of the beach, and the reflected light is particularly intense for a few hours in the morning or the afternoon. On east–west coastlines, the reinforcement of incoming light is less intense because the direction the light comes from is side-on to palms on the beach. The angle of lean of these palms is quite small. Neighbouring palms on the inland side of those closest to the water grow vertically, being shielded from the ocean's intense reflected light.

Leaning palms that have grown tall, placing their centre of gravity well away from the trunk, may experience some shift in the attachment of their foundations (root mass) to the soil. The weight of the crown and upper trunk, amounting to more than half a tonne on a healthy fruit-laden palm, exercises great leverage on the base of the trunk. The combination of saturated soil and strong wind will often cause the palm to lean further—in extreme cases almost laying the palm trunk onto the beach (Figure 3-10). New growth of the trunk will be adjusted back to its original angle, and the result is a very attractive incremental upward curve of the trunk

Maintaining a grip on the earth

The young palm relies first on a small tuft of roots of equal thickness (around 10 mm), each attached to the fleshy base just below the growing bud. Gradually, a woody trunk foundation forms in the soil as an inverted cone, with the now proliferating tuft of roots attached to the point of the cone. There is little change in this geometry until the trunk base reaches its full diameter (in the range 600–900 mm) at about five years in a Tall palm.

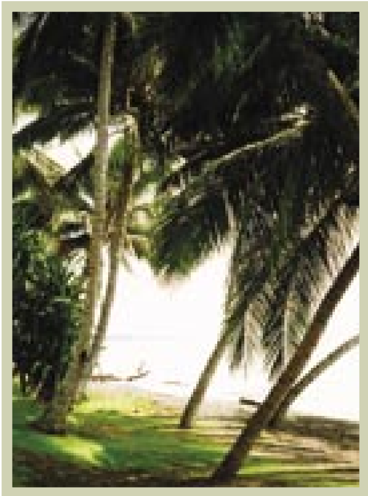

Figure 3-9. Palms close to the beach on the right have a pronounced lean towards the beach in response to reflected light, compared with 'shaded' palms on the left. This effect has been observed to be more pronounced on north–south beaches as the intensity of reflected light reaching the coconut fronds is much higher, especially during early to mid-morning and mid to late-afternoon periods, than on east–west beaches.

Figure 3-10. A coconut trunk on a northern beach in Trinidad lowered almost onto the sand as natural leaning and strong wind have forced the roots to give way. Such an attitude enhances the association of the coconut with relaxed holidays. The author is on the left – 1959.

Figure 3-11. Young palms in Solomon Islands blown down by moderate cyclonic wind in 1967 at a growth stage before their roots had achieved firm anchorage in the soil.

At the early, inverted cone stage, the palm is easily blown over by strong wind (Figure 3-11). Root 'initials' may then begin to emerge from beneath the perimeter of the trunk base, but these outer roots do not usually have a firm grip on the earth until the palm is around six years of age. By then, some dozens of primary roots, now up to 12 mm in diameter, radiate from the entire circumference of the root base.

Palm roots branch two or three times to form ever thinner secondary, tertiary and feeder root branches. Individual primary roots extend many metres and usually die back after three years. There are no root hairs, but reports from India indicate that certain symbiotic fungi form a working association with coconut roots, supplying mineral nutrients in return for energy.

In a Tall palm, the broad base of the trunk (known as the bole) undergoes, from about one metre above the ground, a tapering transition to the long-term diameter (300–400 mm; see Figure 2-1 in Chapter 2). The bole provides a robust foundation for the trunk. Until the peripheral roots develop and take hold, the young palm is very susceptible to wind damage, partly because the

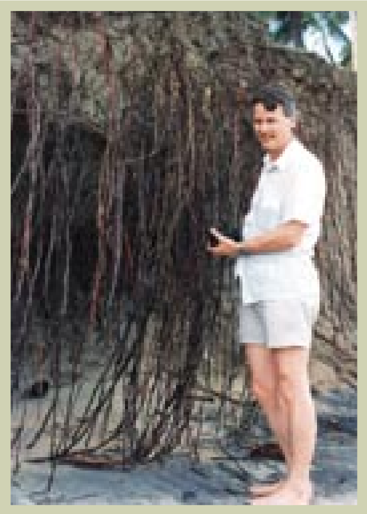

Figure 3-12. The exposed roots of a palm growing on the strand. The wave action of a stormy sea has eroded much of the sand berm, putting the palm in danger of collapse. The huge root mass of the coconut acts as a stabilising influence on many beaches.

trunk extends rapidly once the bole is formed. The trunk of a five to six year old palm is already capped by a full-sized crown, but is not yet long enough to flex properly, and the trunk-to-root interface experiences severe mechanical stress when there is high wind pressure on the crown.

Dwarfs are at greater risk than Talls

The Dwarf palm is more vulnerable to wind than the Tall, as it does not form a significant bole (Figure 2-1). The Dwarf is anchored by a root system attached to a much narrower trunk base, which suffers a severe mechanical disadvantage compared to the base of the Tall. When the wind applies pressure to the crown, the Dwarf palm experiences greater shearing strain between roots and trunk than does the broader-based Tall of similar height. The Dwarf escapes some leverage hazard, however, because at a given age it is much shorter than the Tall.

In a gale, the trunk of a youngish Dwarf palm with stout roots can snap just below the crown. The bole is firmly attached to the soil, but the trunk still lacks flexibility to bend to the wind, and older fronds do not shed as readily from palms in the 10 to 20-year age range as they do from older palms.

In natural coconut woodlands, which are still found on some atolls such as North Keeling (in the Cocos–Keeling Islands in the Indian Ocean), younger palms are to some extent protected from wind damage because they are scattered among taller palms. Risk of wind damage is greatest in plantations, where palms of the same age and height are well spaced over a large area with no natural windbreak except each other, exposing them to destructive winds at their most susceptible age.

Survivors can last (almost) forever

Once a palm has survived the early period of vulnerability to wind and reached an age of 15–20 years, it becomes highly resilient and might live to a much greater age, depending on the situation. Indigenous people are generally reluctant to destroy an old coconut palm that produces even a small fraction of its earlier yield, and old palms make little demand on the environment and cast only a diminished shadow on crops beneath them. Sometimes, very tall palms are blown over during storms because the attachment of old roots to rain-saturated or flooded soil is weak.

It is not uncommon to see very old palms eventually decapitated by wind, after which the trunk will decay, crumbling in sections, over three to five years if it is left untouched. The trunk can be harvested for milling, but this is best carried out in a planned way on younger palms, after setting up the transport system and special sawing tools that are needed for best results (see Chapter 8).

Lightning strike is another hazard for the palm, increasing as the palm grows ever taller. Immediately after a strike there is no apparent damage, but the effect of the electrical discharge seems to be to cut off 'life support' through damage to the nutrient transport system of the trunk. The fronds gradually go brown over a month or so and the crown collapses shortly afterwards. The 'headless' trunk will slowly decay over years, collapsing bit by bit in short sections. In a plantation, a single severe lightning strike can destroy as many as 40 palms.

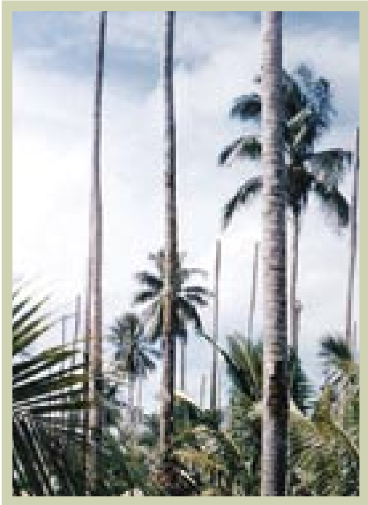

Figure 3-13. Headless trunks of palms that have been poisoned in preparation for replanting. These trunks are destined to collapse in sections from the top, as they decay over a period of two to four years.

chapter 4

Taking the plunge

looking after your own palms

Here are guidelines to determine if the coconut palm is the right choice for a plantation, a home garden, a resort or a public space, for finding a spot where it will do well and for choosing a variety.

This is only the beginning, as there are seedlings to manage, soil to learn about and, perhaps, irrigation to install.

How will the local climate, and any threatening pests and diseases, influence what is to be done?

Latitude and climate might restrict potential

Moderate-to-good fruit production can only be expected within 18 degrees of latitude north or south of the equator (see zones 1 and 2 of Figure 1-5 in Chapter 1), in locations where there is deep fertile soil and assured year-round rainfall (or planned watering where there is a significant annual dry season). In addition, in regions more distant than 14 degrees from the equator, the season of cool temperature must be short (no more than three months) and mild. Some of the most productive palms in the world are found on the well-watered coasts and immediate hinterland of South Pacific islands where there is no cool season, and the diurnal temperature range is generally 23–31°C, with practically no variation in mean temperature between months of the year.

At latitudes greater than 18 degrees and up to 30 degrees (zone 3 of Figure 1-5), the coconut palm may grow well enough to develop a handsome crown, but fruiting will be more erratic with increases in latitude. In locations where there is a period longer than four months during which with the mean temperature is below 21°C, any fruit that sets will usually fall before reaching maturity.

Study the soil and take expert advice

Once you are satisfied that the temperature regime is favourable, or at least reasonable for the desired use of the palm, choose or develop the planting site to do best for the plant.

The coconut (like any tree crop, really) performs best on a well-drained soil that has a two-metre depth of profile, a loamy texture and neutral pH (that is, neither acid nor alkaline), and is well supplied with mineral nutrients. The coconut requires the same nutrients as all other plants and a greater supply of chlorine than most, which is the reason so much folklore mentions the need for 'salt' as a fertiliser. The palm also tolerates a moderate amount of salinity in the groundwater, as long as the saline water table fluctuates regularly (as with a rise and fall responding to the ocean tide) or remains fairly deep. The coconut leaf can accumulate sodium without harm—especially when potassium, for which it has a high requirement, is scarce.

The natural environment in which the palm evolved is the upper strand, or beach ridges immediately above the level of major high tides. While the root system will tolerate brief inundation with salt water, the palm will not prosper if there is no regular seaward flow of fresh groundwater, diluting or even flushing out salinity from the root zone.

At sites away from the beach, free drainage is especially important. A soil profile with impeded water movement due to sodicity (excess exchangeable sodium, which suppresses clay aggregation so that the clay particles form an impervious layer) or due to a high content of non-cracking types of clay, or of crusted laterite (ancient red clay high in iron oxide), is unsuitable for coconut.

Ideal soil types, apart from coralline, volcanic or silica sands accumulated on the strand, are recent alluvium (which is generally loamy), and in situ weathered volcanics, which comprise well-structured red or black clay soils. Coconut also does well on cracking clay over porous uplifted coral benches—not uncommon in Melanesia (Papua New Guinea, Solomon Islands, Vanuatu and Fiji) but rare in Australia.

Annual rainfall of 2000 mm, which is sufficient to match evaporative demand in most coastal environments, would be ideal if it were evenly distributed throughout the year. The palm will not achieve its potential in far northern Australia, or in much of southern India, without some irrigation during extended dry-season periods of severe water deficit.

The coconut is 'building friendly'

Neighbouring plants, and building structures such as pipes and pavements, are not adversely affected by the roots of coconut palms, which are, in botanical parlance, 'adventitious'. Each primary root can grow for about three years, reaching several metres in length but with a small diameter of 8–12 mm. The root dies back soon after reaching its full extension, making way for a new root to replace it. These short-lived, non-expanding roots extend when the soil is moist and easily penetrated. They do not expand during their short life and therefore pose no risk to concrete slabs, pavings or other soil-covering structures, which ordinary trees with expanding lateral roots often seriously undermine.

When very strong wind follows soaking rain, however, the attachment of the entire root mass to the soil may be weakened, allowing the trunk to be forced sideways. In extreme cases, the trunk will end on its side, exposing broken roots encased in a ball of earth. Many roots on the side of the ball that rests on the soil will remain unbroken, and the palm often survives such trauma.

Choosing the best variety for your purpose

The final task, in preparing to develop a coconut garden or landscape feature, is to decide what type of palm to use. Your decision will depend on the choices available, which are in the first instance between Dwarf and Tall, and then between types within the chosen group.

The Dwarf has the advantage of a slow rate of height increase and smaller fruit than the Tall, lessening the hazard posed in public space by falling nuts. The Dwarf also tends to form an attractive, open, spherical crown at an earlier age than the Tall, and the crown is always smaller. On the other hand, the Dwarf is less robust in strong wind, and remains accessible to browsing herbivores for much longer after field planting. The fruit is more readily harvested but, being smaller, contains less water. The kernel is usually thinner and softer at maturity and has less flavour, because it has a lower oil content than kernel from a Tall nut.

When planting mainly for ornamentation, consider both the slender and compact Dwarf varieties. The slender Dwarfs provide a choice of attractive orange, yellow and green

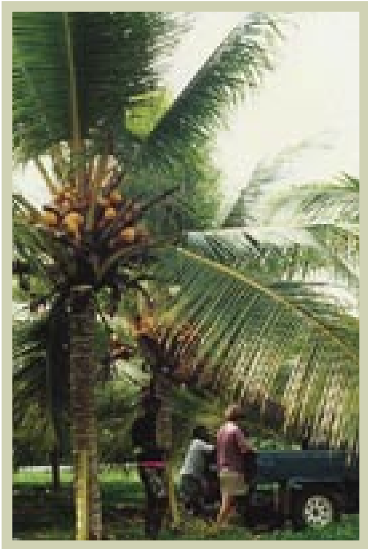

Figure 4-1. A productive orange Dwarf palm in Vanuatu, showing the slightly pale colour of the foliage. The orange character partly masks the natural green of chlorophyll in the leaflets.

fruit colours, as well as a less striking brown (see Figure 2-2), and pose a smaller risk to visitors if the fruit falls from the palm. An indication of the future fruit colour of a seedling coconut can be seen in the colour of the rounded undersurface of the petiole, and also in paleness (resembling chlorosis) of the leaflets. The normal foliage colour of healthy yellow and orange-fruiting Dwarfs is a somewhat pale green, compared with the dark green or brownish foliage of palms whose fruit will be those colours.

Managing the nursery and planting out

Having chosen a suitable location and variety for planting, it is best to raise seedlings in polybags and to plant them out at 8–12 months of age (or a few months older in places with a cool season). By then, growing in a large (20 L) pot or polybag in full sunlight (see Figure 3-4), seedlings are well developed and can easily be examined for normal healthy appearance. During the nursery phase, seedlings need regular watering and they usually benefit from a nutrient supplement of 50 g NPK fertiliser (or its equivalent in compost) at three, six and nine months of age. Where many seedlings are being raised together, keep a careful watch for insect pests and leaf pathogens, which can spread quickly in the nursery environment.

When planting on a commercial scale, seeking maximum productivity, discard seedlings that lag behind in the nursery. Up to one third might be rejected, and some managers recommend even tougher selection. The causes of poor growth include genetic faults, damage to the shoot while it pushes through the husk at germination, and loss of the connection between the seedling and the reserves of kernel within the nut. Leaf damage caused by insects or leaf spot fungus might also cause rejection.

In the field, make the planting hole large enough to allow the complete volume of soil from the container to be inserted, with extra space for topsoil to be packed in all around. It is wise to put a handful (300 g) of NPK fertiliser in the bottom of the hole, and to cover the surface around the seedling with a thick layer of mulch. Treat the coconut like any other fruit tree, but ensure that added fertiliser is rich in potassium and chlorine, two nutrients that are especially in demand by the palm.

If you are planting on a plantation scale (which means a uniform planting of more than a dozen palms) with coconuts destined to become the dominant members of the plant community, it is best to plant on a triangular or diamond pattern at about 8-metre centres for Talls and 6.5-metre centres for Dwarfs. In ornamental situations, the coconut is found planted in tight 'hedgerows', clusters and avenues. There is no particular constraint on density in such situations, but Talls spaced less than 5 m apart will have considerable interlocking of fronds. In a tightly spaced cluster, competition for light causes more rapid elongation of the trunk, and the crowns develop an upswept habit that might be less pleasing than the normal open (relaxed) crowns of widely spaced palms.

Protecting the young palm

Worldwide, a huge range of potential pests can seriously damage the young coconut palm, both in the nursery and in the field. Some of the most damaging of these are discussed in Chapter 5. If you are unfamiliar with possible pests, get local knowledge from

Figure 4-2. Crowded palms, showing how the fronds retain an upwards attitude due to competition for light stimulating growth of long internodes on the trunk.

an experienced grower or a plant protection professional in your neighbourhood. You might protect a small number of seedlings with vigilant inspection, but in some instances you may need chemical protection, especially against scale and leaf-miner pests. In most countries of the coconut heartland, the rhinoceros beetle is the most common forager likely to inflict serious damage on young palms.

The younger leaves of a coconut palm are also very palatable to livestock. It may be necessary, where animals have access, to construct a cage around young palms until they have grown tall enough to escape the attention of cattle, goats, horses and other herbivores. The wild pig, several rat species, other small mammals around the world, swamp hens and some other large birds have all been known to develop a taste for palm heart during the first year or two of the coconut's growth in the field. If there is a risk, use a close-fitting cylindrical shield of wire mesh but remove it before it restricts development.

Where there is an extended dry season with high temperatures and low humidity, the young field palm might need some shielding or shading. In India, the leaflets of a mature coconut frond are woven into a tubular 'umbrella' that is fitted over the palm.

How soon will the palms flower?

Where the temperature and soil conditions are ideal, most Tall palms will flower within four to six years from field planting as polybag seedlings, and Dwarfs within two to four years. There might first be one or two inflorescences devoid of female flowers, but then prolific fruit setting will begin. Within a year or two, there could be a hundred fruit growing on the palm, distributed on 13–17 bunches. As the owner or manager, you must now deal with the special needs of the producing palm and organise an appropriate return from its production. Where the uncontrolled fall of fruit might

Figure 4-3. Woven coconut leaflets installed some months earlier, as shade protection against excessive heat, on a newly-planted young palm which has now outgrown this protection (in India).

become a hazard to people or property, special protective measures are needed (see Chapter 6).

Where conditions are less than ideal, first flowering will take longer and production will be less prolific. However, the coconut is a hardy plant that can produce usefully on mediocre soil, or in a climate with a cool season (mean temperature below 22°C) up to three months long, or with both these constraints combined.

Australian environments and the coconut

A huge range: 19 degrees of latitude

Within Australia, which provides an interesting case-study for temperature response, the coconut is widely scattered along the coast. Only the climate of the Torres Strait Islands, north of Cape York, approaches the ideal temperature regime. However, the temperature on the coast from Townsville (latitude 19 degrees south) northwards and westwards around the Gulf of Carpentaria and across northern Australia, right around to Broome (18 degrees south), comprising 30 000 kilometres of coastline, is quite favourable to the palm. Other, less favourable, environmental factors along much of this coastline include extensive saline wetlands and mudflats, the normally long dry season, an average yearly rainfall well below 2000 mm and, in some parts, a mean daily maximum temperature exceeding 36°C for six months of the year.

Low temperature is only a minor issue on the north coast, as there are only two or three months of the year when the mean temperature falls close to the 21°C mark, which is regarded as the lower limit for active growth and fruit setting. The maps in Figure 1-12 (Chapter 1) show the average isotherms on the Australian landmass for the four seasons, identifying both lower and upper limits for the coconut to do well.

South of the latitude of Townsville (19 degrees south), however, growth and productivity fall progressively, because the weather becomes cooler for longer as latitude increases. Whereas Townsville has a 'coconut winter' of two months, at Byron Bay (29 degrees) the coconut winter lasts for seven months. Even at this limit of southward extension, however, the palm can develop robust fronds and present its typical attractive appearance. The coconut can be found in many other parts of the world at a similar latitude, beautifying beachfronts, city streets and home gardens. The lack of fruit is actually desirable, in terms of safety, in public spaces.

While coconut palms are found in many scattered locations around the north coast of Australia, there are also some palms growing well at locations hundreds of kilometres

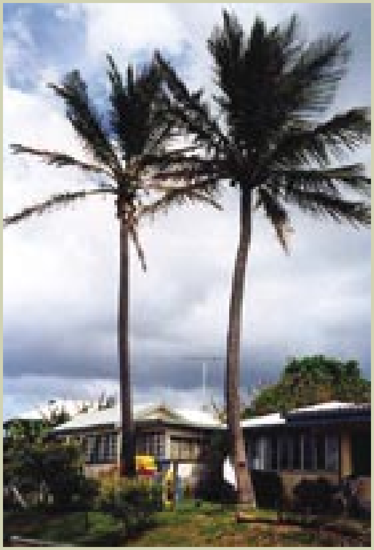

Figure 4-4. Fruitless and therefore 'safe' palms in suburban Brisbane, Australia. The cool season is too long for fruit retention. See the temperature graph in Figure 1-14.

inland, such as at Katherine in the Northern Territory (latitude 14 degrees south) and Moura in Queensland (24 degrees). The young palm will survive in a frost-free location, or where mild frost occurs infrequently, provided that it has frost protection until it is a few metres high and its growing fronds are above the lethal freezing air layer.

Challenges specific to Australia

In north-eastern Australia, the greatest challenge in raising a young palm to fruit-bearing age, apart from measures to avoid severe water stress, is in protecting it against pests.

The palm dart caterpillar (larva of a moth of the genus Cephrenes), which feeds on some native Australian palms, is strongly attracted to the foliage of coconuts of any age. The caterpillar stitches together the two edges of a leaflet to provide a tubular safe haven during the day, and it feeds voraciously at night. Undetected, this pest multiplies rapidly and can completely defoliate a young palm in a few weeks. Protection is simple, as the pest will succumb to all the common garden insecticide sprays. Spraying the underside of the leaflet works well, because that side is less likely to be washed free of the chemical in rain and because it forms the inside surface of the caterpillar's shelter.

Around 1972, the Melanesian coconut leaf beetle (Brontispa longissima), a small black beetle with an orange head, arrived in Darwin and northern Cape York. The newly hatched larva of Brontispa enters between the tightly packed leaflets of the emerging frond and consumes the soft white layers of tissue before they begin to unfold, after which the leaflets become green and unpalatable to the pest. This leaf-mining leaves behind patches of brown, 'dead' tissue, and seriously sets back the growth of the young palm, especially in the first year of two of its life.

Figure 4-5. Leaflets of a young palm severely damaged by the Palm Dart caterpillar (in Brisbane). This pest attacks the leaflets of many palm species on the east coast of Australia, and remains active even during the cool season.

This pest can be killed easily by applying any water-based insecticide to the emerging 'spear', but be careful to follow the manufacturer's directions and wear any recommended protective clothing. Do not spray with a household pressure pack, as the carrier liquid damages living tissue. Application of chemicals becomes difficult on taller palms, once the emerging frond is located more than three metres above the ground.

Palm varieties from Papua New Guinea and Solomon Islands are fairly tolerant of Brontispa, showing only minor damage and therefore needing protection only for the first year or two. Coconut varieties originating in South-East Asia suffer greater damage from the beetle, and should be replaced with plants of Melanesian ancestry. Fortunately, Brontispa is uncommon or absent in major Australian coastal towns other than Broome, Darwin, Cooktown and Cairns, but coconut managers should remain on the alert for outbreaks.

Grasshoppers (locusts) also attack young coconut leaves, but the large dynastid beetles (such as Oryctes rhinoceros) that destroy or severely damage the foliage of palms in many other countries are not found anywhere in Australia.

If other pests appear to be harming your palms, seek local specialist advice.

chapter 5

Caring for the palm from planting out till flowering and beyond

As the palm grows, herbivores from scale insects to buffalo forage on fronds within reach, while trunk-tunnelling beetles remain active and many new insects are attracted to the inflorescence. Some pests and diseases are globally significant; others, including two leaf-eaters, are pests in Australia. Viroid, virus and mycoplasma diseases pose a major threat in some regions of the world.

The coconut has an almost unique nutritional need for ample soil chlorine, reflecting its evolutionary niche on the strand. Palms tolerate some water deficit, a small degree of soil salinity, and seasonal use of saline irrigation water. Nutrient needs can be identified through visual symptoms and chemical analysis of leaves.

Palatable palms attract hungry creatures

Fronds hanging within one or two metres of the ground are at risk from destructive browsing by herbivorous mammals (cow, buffalo, horse, sheep, goat, and pig). A large herbivore can drag a whole frond within reach once it can grasp the drooping end with its mouth. Protection for the palm until the fronds are out of reach will defeat browsers.

The manager must change the focus of protection, however, when emerging inflorescences (see Figure 3-5) begin to supply a whole new range of food supplies, especially for insects. At regular intervals of 25–30 days, each new inflorescence presents a fresh supply of many grams of pollen, tender female flower buds, and a copious amount of nectar. Each of these episodes attracts many new insects, both friendly (such as honeybees) and unfriendly (such as sap-sucking bugs, and web-makers that smother the male flowers).

Adult palms are liable to attack by rhinoceros beetles (*Oryctes* spp.) in many parts of the world; areas free of this pest are fortunate indeed. The rhinoceros beetle, which may be 40–50 mm long, uses very strong jaws to chew its way into the central cluster of developing fronds. When the fronds emerge fully, they display sets of pruned leaflets that form triangular gaps on either side of the frond axis. If the foraging beetle happens to chew its way right into the growing point, the palm dies, as the coconut has (with rare exceptions) just the one vegetative bud.

The rhinoceros beetle breeds only on decaying coconut logs, and therefore precautions against it are crucial when old palms are dying and being replaced by new plantings. A related beetle in western Melanesia, *Scapanes australis*, breeds more flexibly, and can use fallen forest logs. Both types can be checked by clearing away any breeding sites near the coconut palms. When these pests have become active in a plantation, both chemical compounds (insecticidal powders) and biological agents (viral and fungal pathogens) can be used against them, but cleaning around the plantation and hand-picking of the adult beetles are still the recommended ways to control them.

Specialised reading and local consulting services can usually provide appropriate additional information.

Among the few other potentially fatal pests of the coconut is the black palm weevil (*Rhyncophorus bilineatus*). Gaining entry to the upper trunk through the feeding paths of rhinoceros beetles or any deep trunk wound caused by mechanical damage, the weevil establishes itself inside the palm and goes on breeding there until the palm dies. This deadly combination of a 'break-and-enter' pest with one that multiplies profusely within the palm is, luckily, not globally common.

An 'eel worm', the red ring nematode, fatally attacks coconuts in some Caribbean countries. The nematode proliferates within the trunk until the population of microscopic worms clogs up the vascular tissue to the extent that a reddish-brown ring appears in a cross-section of the trunk. This invasion eventually retards the essential movement of water and nutrients sufficiently to cause death.

A few species of locust and stick insect are capable of severely defoliating the palm. Fortunately, such attacks tend to be sporadic, and often the leaflets of older fronds are preferred, so that sufficient leaf area is spared for the palm to survive. In

Papua New Guinea and Indonesia, particularly during the dry season, a grasshopper (*Sexava* sp.) has sometimes completely defoliated palms, which have then taken years to recover.

Leaf-eating caterpillars, scale insects and other creatures (termites in a seasonally dry climate, and root caterpillars on peat soils) can sometimes pose a severe or even fatal threat.

Many forest-dwelling plant species, including other palms, have been found by chemists to manufacture their own protective phytochemicals to ward off attack—the end result of intense natural selection. As the natural home of the coconut palm is the strand, relatively free from sustained attack by the kinds of insects found in diverse forest habitats, the coconut has not evolved a strong survival kit. Some coconut varieties show greater tolerance than others to particular pests, which no doubt indicates that their ancestral wild habitats were closer to insect-rich floral communities. Local knowledge, held by indigenous people and some professionals, can be of great value in taking advantage of this important but invisible protective capability.

Nut-fall bugs undermine yield

Several types of sucking bugs (Hemiptera) feed on the coconut inflorescence. Some eat the nectar, while others simply suck sap from the branches or even the button-like female flowers. This deprives the flowers and young fruit of their full share of energy from the palm and reduces the setting of fruit.

Some sucking pests focus on the successfully set young fruits for the first few months of growth, removing so much sap that the fruits drop off. Such a pest, known as the nut-fall bug, is found on some South Pacific islands and in East Africa.

If the palm is home to certain active 'sugar' ants (*Oecophylla* spp.), the nut-fall bug is kept away from the young fruit. On the other hand, some other ants (*Pheidole* and *Iridomyrmex* spp.) block the access of the sugar ant to palms, giving the nut-fall bug more freedom to do serious damage.

The greatest threat: lethal yellowing disease

Whereas there are usually some visible signs of insects and their damage, the coconut is also prone to several fatal diseases, the symptoms of which remain invisible for a long time after infection, until no countermeasures are possible.

The most worrying disease of coconut, worldwide, is known generically as lethal yellowing disease and, in Africa, by many local names that distinguish some of its variants. Although lethal yellowing does not usually appear in palms before their first flowering, it is listed in this chapter for convenience.

Symptoms include premature fruit drop from all bunches, followed by blackening of the newly emerged inflorescence. There is distinct yellowing and then death of the older fronds first, progressing through the younger ones until there is a complete collapse of the crown. The period between first symptoms and death is 6–12 months.

Lethal yellowing was first recognised as a disease in Jamaica around the mid-20th century and was eventually found to be caused by an pathogen characterised as a mycoplasma. More complex than a virus but lacking the cell development of a bacterium, this type of organism fits somewhere between the two in terms of size and biological complexity. Transmission is most likely due to leaf-hoppers, coincidentally related to those that transmit foliar decay (see below), but there may be other vectors.

The spread of the disease within the past 50 years has been alarming. It has appeared for the first time in many countries of Central America and the Caribbean, and even among ornamental coconut palms in southern Florida and date palms in Texas. The crisis continues in Jamaica, despite extensive planting of Dwarfs (found to be at least partially tolerant) and of hybrids between Dwarfs and some promising Talls, notably Panama Tall.

Figure 5-1. An affected palm at an early stage of lethal yellowing disease, on the left, and a healthy palm on the right, in Miami, Florida. (Simon Foale)

A disease similar to lethal yellowing has been known for many decades in various coconut populations on the coast of West Africa, in Tanzania (East Africa), in parts of southern India (where there is usually a slower decline of the affected palm than elsewhere), and more recently in some islands off the coast of Kalimantan, Indonesia.

There seems to be an important connection between the expression of lethal yellowing disease symptoms and the stresses of extreme weather: symptoms often appear during drought, but also after severe flooding events (for example, flooding associated with intense hurricanes).

Uncertainty exists about the strength of some coconut varieties' observed tolerance to lethal yellowing disease, and about the ability of the pathogen to spread to previously disease-free areas. A concerted, long-term research effort is needed, especially in Jamaica, Mexico, Florida and West Africa. Molecular investigation of the variant forms of the mycoplasma in different parts of the world is under way, along with research into the tolerance found in some coconut varieties. Improving the 'security of production' of the coconut might ultimately depend on this work.

Other viroid and virus diseases

The second most serious disease of coconuts (after lethal yellowing) occurs in parts of the Philippines and on Guam, where it is known as cadang cadang ('dying-dying' in a local Philippines language) and tinangaja, respectively.

This fatal disease is caused by a viroid. Viroids are the smallest known pathogens of plants and are, essentially, infective single molecules. Despite their size, they are somehow able to disrupt the normal functions of the plant cell.

It is not yet known how the viroid spreads from palm to palm, and there is no hint that coconut varieties might vary in their susceptibility to it. In the Philippines, coconut growers in the affected areas 'live with' the disease, replacing dying palms and hoping that the new ones survive long enough to make the effort of planting them worthwhile.

The only known coconut disease attributable to a true virus is known as foliar decay. Confined to some islands of Vanuatu, the disease causes loss of vigour and leads to death within a few months of the first symptoms. Fortunately, it is only transmitted in the saliva of a particular tiny leaf-feeding insect (Myndus taffini) found only in the local region, where it breeds on the roots of a wild hibiscus plant. The threat of spread to neighbouring countries therefore appears to be small.

Fungus diseases of the coconut

Bud rot, a fatal disease of coconut, is caused by the fungus Phytophthora palmivora, which has developed many strains in separate populations around the world. The disease is most destructive when a coconut variety from a region in which bud rot is rare is established in the 'territory' of another strain of the disease. When coconut hybrids that had a West African parent were established in South-East Asia, bud rot sometimes devastated them.

Several other fungal pathogens attack the leaves of coconut, especially in very moist climatic zones. They are usually more of a problem during the nursery phase, when many palms are crowded together and the disease can spread rapidly. Fungicide treatments can give some protection during a disease outbreak.

Weed competition

Other plants can threaten the productivity of the coconut. In plantation settings, the palm competes for water and nutrients with the plants of the 'understorey' (the grasses, small herbs and shrubs constantly regenerating between the palms). In village and smallholder plantings, there is often an 'overstorey' of tall tree species competing with the palm for an aerial resource—interceptible sunlight.

The plantation floor under highly productive young palms is best kept clear of dense understorey vegetation, which might otherwise consume scarce water and nutrient supplies. At the same time, it is not a good idea to have bare soil beneath the palms; this risks serious water erosion, at least on steep terrain.

Where nuts are collected from the ground for processing, vegetation may be kept short either by hand or machine slashing or chemical weeding, or by grazing animals, especially cattle. Beneath old plantations (where the coconut canopy is above five metres) it is common practice to grow shorter-statured perennial crops, such as cacao and fruit trees, and annual vegetables and food staples like maize, cassava and sweet potato, which are often planted much earlier. Productivity of these

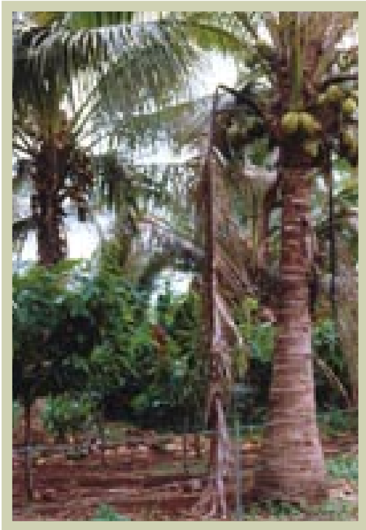

Figure 5-2. Cocoa growing beneath a coconut stand in Ivory Coast. This shade-loving tree takes advantage of the light transmitted through the coconut canopy. (Roland Bourdeix, Centre for International Cooperation in Agricultural Research for Development (CIRAD), France)

‘intercrops’ will depend very much on the density and vigour of the coconut palms, which determine the amount of light transmitted through the upper canopy.

Competition for light from neighbouring palms and other trees in the upper canopy affects coconut production in proportion to its intensity. A heavily shaded coconut palm will not flower until it achieves more-or-less complete exposure of its crown to direct sunlight for much of the day. Whilst shaded, it will direct its resources into rapid growth of its trunk and lean away from the most shaded sector. This is nature’s way of hastening the emergence of the crown into a more sunlit space.

Low humidity endangers fruit

Atmospheric humidity in coconut homelands is always high, varying from close to saturation overnight down to around 50% on warm, clear days. The palm, and particularly its developing fruit, are stressed by low relative humidity, which is not uncommon during the dry season in many subcoastal habitats, reaching an extreme in north-east Africa and north-west Australia (see Figure 1-12).

When the maximum temperature exceeds 36°C, and daytime relative humidity falls below 20% for an extended period, the fruit suffers premature desiccation as a result of severe water deficit within the palm and direct evaporation from the fruit. It appears that development of the fruit is terminated early, resulting in loss of potential production. Irrigation cannot fully overcome this problem, as the evaporative demand at the surface of the developing fruits exceeds the capacity of the palm to deliver water to meet the evaporation needs of both fruit and fronds.

Fruit maturing in the season of higher humidity (during the wet season) will develop normally, provided it has not been damaged by the stress that often precedes the arrival of the wet season.

Physical hazards during the palm’s life

The coconut has a very long potential lifespan, exceeding 80 productive years—although at 50 years its productivity is usually less than half of its peak performance between 15 and 30 years of age, and a steady decline continues after that.

Over such a long lifespan, it will face potentially fatal natural hazards, such as strong winds (in some latitudes, cyclones, typhoons or hurricanes occur yearly), floods, prolonged droughts, lightning strikes, volcanic eruptions, earthquakes, landslides and tsunamis. A cyclone or a volcanic eruption can destroy many palms in one event, while a powerful lightning strike can ‘take out’ 20 or more palms in a plantation setting. Palms that can withstanding a severe cyclone cannot survive the onslaught of a tsunami as high as the crown: the tsunami that struck the northern Papua New Guinea coast at Sissano, west of Wewak, in the late 1990s destroyed palms under 15 metres tall.

There is really no management procedure capable of providing protection against such awesome hazards, except avoidance of locations most exposed to volcanic eruptions, cyclones or tsunamis (lightning, notoriously, may strike virtually anywhere). The age range at which coconut palms are most susceptible to cyclone damage is from five to 20 years: between these ages, the trunk will not be long enough to shed wind by flexing efficiently, and the root system (at least in the early years) will not be sufficiently developed to anchor the entire base of the palm to the soil.

Eventually, coconut palms must be replaced. Yields will decline, deaths will open gaps in the plantation, or the extreme height of urban palms might endanger people or structures.

The earlier-producing, higher-yielding Dwarf–Tall hybrids planted in some modern plantations begin to decline in yield after 25–30 years; managers may have to begin replacing these hybrids much earlier than Talls in order to maintain profitability.

Soil: pH, nutrients and salinity

The coconut palm requires an adequate supply of the usual set of essential plant mineral nutrients in order to grow rapidly and be productive. It is a particularly heavy user of potassium, which is needed for the development of the fibrous husk and is also concentrated in the nut water.

Soil pH (the measure of acidity or alkalinity) affects the uptake of some nutrients, in so far as the elements boron, manganese, iron, zinc and copper (all required only in very small amounts) are more readily taken up from an acid soil than from an alkaline soil. Knowing the soil pH becomes more important if the level in the soil of a trace element, such as any of the five just mentioned, is very low.

The coconut is particularly interesting among crop plants because of its unusually high requirement for chlorine. Even though the palm evolved in an environment where chlorine was readily available from salt (sodium chloride, $NaCl$) in sea-spray and in seawater washing over some of its roots at high tide, it has only limited tolerance for salinity in the groundwater. The permanent presence of more than 2000 parts per million of salt (about one sixteenth the concentration in sea water) severely checks coconut growth, but the palm can withstand brief periods of exposure to much higher salinity. For example, irrigation with saline water close to half the strength of seawater is reported to have relieved water stress during extreme dry conditions in West Africa. However, this occurred on a coarse-textured soil from which salt would usually be leached during the wet season, preventing harmful accumulation.

The traditional belief in many coconut cultures, that salt is important for the good health of the palm, appears to be confirmed. Apart from supplying the chlorine that the palm needs, salt can also be used as a short-term substitute for potassium fertiliser, with the

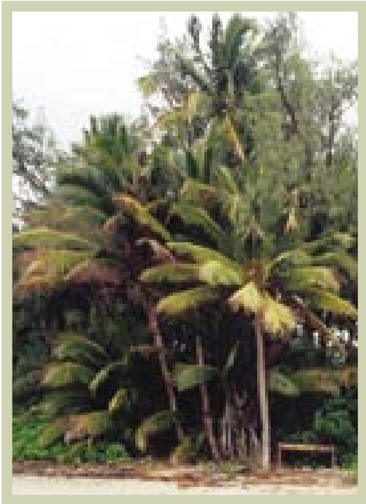

Figure 5-3. Signs of salt spray damage on palm leaves close to the beach, on the east coast of Cape York Peninsula, Australia. The fronds on the left side of each palm show greater damage than those on the right due to greater exposure of the under side of their leaftlets, whipped up by the salt-laden wind. The upper surface of coconut leaflets is protected by a waxy layer.

sodium temporarily preventing the development of symptoms of potassium deficiency.

Sea-spray on the palm leaf

Coconut leaves can also be damaged by sea spray, which is shed successfully from the waxy upper surface of the leaflets but causes desiccation of the unprotected cells of the lower surface. When the palm is located very near the beach, which is the natural home of the wild coconut, strong wind showers it with fine sea-spray. As the fronds whip about, the spray can cover the undersurface of the leaflets, resulting in a greyish, 'burnt' appearance.

Fertiliser needs in Australia

In Australia, almost all non-volcanic soils are deficient in phosphorus, which should be a component of any fertiliser mix used on coconut palms. Mixtures commonly comprise half their weight of the 'active ingredients' intended to be applied. The balance is either elements such as oxygen that are not nutrients, or nutrients such as calcium that are not commonly deficient. A balanced mix will contain N (nitrogen), P (phosphorus) and K (potassium) in the proportions 8N:1P:16K. Give each palm 200 g in year 1, increasing by 200 g each year to 600 g in year 3 and thereafter, which is equivalent to approximately 1.2 kg of fertiliser mixture. Supply chlorine in the form of muriate of potash (potassium chloride), in which almost 50% by weight is chlorine. Apply sulfur (which is present as calcium sulfate in superphosphate, or in ammonium sulfate) in the amount of 70 g/palm/year while symptoms of deficiency last, to achieve best growth and production.

From year 6 onwards, the dose of nitrogen can be reduced and possibly dropped. Monitor phosphorus needs using leaf analysis. Maintain potassium through split applications (early and midway in the wet season), and perhaps increase it to between 500 g and 1 kg per palm if rainfall conditions are very favourable and productivity exceeds 2 tonnes per hectare of oil equivalent. Two tonnes oil equivalent equals 3 tonnes of dried kernel, or about 15,000 nuts/ha.

Depending on soil type, high productivity often requires the application of magnesium and/or calcium (also supplied in superphosphate), and occasionally one or more of the trace elements boron, molybdenum, copper, zinc, iron and manganese. Aim to avoid the development of deficiency symptoms in coconut palms, because correction, using fertiliser, takes up to two years to restore full productivity.

Trace element problems often arise when there is an extreme of soil alkalinity or acidity. If you suspect a nutrient deficiency, foliar (leaf) analysis can be a useful tool to quickly confirm a visual diagnosis. Whereas soil analysis can provide a general knowledge of soil pH, organic matter, phosphorus, sulfur, chlorine and cation reserves, visual symptoms and foliar analysis monitor how successfully the plant extracts and uses the essential nutrients.

Visual foliage guide: symptoms and nutrients

The foliage indicates some of the more common nutrient deficiencies through colour variations from the normal dark green, and through some changes in frond appearance, as summarised in Table 5.1.

Table 5.1. Visual symptoms of some common nutrient deficiencies in the coconut

Deficiency	Symptoms: leaflet colour variation or abnormal shape of frond/leaflet
N—nitrogen	Pale overall, especially the newly emerged fronds (Fig 5-4).
P—phosphorus	Poor growth. Yellowish lower fronds.
K—potassium	Older fronds orange/yellow as K withdrawn into younger growth; frequently a coloured band of aligned brown spots on each side of the midrib of the leaflet (Fig 5-5).
Mg—magnesium	Paleness (yellow) of whichever half of leaflet more exposed to sunlight.
S—sulfur	All fronds bright yellowish/orange (Fig 5-6).
Cl—chlorine	Older fronds 'collapse' early during water deficit (drought).
B—boron	Severe case ('little leaf') shows distorted, shortened frond emerging; mild case ('hook leaf') shows 'folding' of leaflet edge.
Fe—iron	Found in alkaline soils (coral gravel); intense yellow leaf of older fronds, while frond rachis (midrib) remains green (Fig 5-7).
Mn—manganese	Often in tandem with Fe; difficult to tell apart.
Cu—Copper	On peat soil; tip and edges of leaflet 'burnt' adjacent to a yellow zone grading gradually back to pale green near midrib.
Water deficit	General wilted look; older fronds collapse around the trunk; extremes of leaflets have 'burnt' look; petiole weakened.

Source: Foale, M.A 2003. The coconut palm. In: Chopra, V.L. (ed.), Handbook on industrial crops. New York, Haworth Press.

Where there is an abnormal appearance, the cause of which cannot be clearly diagnosed using Table 5.1, consider analysing the leaf tissue. Table 5.2 can be used as a guide to the non-deficient concentration (or critical level) of mineral elements in the coconut leaf. When the value for a nutrient is lower than that shown here, investigate further. The frond position in the table refers to a mature palm; in young palms, the 6th-youngest leaf may be sampled.

5-4

5-5

5-6

5-7

Figures 5-4 to 5-7. Symptoms of mineral nutrient deficiency: nitrogen (5-4), potassium (5-5), sulfur (5-6) and iron (5-7). (Phil Southern (sulfur), and Centre for International Cooperation in Agricultural Research for Development (CIRAD), France)

Table 5.2. Critical levels for mineral elements in the coconut leaf

Concentration of 'major' elements in leaflets of 14th-youngest frond of mature palms in production (% of dry matter)	
N—nitrogen	1.80 to 2.00 (2.2 in Tall × Dwarf hybrid)
P—phosphorus	0.12
K—potassium	0.80 to 1.00 (1.4 in Tall × Dwarf hybrid)
Mg—magnesium	0.20 to 0.30 (strong inverse sensitivity to extremes of K)
Ca—calcium	0.30 to 0.50 (some inverse sensitivity to extremes of K)
Na—sodium	Not essential (temporarily useful when K is deficient)
Cl—chlorine	0.50 to 0.60
S—sulfur	0.15 to 0.20
Concentration of trace elements in leaflets of the 14th-youngest frond (parts per million)	
B—boron	10
Mn—manganese	>30 (difficult to fix a value; very interactive with Fe in strongly alkaline soil; potentially toxic in extremely acid soil)
Fe—iron	> 50 (deficient in strongly alkaline soils and in peat)
Cu—copper	3 to 7 (deficiency found on peat soil)
Mo—molybdenum	0.15 (a common value—no response observed yet)
Zn—zinc	15 (a common value—no response observed yet)
Al—aluminium	>38 (not an essential element but always present; potentially toxic at values well in excess of this common level)

Source: Modified from Plantation crops, with the permission of the Indian Council of Agricultural Research.

The values in Table 5.2 are for the mature palm in a tropical environment, and might need to be modified in the light of experience in subtropical climates.

Where more than one element falls outside the indicated 'sufficiency' range, it is wise to perform tests with different fertiliser nutrients. This is because a deficiency in one nutrient can cause poor uptake of others that would not otherwise be deficient. Seek professional help to test the response to different added nutrients in such a case.

Tissue analysis is expensive; resort to it only after visual symptoms, local knowledge and fertiliser application tests have proved inconclusive.

chapter 6

The productive palm

potential profit or hazard?

The farmer or householder eagerly awaits the fruit, then consumes it or adds value and delivers it to the market. The manager of a public space or resort, on the other hand, must eliminate the risk to passers-by from falling fruit. In either situation, competent harvesters are needed.

The backyard grower consumes most home production by harvesting either drinking nuts or mature nuts. Those with access to many palms have the opportunity to profit from a number of value-adding options.

First fruits: harvest or damage control?

When the young coconut palm first begins to bear fruit, the reaction of the owner or manager will depend very much on the purpose for which the palm was planted. The would-be producer, whether that person is a backyard enthusiast or smallholder farmer, joyfully sees some potential return for the effort of managing and fertilising the palm, and in some cases protecting it against natural hazards. On the other hand, where the palm was planted primarily as an ornamental, the production of fruit will not necessarily be welcomed, and indeed might signal the need prevent the hazard of falling fruit.

Potential yield

A single palm growing well apart from or towering above other palms or trees in a garden, public park or street may become highly productive. If the soil is deep and fertile or well fertilised, if rainfall or irrigation is frequent, and if there is no appreciable cool season, the annual production of a freestanding coconut palm can be as high as 200 fruits. A small-fruited variety might yield more than this, while a large-fruited one will produce perhaps half as many. The lone palm does well because it is not shaded by other trees or palms and therefore intercepts full sunlight, which determines growth rate and yield. The palm owner or manager with a plan to use the fruit will welcome high productivity and, unless they are operating only to supply their household (see Chapter 9), will turn their attention to processing and marketing the fruit.

Figure 6-1. A highly productive young palm on which the heavy bunches are weighing down the older fronds. (Roland Bourdeix, Centre for International Cooperation in Agricultural Research for Development (CIRAD), France)

Harvesting young palms

Young palms can usually offer more opportunities for diverse products, because of the ease of harvesting their fruit. For several years, a harvester can remove fruit from Dwarf palms (such as the one in Figure 6-1) whilst standing on the ground, making it inexpensive to collect drinking nuts, for which Dwarfs are a particularly good source. Harvesting Tall palms usually calls for a ladder right from the start, and within ten years from first harvest the fruit may be hanging five or six metres above the ground.

Harvesting can also be done using a pole and hook-knife, but care must be taken to prevent drinking nuts falling more than a few metres to the ground and splitting on impact (layers of fronds can cushion the fall). Mature fruit, on the other hand, benefits from the shock absorbency of the partially dried husk and is rarely damaged, even when it falls from a great height.

Where the coconut is a traditional part of life, climbing skill is developed from an early age—especially by young men (but in some cultures, young women as well), who can rapidly harvest fruit from a palm with a 10-metre trunk. In India, a climbing-frame device (Figure 6-3) has been developed that allows anyone, even the merely moderately fit, to climb the palm without damage to the trunk, and to have both hands free to perform tasks at the height of the fruit bunches. Monkeys have been trained in some countries, such as Indonesia and Sri Lanka, to harvest mature nuts from palms too tall for the harvesting hook. They are able to leap from crown to crown, working very rapidly.

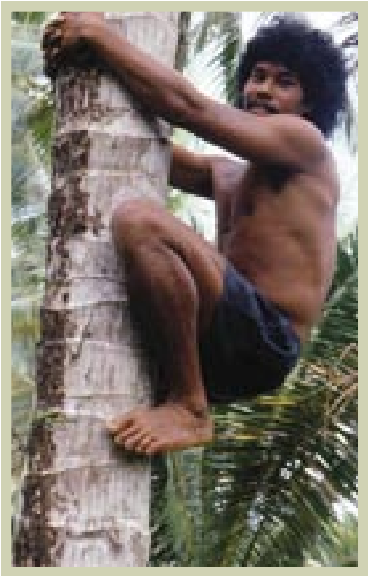

Figure 6-2. A young man climbing a Tall coconut palm on Rennell Island. Skill, stamina and strength are required to perform this feat, especially on older palms, which achieve a great height.

Figure 6-3. A simple and effective two-piece climbing frame invented in India, which enables anyone of moderate strength to gain access to the crown of a coconut palm.

Climbers can also keep the coconut crown free of dead fronds, old flower stalks and any damaged, immature fruit. A clean crown is less likely to be visited by marauding rats.

The most accomplished climbers are found among people who collect toddy, which is the fresh sap liberated at the cut end of the unopened flower sheath (see Chapter 8). A palm that is being tapped for toddy must be climbed twice daily to change the collecting vessel, so the climber often constructs a 'ladder' by chopping shallow notches into the trunk at suitable spacings.

Figure 6-4. No particular fitness or climbing skill is needed to climb a palm assisted by the climbing frame.

Beware: falling fruits

The size and weight of a mature fruit varies from 600 g to 3 kg between different types of palm. Fruit is usually larger on Talls than on Dwarfs, and its size often varies according to the 'load' or number of fruits in the bunch. The fruits of a particular palm maintain a very similar shape and colour, varying only in size when there are more or fewer fruit in the bunch.

A large fruit, falling more than five metres, can seriously injure or kill humans or other creatures. Mature fruits are most likely to be released when the palm is shaken by the wind, but can also fall without warning, especially when there has been little wind for a few weeks. The damage done to an immature fruit, small or large, by a feeding rat will usually bring it down. The high moisture content of the husk at the immature stage makes a large fruit heavy and particularly dangerous.

The incidence of serious injury from falling fruit in coconut countries is low because local people are well aware of the risk, and have a seemingly instinctive ability to avoid the hazard. The iconic or cartoon-like aspect of falling coconuts attracts the attention of the media, inducing a perception that such injuries are commonplace. There is however, more risk at tourist resorts and in the parks of cities where 'coconut consciousness' is low and citizens, especially children, are often not fully aware of the danger of a falling coconut fruit. Figure 6-5 amusingly conveys the sort of scenario that unwary tourists might encounter.

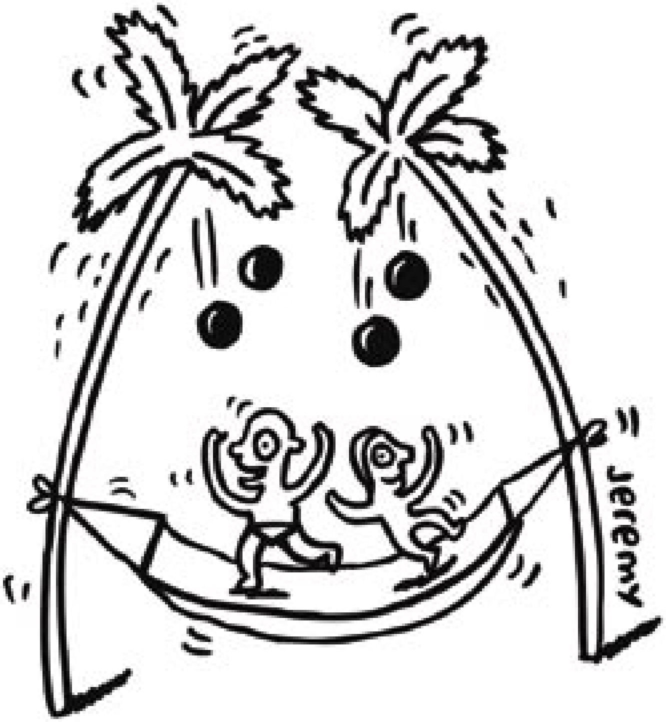

Figure 6-5. Hi-jinks on as hammock stretched between two palms loaded with ripe coconut fruits will surely end in disaster, as depicted on this Minties wrapper. Minties is the name of popular confection available in Australia. The wrappers present many hilariously stressful scenes suggesting that this confection would provide some relief for the unfortunate individual(s) shown in the sketch. (Jeremy for DESIGN lab)

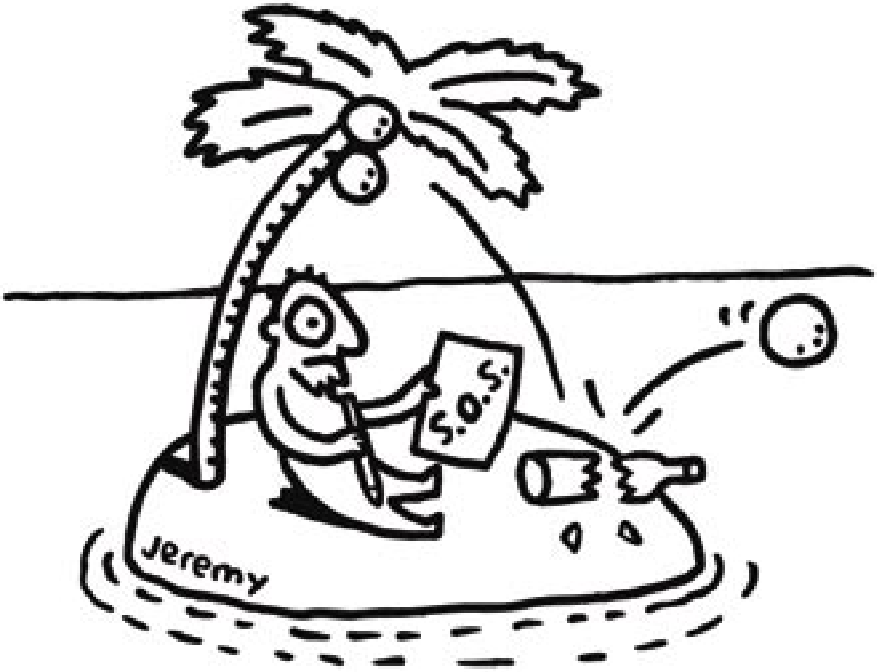

Figure 6-5a. A less likely disaster wrought by a falling fruit on a desert island, preventing the transmission of the SOS message. (Jeremy for DESIGN lab)

Harvesting for production and to reduce hazard

If human traffic beneath a palm cannot be avoided, precautions are needed to prevent fruit-fall once the fruit bunches are more than three metres from the ground. Palms of the Tall varieties mostly exceed that height from the beginning of their productive lives (around 6–8 years of age) while Dwarf palms may be 12–18 years old before they pose a similar danger.

When the fruit bunch is no more than five metres above the ground, a bunch can easily be pruned off using a curved, sickle-bladed hook knife, mounted on a bamboo or metal-tube pole. More skill is required for taller palms, which in some parts of the world are harvested in this way up to a height of 18 metres. Using such a long pole is very difficult and not practical outside a plantation environment. In city parks and streets, and in back yards, specialist climbers or mechanical 'cherry pickers' are needed for Tall palms.

Indigenous harvesting skills

Some Australian city councils contract specialist coconut harvesters, who climb the palm with various types of rigging, often using spiked boots to grip the trunk. The spikes damage the trunk, leaving permanent gouge marks that increase the risk of long-term deterioration: the palm trunk cannot repair itself.

In 'coconut villages', on the other hand, every able-bodied male, and in some cultures many females, have developed the required skills and strength from childhood. Some climbers place their feet into a strong, 400-mm loop of vines, spun rope or the cloth of a lap-lap, which provides grip by wrapping part way around the trunk, and secures the feet on opposite sides of the trunk.

The climber holds the trunk with both arms and draws their feet up so that their body is in a squatting position. They then straighten their legs, which moves their body upward, while their arms maintain their grip on the trunk and the loop around their feet keeps its grip. The climber moves their arms higher, preparing for the next leg movement. In Micronesia, strong toddy harvesters appear to 'walk' up the palm trunk without the aid of a loop, assisted sometimes by shallow foot notches cut into the trunk to increase grip.

Whether the climber is a villager or an urban contractor, harvesting unwanted bunches in urban centres and at tourist resorts usually involves a precautionary cleanup of all those bunches carrying fruits of full size, which means the six most advanced bunches. Two harvesting visits per year, or a complete removal of all bunches (including the youngest) on a single yearly visit, ensures that few fruits of full size are ever likely to fall, and thereby greatly reduces the risk to the visiting public.

Rats can make fruits fall

Where common rats are expected to attack immature fruits, causing their untimely fall, the manager will be forced to program more visits to remove any potentially dangerous fruit. Rat access can be reduced by fitting a slippery metal 'skirt' around the trunk, comprising for example a light gauge (1.2-mm) rectangular aluminium sheet 700 mm wide and long enough to wrap fully around the trunk to be secured with nails at the overlap. If rats can get access to the crown from neighbouring structures or large fruit trees, such as mango, control will be more difficult.

Fruit removal changes the look of the palm

Reduction of the fruit load in this way has a downside, however, because the palm now has energy to spare and it uses this to extend its trunk. The palm grows tall faster, and the shape of the crown is adversely affected: it retains the less attractive inverted-cone or 'feather duster' look of a much younger palm. If the more usual, open, spherical appearance of the crown is important in the particular setting, only two or three bunches should be pruned per visit. This yields fruits marketable for both food and drink, but requires more frequent visits by the harvester.

In such a situation, the Dwarf palm is an attractive alternative because it needs very little 'protective' harvesting in the first 15 years of life, and it develops the attractive spherical crown shape by about its sixth year. Orange and yellow-fruited Dwarfs also have a pleasing pale green to yellow foliage colour.

Profiting from fruit removal

The most mature bunch taken down by the once-a-year harvester will have fully developed kernel, while the least mature but still full-sized fruits will contain only nut water (also known as 'coconut juice'). Fruits of intermediate maturity will contain ample juice and jelly-like 'flesh', which becomes firmer and thicker as the fruits approach full maturity. These fruits all have potential commercial value, providing very enjoyable food and drink, and attract the lively interest of visitors. All but the fully mature fruits have a fairly short shelf-life, however, losing their fresh flavour within three to four days unless refrigerated.

Where there is ready access to a tourist market, it makes sense to protect the unripe fruit against rat damage, and where falling fruits create a hazard, it is wise to install a means of preventing uncontrolled falls. A flexible wire-netting cage big enough to fit around a bunch of about ten full-sized fruits can be installed on each immature bunch and attached to the base of a frond higher up in the palm crown with a light wire loop. This prevents any fruit from falling, and allows the harvester to visit when fruits have reached their most valuable stage for the local market. The cage, which is reusable, is made by folding a 1200 mm × 600 mm rectangle of wire netting (50-mm mesh), and securing the two opposite sides with tie-wire (or the ring fasteners used with special pliers by fencing contractors).

Figure 6-6. A wire mesh basket holding coconut fruit. Such baskets could be slipped over each of several young bunches when the palm crown is visited by the maintenance crew, ensuring that no 'rogue' fruit breaks loose endangering the passer-by. The basket also provides protection against rats.

Palms that carry a full fruit load to marketable size, whether the fruit is harvested for drinking or for mature kernel, will retain the desirable and iconic spherical crown.

Fresh mature nuts have a shelf-life of two months or more, and so can be left uncollected until the whole bunch, or even two successive bunches, are ready. Drinking nuts have a shorter shelf-life and should be used within a few days of harvest, unless stored in a coldroom. The water contained in a mature nut is a pleasant drink, too, but usually has a lower 'refreshment' rating than the water of an immature fruit, at least among experienced consumers.

There are many claims that coconut water has medicinal uses (it is recommended for liver 'flushing', which supposedly clears stones from the gall bladder) or stimulatory effects (probably due to its sugar content) when drunk, and these help to promote sales.

By-products for fuel and thatching

In the urban or home garden situation, the fronds and fruit stalks of the coconut palm must be dealt with. The frond stem of Tall varieties is usually four to six metres long, including its thick, fleshy base (the petiole, up to the first leaflets) and its long, slender main axis (the rachis, which carries the leaflets). A dried frond falling from a tall palm is less dangerous than a falling fruit, but still constitutes a hazard.

Municipal workers trim older fronds from palms when harvesting fruits. It is important not to prune fronds that are still fully green and therefore actively supporting the growth of the palm, but fronds hanging down almost vertically contribute almost nothing. A frond normally has a life of two years, which means that a palm carries about double the number of fronds that is produced in one year. The rate of frond production varies from 16 per year in a tropical climate, such as the New Guinea coast, to 8 per year on the southern coast of Queensland at latitude 28 degrees south.

In coconut villages, green fronds are harvested to provide leaflets for weaving baskets and hats. Fairly young fronds are normally used, because the leaflets on older fronds often have blemishes from the attacks of insects or fungi. The thick frond base becomes useful fuel for the cooking fire, while the long frond stem is often used in fencing, packed closely together and supported by pairs of wires or fine ropes. Bunch stalks, and the sheath that protected the unopened flower, are also used as fuel. In some villages, where there is no alternative thatch that is more durable, the coconut frond is used on the roof and in wall panels. Figure 4-3 (Chapter 4) shows a woven coconut tent used as shade to protect a young seedling.

Figure 6-7. Basket making with coconut fronds for use as seedling containers in a plantation nursery. This ‘home-grown’ solution to the scarcity of poly-bags on remote Christmas Island (central Pacific) typifies the creative use of coconut palm resources in indigenous cultures.

Wherever the sago palm frond is available in Melanesia, it is used in preference to the coconut frond, because it lasts twice as long.

chapter 7

The fruit and its parts

Coconut water is one of the world's most popular and valuable natural drinks.

Coconut kernel and its many derivatives have an immense potential benefit in the human diet, giving energy and sustaining good health.

The husk provides a durable fibre for mat and rope making.

The shell is especially energy-dense and hard, making it a valuable fuel and a long-lasting material for tools, ornaments and curios.

Legacies of evolution

Fossil shells of a coconut ancestor found in New Zealand, once a land fragment attached to the ancient supercontinent of Gondwana, reveal a smaller nut, well outside the range of most modern forms.

After the dispersal of coconut seeds across the ocean, their successful germination on a sandy or gravelly surface probably depends on some water being left inside the nut. Larger nuts hold more water, so natural selection would increase fruit size and water content. This increase in water content would also allow the fruit to travel even further on its sea voyage and remain viable (see Figure 1-7).

The coconut seed is almost unique in the plant kingdom for its large quantity of water, which also happens to be an excellent drink for humans. Nut water usually contains enough sugars to be sweet to the taste, as well as the plant growth stimulants needed to initiate germination of the seed. If the water is evaporated in a laboratory oven, it leaves a residue equal to 3–4% of the original weight. In a medium-sized nut with a 500-mL cavity, this amounts to 15–20 g of solids—mostly sugar and some protein.

There is usually a slight taste of coconut oil, due to a trace suspended in the water.

Under natural conditions, water evaporates from the nut cavity through the kernel and shell as time passes, and the remaining nut water becomes more concentrated. It is likely that when the ancestors of present-day human populations reached coconut shores, probably within the past 100 000 years or so, they began to select for larger coconut fruit to get a higher yield of delicious and refreshing coconut water. The change in fruit characters brought about after many generations of such selection is referred to as 'domestication'.

Wild-type palms bear small fruit

Small-fruited palms, which are found these days mostly on remote uninhabited islands, such as North Keeling in the Cocos group in the Indian Ocean, weigh 600 g to 1 kg at maturity and contain only 50–100 mL of water. The largest fruits of Thailand, Malaysia, the Philippines, Indonesia and Polynesia are all advanced examples of domesticated fruit, weighing around 3 kg and yielding 1 L or more of water.

This great increase in the size of nuts provided larger 'bottles' of this natural beverage, for use when fresh water was scarce at home, and especially on sea voyages: H.C. Harries has referred to the coconut fruit in poetic language as 'the milk bottle on the doorstep of mankind' (see Figure 1-7).

Small nuts are still important in the drink supply in many places, however, because there was no particular motivation among non-seafarers to select for really large nuts purely for local drink supplies. The convenience of the Dwarf varieties for harvesting and their relative safety around the village led to their adoption as the preferred types.

Large fruits were carried far

Tall palms bearing large fruits are found on many islands in the tropical Pacific colonised by Polynesian voyagers between 1500 and 4000 years ago. Because the immature fruit has a short 'shelf life', their great seafaring canoes would have been stocked with the mature fruit. It would have supplied food and drink for months, if necessary, without spoilage. At the end of such voyages, unused nuts would have provided the foundation for a strain of coconut distinct from the wild type, which had already spread naturally to the new habitat. Cross-pollination between old and new palms would have given rise to crossbred palms bearing fruit of intermediate size.

It would have been very difficult for voyaging peoples to colonise most new lands that did not already have a wild coconut population capable of supporting them from the time of arrival. Easter Island in the south-east Pacific is an exception, as it was settled successfully without the coconut (which would have been unproductive at latitude 27 degrees south).

There is evidence on many islands in Polynesia that persistent selection by the new colonisers brought about eventual dominance of the introduced fruit type over the local palm population. Outstanding examples of such large-fruited populations are found on Samoa, Rotuma in the Fijian Islands, Rennell in Solomon Islands, and the Markham Valley and KarKar Island in Papua New Guinea. Similar large fruits are also present on Mindanao in the southern Philippines, in parts of Malaysia, in Indonesia and in Thailand.

Large fruit for high yield, small fruit for natural dispersal

The evolution of the popular large drinking nut within the coconut fruit has coincidentally increased kernel production. There has been a fourfold increase in the amount of mature kernel ('meat' or solid endosperm) found in the largest nuts. When it comes to seed dispersal, such large seeds are disadvantaged in comparison to the smallest 'ancestor-type' nuts.

To remain viable and travel far on the ocean, the coconut fruit depended on buoyancy provided by its thick fibrous husk and, to a lesser extent, by the small air volume within the fresh mature nut. The husk comprises fibres separated by a bulky filler material known as pith or cortex, which dries down to low density at maturity. The whole fruit is encased in an almost impervious outer 'skin', which admits water only slowly.

The nut has been found to remain viable (that is, to retain its ability to germinate) after four months floating in seawater. This is long enough for it to travel several thousand kilometres, depending on ocean currents, prevailing wind and any land in its way. Of course, many nuts, launched on their floating voyages by the quirks of storm and tide, probably return to shore on their landmass of origin within a few kilometres of their starting points.

Nuts from the smallest and most isolated islands and atolls probably have the greatest chance of travelling a long distance. Within the span of human occupation of coconut lands, isolated coconut populations were the least likely to have been affected by domestication because they occupied too small an area to attract purposeful rather than accidental human settlement. Not surprisingly, therefore, palms on the most isolated islands exhibit the 'wildest' traits, being those most favourable to successful dissemination by sea.

Nut water as a fresh local product

While a diverse range of products can be derived from the three solid components of the coconut fruit (kernel, husk, shell), coconut water presents fewer possibilities and is mostly consumed directly as a thirst-quencher and moderate stimulant.

However, coconut water varies through stages of fruit maturity, beginning with the six-month-old fruit. At this age, the fruit has reached its full size but there is no kernel or air inside the nut, simply water containing solutes and some suspended (cloudy) matter. The water is reputed to taste best when the fruit is six to nine months old (fruit would be mature at 12 months) but the concentration of sugar and other ingredients varies greatly, perhaps because the water is a temporary store for nutrients being deposited into the kernel. At nine months, the kernel comprises a nutritious soft jelly, which is easily scooped out.

Figure 7-1. Fruit being sold for drinking of the nut water, in Vietnam. Visitors to most coconut regions will be able to partake of this most refreshing of drinks.

A spherical nut of 130-mm internal diameter holds a maximum of 1150 mL of nut water (before any kernel develops), compared to 550 mL in a nut of 100-mm diameter. Gradually, over the ensuing six months, kernel accumulates on the inside wall of the shell, at first taking the form of soft jelly and then becoming rubbery by ten months and solidly crisp when mature at the end of the twelfth month.

No detailed description of changes in the composition of nut water during this period is available, but folk who drink nut water regularly are able to recognise early, intermediate and 'old' flavours. At maturity, slow evaporative water loss from the nut begins. Airspace in the nut can be detected from a sloshing sound when the fruit is shaken. This loss of water concentrates the dissolved or suspended compounds, so water from mature fruits often becomes increasingly sweet during storage.

Confusing water and milk

In countries far from the coconut heartland, confusion arises when the clear water from within the nut is referred to as 'milk'. Below, we examine the preparation of true coconut milk, an emulsion extracted from the mature kernel. Water from immature fruits is extremely popular direct from the nut and is also marketed in containers labelled 'coconut juice'.

The shelf-life of immature fruits is limited to about a week unless they are refrigerated; the mature fruit, and the nut extracted from it by dehusking, last either until germination, following which the remaining water is absorbed into the spongy haustorium (see Chapter 3), or until the all the water has evaporated out through the kernel and shell. During this time, the nut might be invaded by microorganisms, which gain access through the minute pores in the shell that admit fibre-borne nutrients from the 'mother' palm, or through the nut's 'soft eye'. The microbes attack the water and kernel within, destroying their flavour. If the nut escapes such an attack, which is more likely in a dry climate where the loss of nut water is rapid, the kernel may remain uninfected until it dries out, forming 'ball copra'.

There is much traditional mythology surrounding mature coconut water, and modern science bears some of it out. The water carries traces of many minerals, such as potassium and sodium, as well as 'growth substances'. The trigger for germination of the embryo embedded in the kernel may well come from the water within, initiating the development of the spongy haustorium that nourishes the tiny seedling by transferring nutrients from the kernel. Nut water is widely used as a tool in plant science to stimulate cell division in tissue taken from many plant species The active cell-stimulating molecule in coconut water is one of a group of chemicals known as cytokinins.

Coconut cream and coconut milk

The kernel is especially important, as it has been a valuable item in the indigenous human diet of the coconut heartland for countless millennia. Indigenous people mainly use it as coconut milk, the emulsion squeezed from finely shredded fresh kernel. This is added, for flavour enhancement, to starch dishes such as rice and the several root crops—sweet potato, taro, cassava, yams and so forth—and to fish dishes, where its flavour and high energy content are much valued. Without the combination of fish and derivatives of the coconut kernel, human survival on the dozens of inhabited atolls across the Pacific and Indian oceans would not have been possible.

It appears that the short-chain fatty acids of coconut oil not only provide ample energy with no risk of obesity, but they also enhance the physiological activity of the essential fats found in fish. In the era before urbanisation, health professionals, as well as early European navigators, noted the remarkably robust physique and general good health of indigenous coastal peoples consuming a coconut diet.

A description in 1695 by the English buccaneer, global voyager and author, William Dampier, of the uses of coconut in India shows that traditional processing and use in the tropics has changed little in three centuries. Dampier seems to have been most impressed, however, by the immature coconut as a source of drink and soft kernel:

> While it is young and soft like Pap, some Men will eat it, scraping it with a spoon, after they have drunk the Water that was within it. I like the water best when the nut is almost ripe, for then it is sweetest and briskest.

Traditional coconut cream and milk preparation

To make coconut milk, the person preparing food for the indigenous household takes a dehusked nut, cracks it in half, and scrapes the kernel from the inside of each hemisphere. The preferred tool is a round-ended metal 'comb' with short teeth that shred the soft kernel. The cook places the shreds into a bowl in which has been laid a piece of coarse cloth, and adds water, which is often hot. They then draw the cloth around the kernel and squeeze hard, using a rolling action at either end of the bundle. In some places, the cook dispenses with the cloth and kneads and squeezes the mix of shreds and water with their bare hands. The milk is collected in the bowl.

More water can be added and the pulp squeezed again, yielding a milk of less 'strength' that the one before. The first extract (which is richest) can be considered 'coconut cream'; later, more dilute, extracts are 'coconut milk'

The residue can be fed to poultry, dogs or pigs, or added to other dishes. The cook will add the cream or milk to whatever is being prepared for the main meal, such as taro, sweet potato, yam, tapioca or rice.

Coconut cream, and the more dilute coconut milk, are available in both canned and dehydrated formulations in supermarkets around the world. Urban-dwelling indigenous people, who have less time to prepare food than villagers, often use the canned or powdered forms for convenience. Among expatriates in the tropics, and in developed countries, the number of cooks with a taste for curries and other exotic dishes that include coconut milk is on the increase.

Coconut in your kitchen

Coconut has long been used as a vital, delicious ingredient in cakes and other sweet foods and as a compatible partner to chilli-spiced dishes in traditional coconut producing countries, such as India, Thailand and the Philippines. These countries have produced a plethora of recipe books featuring the coconut.

The simplest procedure in coconut cuisine is to add coconut milk, which comes under many brand names in the supermarket, to a stir-fry vegetable dish, to rice after boiling, and to fried fish and meat dishes. Through experience, you will quickly determine the correct amount to suit individual or family tastes.

A search of the internet using the word 'coconut' will find many published recipe books.

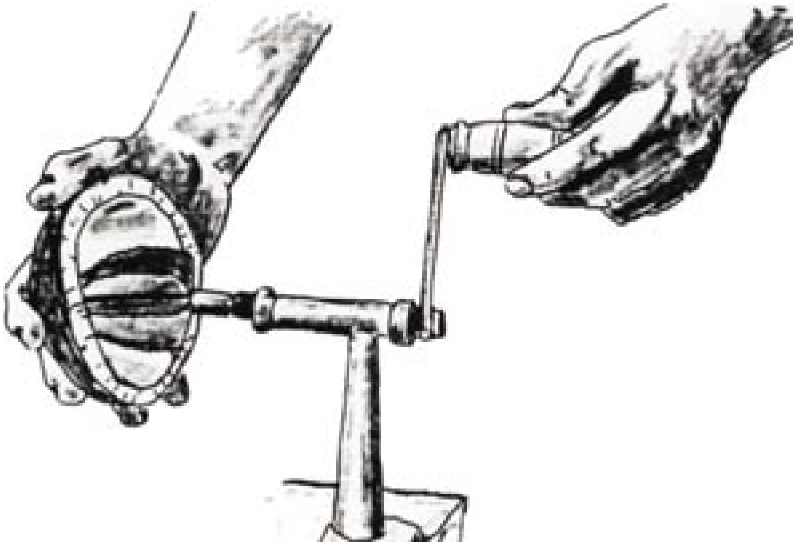

Figure 7-2. A toothed mechanical device designed to speed up the shredding of kernel from the nut.

The kernel as food: solid or shredded

The kernel, consumed raw, is widely popular outside the tropics for its flavour, its oil content and its health benefits. It is a concentrated energy food, contains fibre and protein, and is ideal for children.

Desiccated coconut is produced from shredded or ground kernel that has been dried sufficiently to be preserved against the attacks of insects, bacteria and fungi, although some processors also add a sulphite as a precautionary preservative. This form of coconut kernel is ubiquitous in Australian kitchens, and essential for lamingtons (sponge cake coated with chocolate icing and rolled in shredded or ground

Figure 7-3. Coconut milk being squeezed from the shredded kernel in the bare hand, in Mozambique. Many consumers strain the milk through a coarse woven cloth.

desiccated coconut), cake toppings, macaroons (desiccated coconut mixed with egg white and baked) and 'coconut ice'. It is also used widely in many commercially made snack bars, including the well-known 'Bounty' bar, muesli mixes and the like. Similar candy products using coconut are popular in most countries.

Coconut oil: a major trading commodity

The other major product derived from the kernel is coconut oil, traditionally separated from coconut cream by heating to drive off the water, or by allowing the cream to stand for up to 48 hours at about 25°C while fermentation causes the oil to separate and float to the surface.

Coconut oil has a multitude of uses: as cooking oil and in all applications that call for shortening (the ingredient that makes pastry crisp); in body and hair lotions; in medications for abrasions, skin rashes and burns; as lighting and engine fuel oil; and as a feedstock for soaps and detergents. Coconut soap is especially valued because it lathers tolerably well with hard water and even with seawater, unlike most other soaps.

A shortage of oil for household purposes in Europe, where modern soaps had been invented early in the industrial revolution, initiated plantation-scale copra making in coconut countries. The copra (the dried kernel of the nut) was taken to Europe, where the oil was extracted mechanically.

Copra remained a major traded commodity for a century or more. At around 5% moisture content, copra remains free from insect attack and chemical deterioration for many months. Traditionally, the kernel might be dried in the sun during fine weather, or 'smoke dried' on the smallholder's farm using coconut shell and husk to heat the dryer. Both these traditional methods produce a poor grade of copra.

Modern small driers sometimes supplement the heat from the fire by using a thermal store, consisting of a bed of large rocks in a shallow pit beneath a glass sheet, which accumulates heat from the sun and releases it when the fire is not burning. Industrial plantations normally use firewood or fuel-oil driers.

Industrial processing of coconut oil

Oil is extracted by passing shredded and heated copra through very powerful presses. This yields up practically all the oil present, amounting to more than 60% of the dry weight of the feedstock.

The residue of 35–40% has around 20% protein and 10% residual oil content, and is known as organic 'copra cake' or 'copra meal'. This feedstuff has found a valuable niche in the market for cattle feed, for organic beef production, and horse feed. In cattle, it delivers a similar weight gain to feeds with a much higher protein content. Working and racing horses show sustained energy and tend to lose some weight, which also enhances performance.

In developed countries, coconut oil usually undergoes further processing (known as RBD—refine, bleach and deodorise) to remove undesirable flavours, colours and aromas associated with inadequate copra making. The oil remains an important industrial feedstock for the manufacture of soap, and in recent decades the lauric oil present in coconut and palm kernel has also found an important niche in the production of high-quality detergents. Coconut oil has also been used in developed countries for deep frying and other food preparation methods from the early 1800s to the present.

Virgin coconut oil: a valuable new product

There is a growing demand for virgin coconut oil (VCNO) for quality cooking purposes, as a health food and for medicinal use. VCNO is produced by several processes, including drying freshly shredded kernel to 12% moisture content at moderate temperature, and immediately pressing out the oil. Only moderate pressure is required at this moisture content, whereas copra (at 5–6% moisture) requires both high temperature and very high pressure to release its oil.

Another pathway to VCNO is via fermentation, in which microbial activity releases the oil, which floats to the surface in 12–24 hours and can be poured or skimmed off. A little heat removes the small amount of residual moisture (see Chapter 10).

Husk and fibre: versatile raw materials

The coconut husk, which in nature aids the protection and dispersal of the seed and conducts nutrients from the palm to the nut, consists of a great many fibres of differing length and thickness, embedded in a matrix of pith or cortex. The fibres can be separated from the cortex by combing after a hammer-milling process, which softens the husk without breaking the fibres, or traditionally by retting (prolonged soaking) in a pond.

Coconut fibre (or 'coir', from the Malay kayar, for cord) is spun to form yarn, which in turn is twisted into durable ropes that match ropes of other natural fibres for their ratio of strength to diameter. Coconut rope does not stretch or shrink in water, unlike many synthetic fibre ropes, and this outstanding stability makes it especially valuable in the rigging of seagoing craft. Its use in coconut lands goes back many thousands of years, and it is still much in demand internationally.

The raw fibres, varying in thickness and strength, can be separated for different applications. Coarse fibre is ideal for the durable coir doormats traded worldwide. It is also incorporated into rubberised slabs of fibre, manufactured in several Asian countries and widely used in automobile upholstery. Finer fibre makes softer yarn, which is used in attractive netting bags of all sizes. Soft fibres also form the basis of magnificent tapestries and mats, produced particularly in India and Sri Lanka, featuring vivid colours and elaborate patterns.

The cortex material, combed away when the fibres are extracted following hammer-milling, is biologically inert and valuable for moisture retention in horticultural potting mixes.

The domesticated type of nut, with its much-reduced proportion of husk, yields much less fibre and cortex than the wild type, with its bulky husk.

Coconut shell: fuel and toolmaking material

The shell of the coconut serves as a barrier to maintain the sterile state of the kernel and water in the seed. Before the half-mature stage of fruit development, the shell is soft and thin, comprising sheets of conducting fibres connected to the fibres in the husk. Subsequently, very dense deposits of lignin accumulate around the shell fibres, while water and nutrients continue to flow into the nut. The now hard and brittle shell retains an inner lining at maturity, consisting of a mat of fibres, which eventually disconnects from the kernel. The shell varies in thickness from light (2 mm) to heavy (6 mm), depending on the variety and vigour of the palm.

The shell has proved to be very valuable in human economies. Most importantly, it provides fuel for domestic cooking and heat for drying coconut kernel to produce copra and for drying fish to be preserved. The brittle, high-density, woody material of the shell is rich in hydrocarbons and burns with a fierce heat.

With controlled burning, coconut shell can be converted to high-quality charcoal, which is prized as a feedstock for making the activated carbon needed in much industrial chemistry. For example, activated carbon is used in the separation of gold fragments from the waste material in pulverised gold ore.

The shell is also ground to a fine powder and used both for lubricating paste for rock drills and as the fuel component in mosquito coils.

In the traditional household and village, the half-shell is a valuable utensil to hold food and drink. When Captain William Bligh was cast adrift by the Bounty mutineers off Tonga in 1789, in an open boat with some loyal crewmates, he used a large coconut shell to help measure out the scanty fresh water supply. Strictly rationed water, some dry bread, and a quantity of coconuts in the boat enabled the hapless band to survive for 40 days and reach safety in Timor—one of the great voyages of Pacific seafaring in which the coconut played a significant role. Bligh's coconut was auctioned by his descendants in London in 2002, for many thousands of dollars.

The coconut half-shell is very useful as a hand-held scraping tool in the food garden, and makes an efficient miniature scoop that fits comfortably in the human hand—ideal for removing soil loosened with a crowbar when preparing a post hole.

The attractive dark brown colour of polished coconut shell lends itself to a many ornamental and practical uses. Its hardness allows it to take a fine manual polish with sandpaper, after a preparation stage using a coarse powered disk to remove the traces of fibre attached to the outer surface. The layer of compressed fibres attached to the inner surface is best removed with sandpaper stretched over a dome-shaped tool.

Polished shell is used to make buttons and household utensils, including ladles, small bowls and drinking vessels, and a great variety of ornaments. The wide range of shell sizes allows the production of cups, bowls and goblets. Creative artisans in coconut countries, limited only by their imaginations, fashion many other curios and practical articles from coconut shell. In some communities, half-shells serve as percussion instruments to accompany song and dance.

The half-shell pieces can also be fitted into each other to form a line of fuel, for example in the controlled heating of a rack for drying coconut kernel or other fruit (Figure 7-4). Within a sheltered enclosure with a rack over the top, the shell line

Figure 7-4. Coconut-shell fire comprising shells nested into each other. This arrangement gives a prolonged steady burn, consuming the line of shells at 30 cm per hour. This convenient heat source, practically smoke free, is used to dry coconut kernel yielding copra, and to dry other products that require a controlled situation.

Figure 7-5. Coconut knife, designed with sufficient weight to crack open the dehusked nut and remove the kernel in strips.

Figure 7-6. A dehusked mature nut held ready to be cracked open using the coconut knife.

Figure 7-7. Hemispherical halves of a mature nut ready for shredding or slicing out of the kernel

Figure 7-8. A narrow strip of kernel extracted in a spiral configuration by working the coconut knife blade around the edge of the half-nut.

is lit at one end (requiring coals from another fire, or kerosene soaked into the first shell) and will burn progressively at the rate of 30 centimetres (approximately eight shells) per hour. The shell fire burns with a modest flame and emits only a little smoke, thereby allowing a hot-air drying process that leaves the dried material more or less free from smoke odour. Depending on the space available, the line can be doubled back, or two or more lines of shells can be burned simultaneously for more heat. This process is widely used by coconut farmers to dry copra laid on a slatted rack about one metre above the fire.

Figure 7-9. Kernel from the 'inside' of the half-nut may be extracted in triangular pieces using the coconut knife.

Coconut products available in Australia

The most familiar derivative of the coconut fruit in Australian markets is the bare-shelled nut. The husk has been removed, but there are usually many loose fibres attached to the surface. A sharp blow on the 'equator' of the nut with a heavy-bladed knife usually succeeds in partly splitting it into two roughly equal sections. The water can be collected as the halves are fully separated, revealing the broken edges of the shell and the attached white kernel.

Canned coconut cream, milk, 'lite' milk and juice are imported from many source countries and are readily available. The widely used mosquito coil incorporates ground coconut shell as the material that burns to release the insect repellant. Coconut fibre (coir) mats imported from India are common, as well as horticultural 'mulch' mats for soil-surface protection. The pith separated from the fibres is available in compressed briquettes for incorporation into potting mixes as a medium to retain moisture.

Specialty shops carry curios made from coconut shell, such as buttons, buckles, cups and goblets.

chapter 8

Abundant products

health drink, liquor, structural components, shade, fuel and more

The coconut palm produces a great variety of products other than its fruit and nuts.

The sap (or toddy) provides drink (sweet and rich in vitamins when fresh; alcoholic after fermentation) and sugar. The trunk is a valuable source of structural and ornamental timber. Fronds, flower sheaths, stems and branches have many potential uses. The frond is used in decoration, costume and headwear, and as light fencing material. The flower stem and sheath are useful domestic fuels.

Coconut sap for toddy and sugar

In many cultures, the sap (or toddy) of the palm is tapped for food and drink. Fresh toddy is a valuable source of vitamins in places where fresh fruit and vegetables are scarce, as well as being a feedstock for the production of both palm wine and palm sugar. After a year or so of tapping, during which fruit production ceases, toddy palms are usually rested for a while. There is commonly a growth reaction to the toddy phase, shown by overproduction from several bunches, which carry 50 or more fruits each, resulting in some being extremely small and of little value.

Toddy is harvested by cutting off a slice of tissue from the tip of the spathe (the newly emerged but not yet open sheath of the flower). Before the first slice, the spathe is prepared for sap harvesting by coiling a fine rope around most of its length to prevent the normal splitting of the sheath that allows the inflorescence to emerge. A container (bottle, bamboo tube or large shell) is hung from the end of the spathe to collect the flowing sap, which may amount to as much as a litre overnight and a little less during the day. If the palm is experiencing water deficit, less sap will flow. The cut is refreshed every morning and evening for two to four weeks.

Toddy is rich in sugar, vitamin C and some B vitamins, and makes an excellent drink for children when it is fresh. Coconut sugar contains mostly sucrose and can substitute directly for cane sugar. Known in the coconut heartland as brown sugar or palm sugar, it has many food uses in local communities. For example, Indonesia's well-known Bandrek drink, based on ginger, would be barely drinkable without added palm sugar. It is likely that human communities could not survive on isolated atolls without using fresh toddy to avoid vitamin deficiency, especially where rainfall is marginal for growing fruit and green vegetables.

Fermentation of fresh toddy is rapid at tropical temperatures, so that within a few hours of collection there is an appreciable build-up of alcohol, which can be delayed by refrigeration. Left for two days, toddy becomes a strong alcoholic drink, which sometimes has a negative social impact in communities where it is widely consumed. Fortified alcoholic toddy is produced for some local markets, and is also available under the name of arrack, for example in Sri Lanka.

Sugar, which is extracted from fresh toddy by evaporation, has some potential as a cash commodity where productivity is high. The high cost of climbing to harvest toddy, twice daily, dictates that young palms are very much preferred for profitability. On a plantation scale, the coconut can produce as much sugar per hectare as well-managed sugarcane, and has the advantage of being a fully perennial crop that can be redeployed to generate other products in response to market variations. On the negative side, sap harvesting requires constantly higher labour inputs.

Uses for the frond

Other components of the coconut palm provide valuable products in traditional villages. The frond comprises a robust petiole (measuring about one quarter of the overall length and forming the base portion attached to the trunk and the tapering section extending to the first leaflets) and the rachis (or frond mid-rib) and its attached leaflets. The frond of a mature Tall palm is 5–7 metres long, while that of a Dwarf may be 3–5 metres. The petiole and rachis are useful as fuel, having a dry weight of 2–4 kilograms. When the rachis, which is usually straight and rigid, is stripped of leaflets, it makes a useful light fence picket.

Coconut leaflets are woven into temporary baskets, or into hats, mats, and panels for the cladding of fence, wall and roof. One edge of the panel is usually held together naturally, by retaining a thin strip from the side of the rachis.

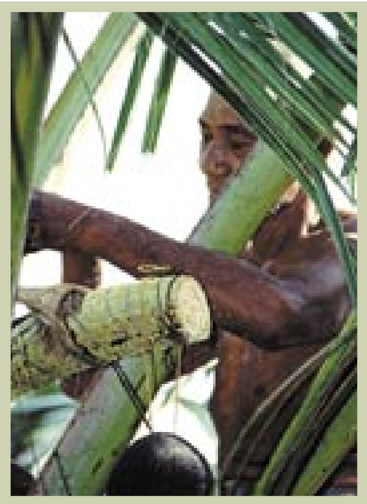

Figure 8-1. An inflorescence sheath bound up for toddy tapping. Short pieces of leaflet are attached vertically to guide the toddy into the shell vessel suspended below the freshly-cut end. The 'leaking' end of the sheath is freshly cut (tapped) twice a day, when the vessel is changed.

The pale yellow leaflets of the immature frond, cut before they unfold after emerging spear-like at the top of the palm, are made into attractive dance costumes and decorations in some indigenous cultures. In Bali, immature leaflets are available in many markets for use in day-to-day religious offerings.

Fuel from the old flower parts

The dried-out sheath and skeleton of the inflorescence provide readily combustible fuel for domestic use in the traditional village. The sheath's canoe-like shape makes it popular in children's games, perhaps providing their first awareness of the buoyancy of a solid object on water.

Palm wood: strength and beauty

The palm trunk is valuable as a raw log for short-term bridge supports in the village, and for sawn timber provided that it is milled carefully (see below).

The wood of the outer bulk of the lower trunk of a mature palm (over 25 years old) has achieved a fairly high density (above 600 kg/m^3) through the progressive accumulation of woody tissue. Within this dense 'tube' is another zone of wood of medium density

Figure 8-2. A primitive drying rack for coconut kernel, made from lengths of frond rachis (stalk). The smoked copra from this process yields poor quality oil that needs to be refined, bleached and deodorised before industrial use.

(400–600 kg/m^3), and finally there is a column of softer wood (200–400 kg/m^3) at the core of the trunk. In the upper sixth of an older palm trunk, the high-density outer tube is missing because this part of the trunk is relatively younger, and the inner zone of low density predominates.

Figure 8-3. An ornamental house post prepared from a coconut trunk. The coconut log was infused with a special wax to impart stability before being machined into this cylindrical post.

In common with all other palms, the coconut palm has a distinct internode space on the trunk between the 'ring of attachment' of each successive frond. The result is that the height of the coconut trunk increases with each frond produced. In the young palm, the internodes are large: a young Tall-type palm might grow one metre each year for a few years, but once fruit production begins the new internodes become smaller, with annual height increase falling to just a few centimetres in very old palms.

Beyond 40 years of age, height increase diminishes further as fruit production takes greater priority. However, the density of the lower three-quarters—which extended more rapidly in the first 40 years—continues to increase for several years, thereby raising the overall density and quality of the wood.

In contrast to the diminishing rate of extension of trunk height, the trunk diameter remains more-or-less constant for many metres. The Tall palm's trunk has a uniform

Figure 8-4. A box carved from coconut wood, showing natural decorative dots in cross-section and stripes when cut lengthways.

300–400 mm diameter above about 1.5 metres, while the trunk of the Dwarf has a diameter of about 200 mm from ground level up. After 30–40 years, however, both the Tall and the Dwarf show some tapering of trunk diameter. In very old palms (more than 80 years), and in palms stressed by disease, nutrient deficiency or drought, the taper may be more severe. This 'pencil pointing' is usually a prelude to death caused by decline or the wind-induced snapping of the frail upper trunk.

Coconut timber from the outer tube of the trunk is visually very attractive, with a distinctive pattern of 1-mm dark reddish spots (formed by the bundles of cells that conduct water) revealed in a cross cut, or 1-mm wide stripes in a lengthways cut, against a light cream-to-brown background. There are no growth rings because, as with all palms, the diameter is fixed by the size of the trunk 'template' located beneath the growing point. Because there is no bark on the trunk, there is no repair mechanism to deal with damage from cutting, gouge marks from boot spikes, the impact of bullets or any other hazard. A period of growth-checking stress, followed by stress alleviation and normal growth, can produce an 'hourglass' effect, in which the trunk has a zone of restricted diameter part way up.

Preserving and milling the coconut log

Coconut wood is milled where palms are plentiful and the price is right. Indigenous people are reluctant to sacrifice old palms, even though production of fruit is very low, but as the usefulness and value of the timber have increased, the prices paid by the millers have become more attractive.

It is wise to remove the fronds before felling a palm, to achieve more control and minimise the risk of collateral damage to plants or structures nearby.

If a palm trunk cannot be milled immediately, it should be 'preserved' against fungus and beetle attack by immersion in an appropriate chemical bath, thereby avoiding very rapid deterioration in outdoor storage. The trunk treated this way can be used unmilled as a post or pole in buildings and fences.

The coconut log is composed of thick, hard fibres separated by a softer matrix, which comes adrift from the sides as the saw cuts through—generating a great deal of heat from friction. It is necessary to use a blade with heat-resistant teeth made of stellite or tungsten carbide material. Even so, water must be squirted onto the blade to keep the temperature down. Because of the gradient of declining density from the outside to the centre (the radial gradient), trunk sectors of only relatively small cross-section can be milled if uniform density is required.

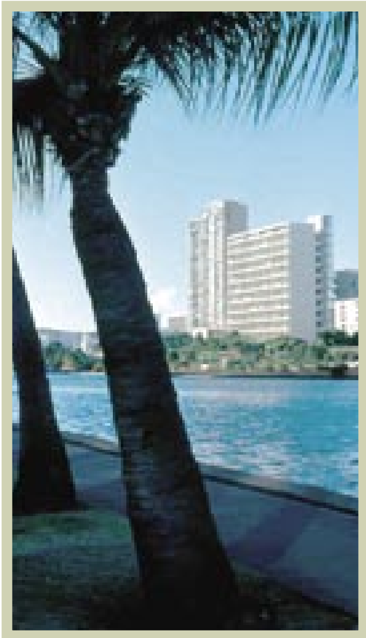

Figure 8-5. A palm in Hawaii showing a severe restriction in the trunk due to a prolonged period of stress.

Precision cutting recovers the best wood

Figure 8-6 shows how a log might be cut to recover a high proportion of the dense outer tube, which can be used for load-bearing structures, flooring, tool handles and furniture and has the highest market value. Material from the inner tube can be used for limited-load bearers, furniture, wall panelling and curios. The lowest-density inner wood is suitable only for wall panelling.

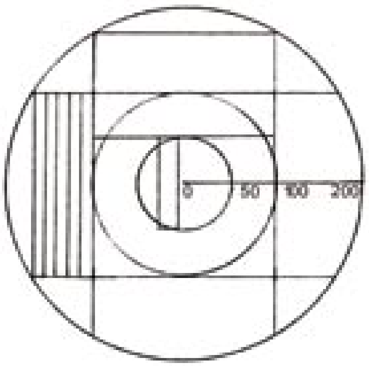

Figure 8-6. A guide to the milling of the coconut log allowing separation of structural timber of differing density and strength, relating to location within the trunk structure. The radius of the log reduces from 200 mm in the lower trunk of a Tall palm to 150 mm at a height of 4 to 8 m.

The very attractive colour and pattern of well-finished coconut wood from the outer zone makes it an ideal raw material for many forms of decorative furnishings (tables, chairs, bookcases, desks), or for veneer to cover the outer surface of a briefcase or display cabinet (this use is a feature of coconut woodwork in Tanzania). The timber is also popular as raw material for small carvings of many kinds. As the greater part of the Tall's trunk has a diameter in the range of 300–400 mm, there is no scope for thicker planks to be recovered, but larger items, especially for structural use, could be made by gluing together smaller slabs to form a compound unit.

Coconut shade benefits other crops

A significant by-product of a mature grove of palms is the open and only moderately shady environment beneath the elevated canopy. There is plenty of space for other tree or annual crops, but the annuals usually do better under full sunlight. Cacao (chocolate), in particular, benefits from diffuse light of around 50–60% full intensity, such as that transmitted by a stand of middle-aged palms (see Figure 5-2 in Chapter 5). Other crops, such as coffee, kava and vanilla, also do well in this situation. Shading may limit their yield, but the shade reduces evaporative demand, thereby moderating water stress, and the palms also reduce the risk of wind damage to the intercrop. Weed competition is usually moderate in such a mixed-crop arrangement, because of the high aggregate shading effect.

Figure 8-7. Using a chain saw on Manus Island, Papua New Guinea to mill a coconut log for structural beams. (Dan Etherington)

An image with global appeal

Palms of many kinds are valued for their ornamental beauty, but the coconut has achieved a special status as the symbol of the warm, languid and relaxing seaside or island holiday environment. Europeans also associate the coconut with exotic and tempting places, inhabited by attractive indigenous peoples untroubled by the frenetic lifestyle of industrial cities. Whereas there are many other attractive palms (the Cuban Royal of the Caribbean, the palmyra or sugar palm of Asia, and the Livistona and bangalow palms of Australia, to name but a few), none of these has the evocative cultural and lifestyle associations of the coconut. Few tourist resorts in tropical climes lack coconut palms in their landscaped or natural environments.

One other image of the coconut palm has been widely used: the solitary palm on a 'desert island'. This symbolises the ability of the marooned sailor or traveller to survive on any island, no matter how small, as long as there is a food supply from a coconut palm. This image is popular in industrial society, having evolved from the era of first contact between European cultures and the 'East', and it has remained popular because it sustains the notion that one can escape the stressful pressure of the world by having a 'personal' desert island.

Nowadays, the threat of sea-level rise as a consequence of global warming has rather altered the perception of tiny islands where palms grow. The atolls and coral islands of the world rarely rise more than two metres above the current high-tide level. A sea-level of rise of

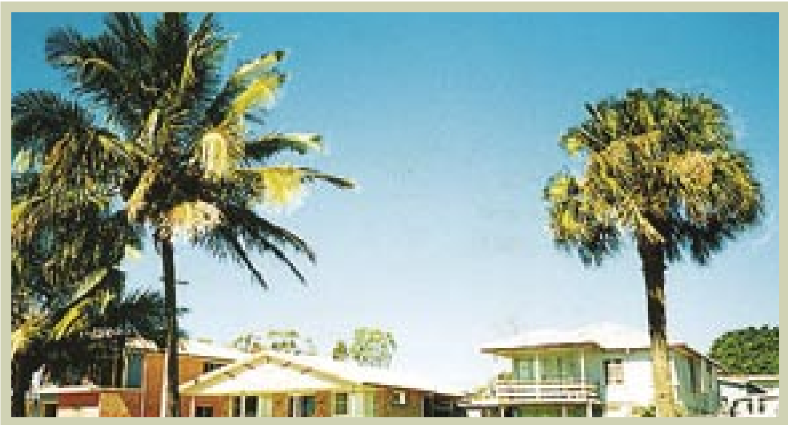

Figure 8-8. Contrast between the equally visually attractive crowns of coconut and Livistona palms on the east coast of Australia. Unlike coconut petioles (frond stems) those of the Livistona palm are thorny, reducing its appeal.

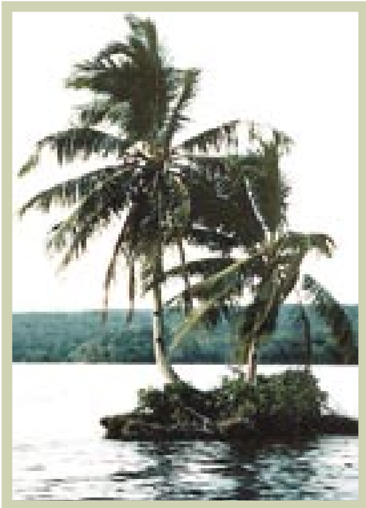

Figure 8-9. A 'desert island', comprising two palms on a land fragment in fresh water, at Rennell Island, Solomon Islands.

even one metre would be enough to 'sink' such islands, rendering them uninhabitable and delivering the outcome depicted in the Minties wrapper scene reproduced in Figure 8-10.

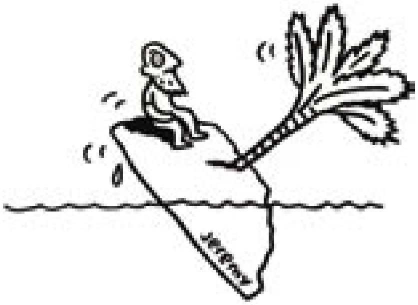

Figure 8-10. Sea level rise could produce the same result as shown here (taken from a Minties wrapper) on tropical strands, atolls and coral islands that are the natural home to the coconut palm. (Jeremy for DESIGN lab)

Figure 8-11. Examples of furniture manufactured from coconut wood by the Pacific Green Company.

chapter 9

Selecting a sound coconut at the market, and processing it at home

The immature fruit (the 'tender' or drinking nut), prized as a source of pure and refreshing drink, is opened while you wait by skilled vendors in tropical markets. The amateur, trying to do this at home, must use a suitable machete in a safe manner. Practise makes perfect.

The mature fresh fruit must be dehusked to allow access to the bare nut, or split with an axe to get directly to the kernel. Suitable tools allow dehusking by the unaided beginner. After the water is recovered, there are various ways to remove and process the kernel.

Preparing a 'tender nut': a specialised task

The urban dweller does not usually find a coconut for drinking, called a 'tender' or 'drinking' nut, on sale in the local markets. But coconut juice (known also as coconut water, and by many visitors erroneously as 'coconut milk'; see Chapter 7) is a featured drink at informal markets and roadside stalls close by the farms where the fruits are produced. The roadside drink seller presents the fruit with the husk already sliced from the lower end and cuts a hole through the shell to take a drinking straw.

Figure 9-1. A metal dehusking pipe supported by a triangular base. The pipe may be unscrewed from the base for easy portability.

If you are a novice, trim the tender nut carefully at the lower end, where the husk is thinnest. Be careful with the trimming knife; the risk of injury will diminish with accumulated experience. Another approach is to dehusk the fruit and then pierce the 'soft eye' to gain access to the water with a straw. The immature fruit is more difficult to dehusk than the mature fruit. And beware the moist husk, because it stains all that it touches!

Dehusking: a choice of tools

There are two basic ways of dehusking a coconut fruit by hand: first, using a spike fixed firmly and more or less vertically so that its tip is about 600 mm high (higher for a tall person); second, using a 'coconut knife'.

The spike technique is used wherever the coconut is grown. The operator holds the fruit horizontal and pushes its upper or 'stalk' end firmly down onto the spike, opening the first incision in the side of the husk. The fruit is then rotated about one fifth of a turn and pushed onto the spike with a movement that drags the husk outwards between the first and second incisions. That strip of husk can then be pulled by hand towards the bottom of the fruit, exposing a narrow section of the nut within. A series of similar moves completes the removal of the husk in three or four more pieces.

Figure 9-2. The spike of a common digging pick being employed for dehusking — convenient, but not an ideal height for comfortable use.

There are many good dehusking spike designs, including a wooden or metal shaft with the upper end formed into a 'blade' and with the base driven into the ground or attached to a portable base (Figure 9-1). It is also possible to use the point of a trenching tool, known in Australia as a 'pick', and there are many ingenious mechanised dehusking devices that use hooks in various ways to grab chunks of husk, or that have a split spike with one hinged half that is forced away from the other half with a pedal-operated lever, dragging a piece of husk with it.

The coconut knife (Figure 7-5 in Chapter 7) serves as a dehusking tool, as its flat, sharpened end is easily inserted into the husk. With the fruit resting on the ground, insert the knife deep into the husk near the upper end of the fruit and then push the knife, edge first, towards the top of the fruit, creating a sliced incision. Rotate the fruit about one sixth of a turn and make a second incision before pushing the handle sideways to lever up the tuft of husk between the incisions, separating it from the shell (move 2 in Figure 9-3). Grasp the tuft and use a strong pull while holding the fruit firmly to separate the tuft from the fruit. Repeat this procedure, levering with the knife and pulling the husk off bit by bit, until the nut is fully dehusked.

Buying a fresh mature nut

The coconut user who has access only to dehusked nuts at the market needs to be alert to indicators of freshness. Choosing a nut requires care and the use of indirect indicators of quality, because the edible portion is completely concealed within the shell.

The first thing to do is to feel the weight of the nut: if it seems light compared to others, there will be

Figure 9-3. A sequence of moves in dehusking the fruit with a 'coconut knife'. The first incision (left) is followed by another and then a tuft of fibre is levered out (centre) so that it can be grasped and pulled right off (right).

little water left inside. Select only a nut that makes a splashing sound when you shake it, indicating that plenty of water remains.

Next, examine the soft eye, making sure that you have distinguished it from the two 'blind' eyes. The shell is usually slightly raised around one side of each blind eye. Also, there are three faint 'stripes' on the shell extending around from the bottom to the top (the end where the eyes are), and meeting at a point between the three eyes. The angle between the two stripes closest to the soft eye is much wider than the other two

Figure 9-4. A spiral of kernel extracted using the coconut knife which is shown in Figure 9-3.

angles. Quite often, the soft eye is notably larger than the other two and the shell encircling it is not raised, making recognition very simple.

Look carefully for any discolouration on the soft eye; it is normally covered by a dry, brown disc. If the embryo is exposed or protruding through the eye, reject the nut because infection and spoilage of the kernel is likely. Bacterial and fungal 'spoilers', which enter through the soft eye, spread very quickly inside the nut. The nut water and the inner surface of the kernel are a very favourable place for invading microbes.

Look at the whole nut for signs of patchy staining due to leakage of moisture from a crack in the shell. 'Old' nuts have a greyish look on the fragments of husk that remain on the surface, instead of a fresh brown look. Fresh mature nuts have a shelf-life of perhaps two months at moderate or low temperature (below 20°C). The delay between collection from a farm and presentation in an urban market can sometimes be longer than this, and a proportion of nuts is generally unsuitable for consumption. The vendor faces the same problems as the buyer and may have difficulty screening out bad nuts. So buyer beware!

Nuts from the Caribbean are marketed in the United States, Canada and Europe in a plastic shrink-wrap package with an opening surrounding the eyes. This is intended to extend the shelf life by slowing down evaporation of the nut water. Such wrapping might also reduce the access of decomposing organisms to the kernel via minute channels through the shell (the channels were once connected to fibres and through them to the palm). Arguably, a nut with a 10–20-mm coat of intact fibre is less prone to bacterial invasion than a nut that has been scraped clean. In the future, a processor may devise a way to seal the shell and soft eye so well that the nut has a greatly prolonged shelf-life, becoming equivalent to a sealed, canned product.

Cool storage suppresses the activity of microorganisms, keeping the nut fresh for longer, and freezing has been shown to work on a small scale. The value of the nut is probably not high enough, however, to justify freezing by the marketer. Defrosted kernel is softer and more easily chewed, having lost some of the firm crispness of the fresh kernel, without loss of any flavour. This makes shredding in a blender or juicer easier, and allows you to make coconut milk in your own kitchen.

Recovering the water

There are many ways to deal with the fresh mature coconut. The task is usually a novel one for the buyer, and usually involves piercing and reaming out a small plug of kernel from behind the soft eye in order to recover the water for drinking. It there is a bad aroma in the water, reject it. In such a case, the kernel is likely to be off-flavour too, but not always—if there is no trace of discolouration, the kernel may still be 'sweet' and edible.

Many users open the nut after draining by throwing it down hard on concrete, or by placing it in two shopping bag (one inside the other), and then smashing it against a hard surface. The kernel is fairly easily prised away from small pieces of broken shell. With a suitable tool, however, such as a heavy-bladed coconut knife (Figure 7-5 in Chapter 7), a 300-mm length of 12-mm iron rod, or a small axe or cleaver, you can split a nut into two neat hemispheres with a very firm, sharp blow or two on the nut's 'equator'.

Figure 9-5. Mature nuts partially dehusked, with a coating of intact fibres. Leaving some fibres attached extends the shelf life of the nut but may not be acceptable to plant quarantine inspectors where nuts are imported.

If you fear injury to the hand that holds the nut, play safe by using a guide stick to control the splitting implement. Rest the nut on a firm surface, supported with a loose towel so that it does not roll. Hold a ruler or stick vertically and firmly against the equator of the nut, and then slide the tool down, striking hard parallel to the equator, to open a crack in the nut. Once a distinct crack appears, you can insert a knife to prise the two halves apart. Some nuts have quite thick shells, requiring blows of increased force with the cracking tool; others have thin shells that crack wide open at the first try.

Water drains out as the nut halves are separated. It is easily collected in an open dish, and this method is simpler than draining it out beforehand through the soft eye.

Recovering the kernel

The kernel can be extracted in narrow strips from the half-nut in two ways. One way is to carefully push the sharp end of a coconut knife into the edge of the kernel and then make a parallel cut 10–15 mm from the edge while the blade slides along the inner surface of the shell, prising the kernel sideways and separating it from the shell. Push the knife all the way around the edge of the hemisphere, removing the kernel in strips, or perhaps forming a spiral if the kernel holds together (Figure 9-6). Alternatively, use a strong, thin-bladed knife to cut along a similar line to that made with the coconut knife, but without displacing the kernel sideways. After making a cut halfway around the half-nut, slide the knife between the strip of kernel and the shell to separate them.

The second method of kernel extraction is to shred it out of the half-nut using a tool with special teeth or scraping loops, as described below. You can also remove the kernel in a half-nut in one piece, after 'loosening' it with heat. After two or three minutes in a microwave oven set to 'high', the kernel around the edge begins to separate from the shell. Coax it right out of the shell with a flexible knife blade.

An innovative way of removing the soft or medium-firm kernel of immature nuts has been developed in India to produce a culinary product known as the 'snowball' (see Figure 10-8 in Chapter 10). The dehusked nut is held against a shielded circular-saw blade and rotated to achieve a cut right around the equator that is at most 8 mm deep (the shell is usually 4–6 mm thick). A thin, flexible blade with a rounded end is inserted between the shell and the kernel, and pushed around to separate the kernel from the shell on each half of the nut. The white sphere that emerges can be presented as dessert, with a straw inserted for drinking the water, after which it can be divided up and consumed.

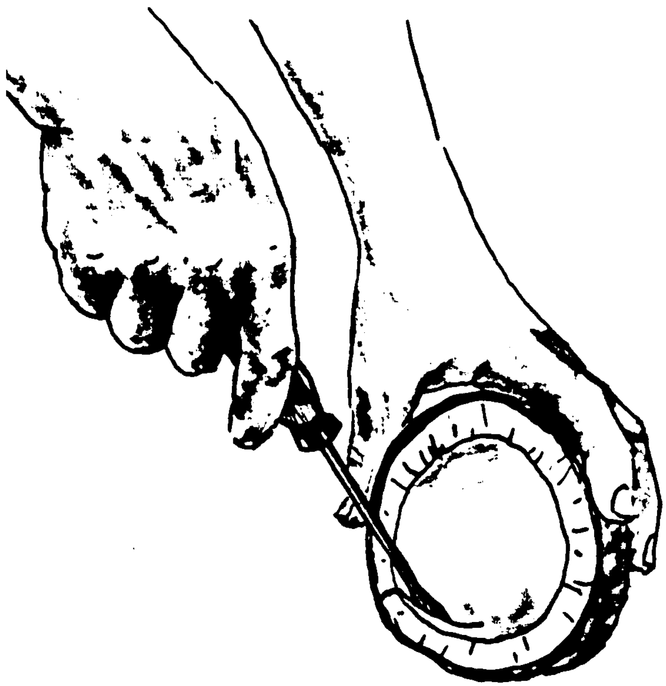

Figure 9-6. Coconut kernel being extracted from a half nut using the blade of a screw-driver. A robust table knife with a rounded end could also be used, but a coconut knife performs this task more efficiently.

The mature nut, partially dehusked but with a layer of fibre left all round, is used as an offering in Hindu ritual. Market demand for fresh mature nuts increases in the lead-up to certain major festivals. In the course of the ritual, the nut is broken open and the water poured out. Usually, the kernel is taken for consumption after the ceremony.

Figure 9-7. Diced kernel that can be partially dried and browned in the microwave to produce tasty coconut 'nibblies'.

Ways to use the kernel

The industrialised production of desiccated coconut usually begins with the removal of shell from dehusked nuts by a highly skilled operator, who chips the shell away with a special curved metal knife, leaving the kernel as an intact ball in the hand. The brown outer coating on the kernel is then pared away, the water is collected, and the white ball of kernel is washed and fed into a machine, which converts it to the type of shreds, fines or flakes required. Prompt drying to below 5% moisture content, combined with very careful sanitary procedures throughout, ensures a stable and uncontaminated final product. Some processors add sugar to desiccated coconut to increase the appeal of its flavour, and some also add a preservative, such as sulphite, as 'insurance' to suppress any microorganisms.

Once the kernel has been removed in strips, chunks or half-nut form, people with sound teeth can chew it and enjoy the fresh coconut flavour. Kernel chunks that have been frozen and defrosted are softened and more easily chewed, but will not have lost any flavour. These soft pieces are also more easily processed in a blender or juicer for the preparation of coconut cream (unfrozen kernel should be chopped into small pieces before processing). The product from the blender can be used as topping for dessert or squeezed by hand or through a cloth to produce coconut cream, as described in more detail below.

Small, 10-mm cubed pieces of fresh kernel make attractive 'nibblies' after being roasted in a microwave to enhance the flavour (Figure 9-7).

Shredding the kernel for coconut cream and coconut milk

An alternative to cutting the mature kernel free from the shell in chunks is to scrape it out using the traditional 'comb' of ancient coconut cultures (a flat metal strip 20–40 mm wide, with a dozen or more short teeth formed by making shallow saw cuts across one end), the hand-held scraper of the Philippines, or the rotating Sri Lankan hemispherical shredder operated either by hand or motor. The hand rotation device (Figure 7-2) is quite rapid, as the entire kernel contents of a half-nut can be extracted as shreds in a minute or so. It takes a little practice to avoid including some of the brown scrapings from the inside of the shell in the extract. In many local markets in Sri Lanka and elsewhere, the buyer can now choose a nut from the pile and hand it to the vendor, who shreds it expertly with a motorised device for little extra charge.

The main reason kernel is shredded is to permit the extraction from it of coconut cream or coconut milk. One extraction method involves squeezing the raw shreds inside a cloth 'filter' to force out the thick coconut cream, which has a high oil content and a strong coconut flavour. When the cream has been collected, a chosen volume of hot water is added to help extract the remainder of the emulsion from the kernel and the cloth is squeezed again, producing the lighter liquid known as coconut milk.

Some villagers simply knead the shreds and water vigorously and squeeze the it in their bare hands to separate out the milk (see Figure 7-3 in Chapter 7). Two such pressings will yield most of the potential coconut milk. Passing the milk through a strainer (such as muslin cloth) will separate remaining shreds from the liquid.

Various types of mechanised press are used industrially to extract cream from the kernel more effectively and efficiently than hand methods.

From the consumer's point of view, it is useful to know the 'strength' of a coconut milk product. Standards proposed by the Asian Pacific Coconut Community for different grades of kernel extract are shown in Table 9.1:

The composition of preserved coconut milk and cream is revealed on some labels, but manufacturers are obliged to do so only in response to national legislation. It is up to the consumer to demand product specification for the sake of consistency.

Table 9.1. Standards for kernel extracts

	Minimum coconut fat (%)	Maximum water (%)	Gap (%)[a]
Coconut cream	19.0	75.0	6.0
Coconut milk	11.5	85.0	3.5
Coconut light milk	6.0	92.5	1.5

[a] The 'gap' may be filled with coconut fat or other ingredients, such as natural sugar and protein.

Source: Asia Pacific Coconut Community Draft Standard APCC STAN 3:1995D

Coconut milk: culinary uses

Coconut milk should be used soon after extraction, as it has a refrigerated shelf-life of only 3–4 days. It is rich in oil, sugars and proteins, and is a very hospitable medium for microorganisms.

Coconut milk has formed part of the traditional diet of many indigenous tropical peoples for millennia, and is credited by nutritionists with contributing to those peoples' outstandingly high level of dental and physical health (see Chapter 11). When such people move from traditional foods to a diet high in carbohydrate and 'long-chain' fats, their health deteriorates alarmingly. Many people in industrial societies now seek minimise their intake of coconut oil for health reasons, but most are confused about its use because of the negative massages delivered by marketers of competing food oils.

It would require a large consumption of coconut cream in one's prepared food to achieve the common target of a daily intake of 50 mL of oil. Enthusiastic users are inclined to consume coconut oil 'raw'.

Extracting oil from shredded kernel

Partially dried, shredded coconut kernel is a useful feedstock for the separation of high-quality coconut oil. Fresh kernel has a moisture content around 50%, which should be reduced to around 12% for oil extraction. Shreds release oil far more readily at this moisture content than when dried for storage, usually to around 6%. Desiccated coconut is usually packaged at 5% moisture content, and would require careful remoistening to enable efficient oil extraction.

The Direct Micro-Expelling (DME) oil extraction kit produced by Kokonut Pacific Ltd allows 'virgin' coconut oil to be extracted with 90% efficiency (see Chapter 10). Virgin coconut oil has outstanding qualities of aroma and flavour, and is much in demand for cooking, cosmetic and pharmaceutical uses.

Separating coconut oil from coconut milk

A technique widely used in the Philippines to produce high-quality virgin coconut oil relies on natural separation of the oil from the standing milk at ambient temperature. The technique is explained in Chapter 10.

In Melanesia, where firewood is plentiful, the milk or cream is heated directly until all the water has evaporated. This product loses some of the aroma retained in oil that has not been subjected to prolonged heating.

chapter 10

The coconut's industrial history, and future

The coconut has had a 150-year 'industrial' history affected by war and depression. Productive capacity is still limited by this legacy.

Familiar coconut food products have an assured future, and some have untapped market potential.

Coconut oil is ideal for cooking, but is also used in superior soaps and detergents. Its proven performance as diesel motor fuel has added to its value, especially in remote locations.

Industrial demand builds the early copra trade

The coconut production from many of the most favoured tropical environments has recently come almost to the end of a 150-year period of 'capture' by industrial economies. That era began early in the 19th century, with investment in ever more production capacity to meet demand for soap and lighting, and for substitutes for scarce animal fats in cooking. In the United States, coconut oil was especially prominent, partly because of that country's decades-long colonial tie to the Philippines, which ended only with the 1941 Japanese invasion.

Demand for soap in Europe in the early 19th century translated into imports of coconut oil from the Far East, when sources of home-grown and imported animal fats (including tallow from remote colonies like Australia, and whale oil), failed to meet demand. By the end of the century, European investment capital was being directed into coconut plantations in Sri Lanka, the Netherlands East Indies (Indonesia), Malaya, Fiji, the Philippines, some Caribbean colonies and elsewhere to produce copra—the storable, transportable form of coconut kernel. For many decades, oil extraction from copra was done only in the importing countries, chiefly the United States and the European countries.

Plantation development remained buoyant during World War I (1914–18) and reached a peak just before 1920, when it encompassed the colonies of the South Pacific (Papua and New Guinea, Solomon Islands, Vanuatu, Fiji, Samoa). There was even a flurry of small-scale planting in Australia to supply oil for glycerine to support the manufacture of explosives. The global economic depression, beginning in 1929, saw profits from copra production fall and foreign investment in new plantations cease.

War brings competitors

Military occupation during the war in the Pacific (1941–45) interrupted exports from several large coconut-producing regions, which led to a severe shortage of vegetable oil in industrial nations. The shortage was particularly acute in United States, which responded with a huge research effort to boost the local vegetable oil supply

Figure 10-1. Some examples of merchandised coconut products: (L–R) soap, cooking oil, two brands of milk, and juice. There are many brands of milk and cream, and the buyer should check the label for a listing of ingredients, including the percentage of fat (see Chapter 9 for details).

using annual oil crops. Until then, home-grown American vegetable oils (by-products from cottonseed, soybean and maize) had mostly been used in paint formulations for structural timber, but now they were promoted vigorously in the food market. Soybeans, in particular, were selected and bred to become highly productive under the farming conditions prevailing in millions of hectares of the American mid-west.

By the end of World War II in 1945, soybean oil had the potential to capture much of the market share previously held by coconut oil. In the next two or three decades, that is precisely what happened.

An unrestrained marketing campaign succeeded in persuading most consumers that soybean oil and its derivatives were healthy, and that coconut oil (along with dairy and other saturated animal fats) was not. In spite of a substantial postwar recovery in the supply of coconut oil, the market share and price gradually declined to a level too low to revitalise plantation-scale production.

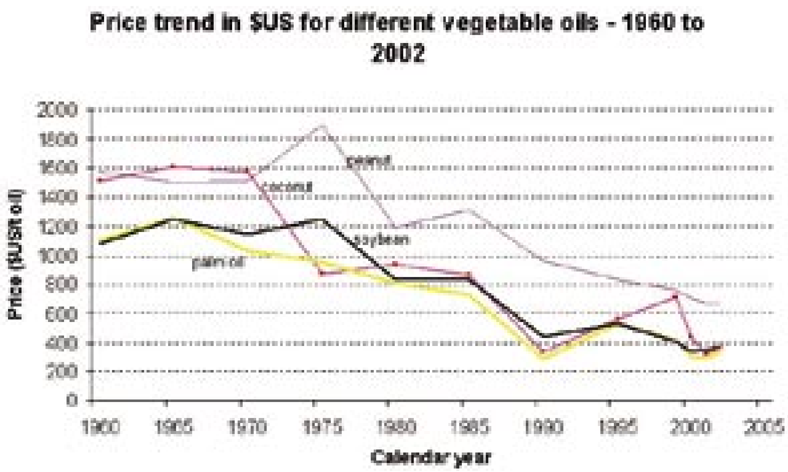

Figure 10-2. Price trend of coconut oil and three other vegetable oils between 1960 and 2001. In 2002 the price is so poor that many smallholders no longer find it worth while to produce copra. Coconut oil showed a sharp decline in price during the 1970s. The attack of the marketers of unsaturated oils on saturated fat, beginning in the 1960s, eventually depressed the entire market for vegetable oils as consumers mistakenly came to believe that dietary oil was dangerous.

Failure to stop a downhill slide of market demand

During the decades since 1960, the export price of copra fluctuated wildly in response to short-term variations in supply, but always showed a strong downward trend (Figure 10-2).

Oil palm, which yields both palm oil and palm-kernel oil, expanded rapidly as a crop during the 1960s despite similar price fluctuations, and succeeded in countering the downward price trend with yield improvement through breeding and management. Fortunately for palm-oil producers, their plantations were mostly established in regions free from the destructive hazards of cyclones, hurricanes and typhoons, which frequently disrupt coconut production. The coconut palm usually survives such weather, but its production is depressed for a year or more after the event.

It was thought that coconut would be able to recover its profitability with similar yield increases, but it is now recognised that coconut has a substantially lower potential yield of oil than oil palm, mainly because of the coconut's high proportion of non-fatty fruit components. Coconut also exhibits strong, age-related changes in its capacity to intercept light, the ultimate determinant of yield. There have been impressive yield increases achieved with hybrid coconuts in high-resource environments, because of their earlier fruiting and because of beneficial changes in the partitioning of energy between oil and various organs (shell, husk and trunk).

The very diversity of the coconut palm's usable components, however much it decreases the output of oil, perhaps ensures that the palm will retain a buoyant place in the economy of traditional coconut regions, which relies on the enterprise of smallholders.

Demand for lauric oils underpins market

The prospect of reviving a plantation-based economy for coconut oil seems now to have faded completely, as resources that might suit that scale of operation are probably more profitably invested in other crops, especially oil palm. Fortunately, the demand for the coconut's lauric oil for industrial use in developed economies has underpinned demand for coconut oil in that sector, preventing a collapse. Sodium laurel sulphate (SLS, a derivative of lauric acid) and other coco-chemicals are used in many detergent products. SLS is a staple product in the detergent industry because the major alternative, alkyl benzene, has been banned for use in household detergents in most countries. Alkyl benzene has very poor biodegradability, whereas SLS is an excellent cleanser and is biodegradable as well.

Coconut faces uncertainty even in the lauric oil market, however, as genetically modified 'lauric canola' is now widely grown in North America. Ironically, the appearance of this competing oil, along with a huge increase in the supply of palm-kernel oil (which has a 30% lauric oil content), has somewhat stabilised the supply and steadied the sluggish market (Figure 10-2). When coconut oil was the principal lauric oil, prices fluctuated widely in response to variations in supply.

Figure 10-2 also records a decline in the prices of all vegetable oils. It is mainly the huge decline in food uses of coconut oil in industrialised countries, however, that has eroded coconut oil's once leading price in the oilseed market.

This is attributed to wide adoption of low-fat diets in the United States, as a result of the denigration of saturated fats by the promoters of unsaturated fats, followed by the realisation that hydrogenated unsaturated fats present a whole new set of health problems. Coupled with these changes is a widespread 'gut logic' suggesting that fat in the diet translates to fat accumulation in the body. In Chapter 11, I explain in detail why this is a misguided view.

This combination of confusion and contradictions in the food industry about healthy and unhealthy fat, and an aversion to fat in favour of high-carbohydrate diets, has left the average consumer baffled—and the market for fats and oils very flat.

Besides market warfare, the coconut has faced further difficulties because supply to its principal markets is prone to disruption by to extremes of weather. Drought affects production in many places, and typhoons do so in the Philippines, which is the largest exporter. India and Indonesia may be larger producers, but they do not export as much. Indian producers, particularly, cater to massive home market.

The legacy of copra production

A strong industrial 'hangover' still affects the production of many coconut farmers, especially in large producers like the Philippines and Indonesia, where copra was once the lynchpin. Old processing technology and infrastructure are still in use. Smallholder clients are more or less 'locked in' by the dominant industry of their districts, either copra making or sale of fresh nuts for desiccated coconut, and are nearly powerless to generate alternative products. They have delayed replanting because of their need to hold on to the meagre income that old palms can generate, compared to the alternative of lower income during the regeneration phase. There is also an expectation that higher-yielding coconut palms might be made available some time soon.

Farmers need reminding that young palms will probably yield five times more than palms of the same variety, in the same district, greater than 50 years of age. This might spur some farmers to begin replanting, ideally in a phased operation taking perhaps one quarter of the farm at a time, and generating some extra income by selling the trunks of the old palms for milling. In some areas, coconut trunks are now highly prized for their timber value, which would ease the financial risk of replanting.

The traditional coconut plantation was dedicated to the production of copra, which is simply the dried kernel, for transport to a processor in an industrialised country. In many cases, copra was produced by cutting the kernel from split whole fruit in the field and transporting it 'green' to a drier fuelled by firewood, husks and shells, or mineral oil.

Alternatively, the whole nuts were transported to a central area and dehusked there. The split nuts were dried and the shell separated later. Both husk and shell made up the fuel supply.

Once dry, the copra was stored in sacks and exported from the nearest port. This meant that many months passed between production and further processing. Some quality control was imposed to ensure that the copra did not become seriously infested with destructive insects or microorganisms during its long journey.

The processor expressed the oil after grinding and heating the copra, and then applied three treatments—refining, bleaching and deodorising—to bring the oil to an acceptable standard of clarity, colour and aroma. This oil was then marketed as deep-frying oil, as shortening for general domestic use, and for soap and detergent making.

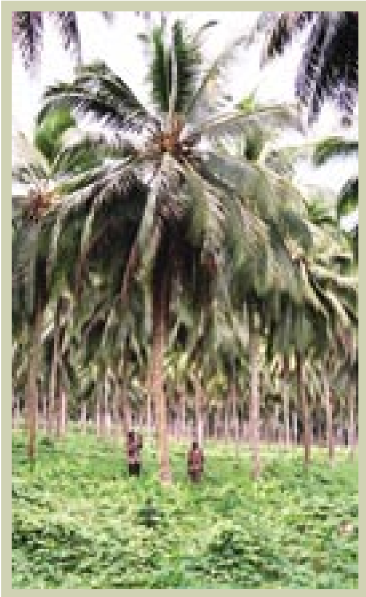

Figure 10-3. Extensive coconut plantation — a rare sight at the beginning of the 21st century. (Roland Bourdeix, Centre for International Cooperation in Agricultural Research for Development (CIRAD), France)

Naturally, the highest price was paid for the food uses of oil—the market that has been all but destroyed by the marketing push of the producers of polyunsaturated oil from soybean, cotton and maize, and more recently from sunflower and canola.

Small-scale and medium-scale processing for high-quality products

Very few large-scale copra plantations remain, because the price has generally become uneconomical for that mode of production. However, many smallholders in the really large coconut economies of Indonesia, the Philippines and India remain locked into particular processors, who still specialise in extracting oil from copra.

There is hope that small-scale local production of coconut oil will experience a resurgence in the near future, as appropriate technology in the form of the DME (Direct Micro-expelling) method (invented in Australia by Dr Dan Etherington), or the fermentation method employed in the Philippines (see below), become more widely used. Besides making good quality oil that qualifies for the 'virgin cold-pressed coconut oil' (VCNO) label and is available for local food use, these processes hold out the prospect supplying an economical diesel fuel replacement in isolated areas.

Figure 10-4. Large-scale processing area for coconut fruits in Mozambique, with dryers close by.

The DME oil extraction kit produced by Kokonut Pacific Ltd consists of a perforated cylindrical metal tube and a compressing plunger connected to a hand-operated lever. This kit allows up to 90% of the oil to be extracted from well-prepared coconut shreds.

Medium-scale mechanical processing of 3600 coconuts per hour has been achieved by another Australia-based inventor, Coconut Processing Company Pty Ltd. Whole fruit are fed into a machine, which slices them in half lengthways and uses a water jet to extract the kernel in one piece from each half. The extracted kernel is shredded, dried quickly and pressed. The oil produced is of the highest quality, outstandingly fresh, and suitable for food or any other use. The husk and shell are passed though a beater and separator, producing clean shell, pith and coir.

A traditional Philippines' process, based on fermentation over a period of one or two days, also produces high-quality oil from extracted coconut milk. Practised at the cottage level, this method relies on the separation of oil from its emulsion in the milk as the sugar and other ingredients in the milk are consumed by the fermentation process. The oil floats to the surface to be skimmed off and then heated to a moderate temperature to evaporate any residual moisture. With rigorous attention to cleanliness and temperature control, this oil also qualifies for the VCNO label, to which in most cases an 'organic' label can also be added, as chemical use in coconut groves is rare indeed.

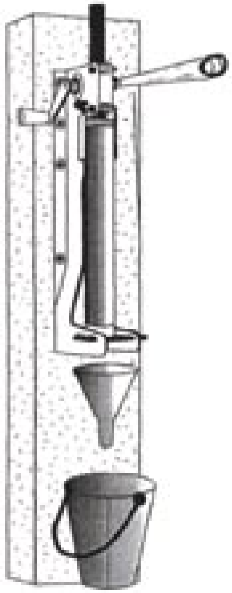

Figure 10-5. Schematic of the press used in the DME (Direct Micro-Expelling) system of coconut processing. The lever drives a plunger which compresses shredded kernel previously dried to a critical moisture content. Up to 90% of the oil can be extracted with this device. (Dan Etherington)

Figure 10-6. The coconut press being operated in a Fijian village where steady production of high quality virgin coconut oil in now taking place. (Dan Etherington)

High-quality coconut oil would also prove to be a profitable cash earner when supplied to soap and cosmetic manufacturers in smaller nations as an import replacement.

A regional marketing approach for these products, and especially for food derivatives of coconut oil, seems essential to meet the challenge from palm oil. Coming from very highly capitalised enterprises, palm oil has made great inroads into the urban food-oil markets in India, Malaysia, Thailand and China, depressing the local price of coconut oil. The unique health and chemical stability advantages of coconut oil, based on its predominantly short-chain fatty acid mix (see Chapter 11), need to be promoted very strongly to recapture market share.

Some food uses require economies of scale

Access to lucrative markets for desiccated coconut (as an example) in industrial economies is in the hands of large companies whose local monopoly of processing enables them to pay a low price for the supply of fresh nuts. One advantage of such large-scale production units is that quality control is more readily monitored.

Similarly, production of coconut milk for export is highly capitalised, requiring skilled management and technical expertise to succeed. Here too, fresh nuts are purchased from the farmers at the lowest possible price and de-shelled as for desiccated coconut. The kernel is shredded and the cream is pressed out and mixed with water to achieve the desired fat content. After a brief heating to pasteurise it, the product is placed into a can or tetrapak for export (industry standards for coconut cream, milk and lite milk are given in Chapter 9).

Coconut oil as engine fuel

In places where the market for food oil is limited, and particularly on isolated islands, operators of diesel engines have begun to use coconut oil as a fuel replacement. Within the tropics, where the mean temperature is generally above 25°C, coconut oil remains liquid and flows readily through the injectors of a diesel engine. Mixing coconut oil 2:1 with conventional diesel fuel insures against it solidifying if the temperature falls below 25°C and reduces the risk of 'crusting' of the valves with incombustible residue after many hours of running time. In cooler environments, the engine can be started on diesel fuel and switched over to coconut oil once the coconut oil has been warmed sufficiently by heat transfer.

Nut water or coconut juice

Coconut juice has also become an important commodity, and is exported in bottles and cans from Hainan Island and Vietnam to mainland China (see Figure 10-1). No quality standards have yet been set for the level of any particular components of coconut juice. Juice from markedly immature fruit is quite high in natural sugar (5% or so), but this diminishes as the fruit approaches maturity. Extra sugar is added to many lines of canned coconut juice, but the amount is not specified on the label. One large plantation in Indonesia exports almost its entire production of coconut kernel and water as canned products to a range of markets.

Possibilities for derivatives of coconut sap (toddy)

Palm sugar from coconut sap, or toddy, might become an important product where young, highly productive palms are established. Tapping palms for toddy is a very labour-intensive but traditional pursuit in some parts of Indonesia, where the sap is collected twice daily, and then evaporated to yield palm sugar, prized locally over cane sugar.

Some coconut hybrids produce as much sugar (in tonnes per hectare per year) as sugarcane, but the relative economics of these two sources of sugar, in a range of environments, has not yet been studied. Cane sugar production costs can be greatly reduced by mechanisation, whereas toddy tapping of the coconut will always be labour intensive. There appears to be great potential for high-value nonalcoholic derivatives of coconut toddy as a health drink, especially for children.

Processing fibre and shell requires specialised skills

Coconut fibre (100 000 tonnes per year) and shell (300 000 tonnes per year) are still traded widely on the global market, and are especially valuable to India and Sri Lanka, where there is a strong tradition of processing them and a substantial export trade. In countries that lack this tradition, there is little inclination to begin processing fibre, partly due to the absence of the required specialised skills. The introduction of simple hammer-milling and combing might stimulate fibre processing in other communities.

The dependence of many producers worldwide on husks and shells for domestic fuel might militate against adding value to husk in this way. The ash from husks and shells is particularly high in potash and is used to fertilise potassium-hungry palms. Potash is also readily leached into the soil from mulched husk kept in the field. This is an important matter, because potassium deficiency frequently limits the productivity of the coconut on many different soil types.

Coconut shell continues to be in demand as a source of charcoal and particularly of activated carbon for chemical processes like the separation of gold from crushed ore, with the Philippines and Sri Lanka being major exporters. Coconut shell powder is used as the combustible carrier in mosquito repellant coils.

Great potential remains for coconut shell in artefacts produced on a cottage scale for the tourist market. The shell can be polished very easily using a succession of sandpapers (such as grades 60, 120 and 240) to provide an increasingly fine finish.

Polishing the interior of the curved shell is a greater challenge, requiring a rounded carrier for the sandpaper.

Objects of great appeal can be made from coconut shell, especially when they are finished with a dark varnish.

Figure 10-7. A very large, polished coconut shell used to support a flower display.

Niche marketing of high-value products

In local markets of the coconut heartland, a wide range of coconut food products is readily available. These include fresh coconuts, raw and shredded kernel, coconut chutney and coconut jam, oil (both virgin and copra-derived), coconut milk and coconut water, and, in certain cultures, both fresh and fermented toddy.

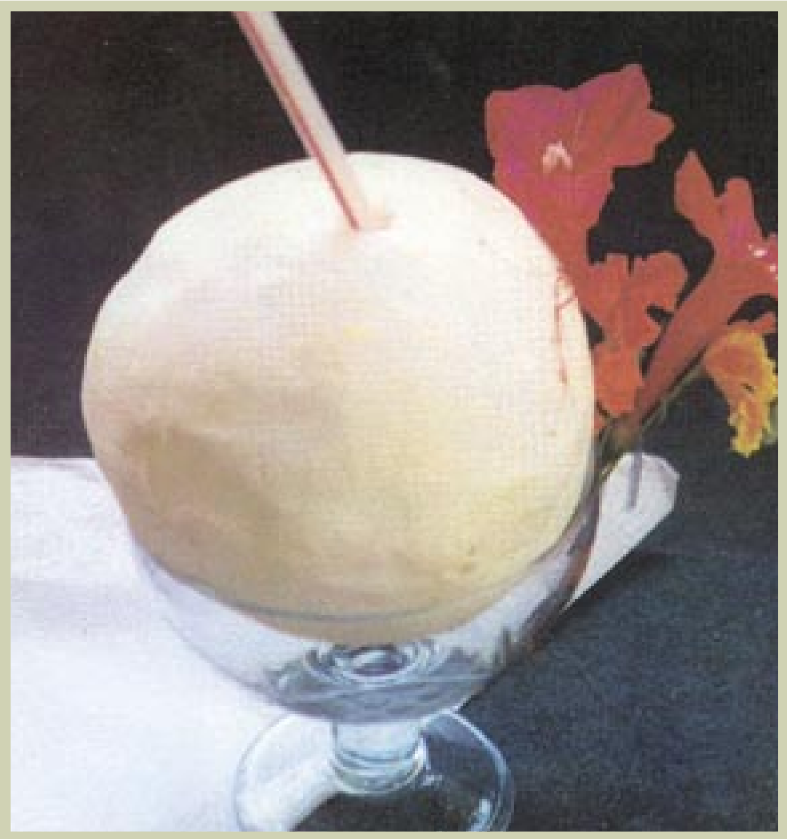

Figure 10-8 A 'snowball' prepared from an immature nut and presented as dessert, comprising both soft kernel and its contents of nut-water (fresh coconut juice).

In India, there has been a concerted effort to develop novel products, and recently two very promising items have emerged. One consists of sweet, dried flakes of coconut kernel, produced by immersing thin flakes of fresh kernel in a concentrated sugar solution long enough to remove most of the water. The flakes acquire a trace of sugar coating while retaining their distinctive coconut flavour, making them very attractive indeed.

The second new product is known as the 'snowball'. It is a complete ball of immature kernel extracted from the nut while retaining the water inside (the technique is described in Chapter 9). The pure white sphere is placed in a goblet and a straw is inserted to allow the water to be drunk. The kernel is then consumed, using a small knife or spoon. The snowball fetches the equivalent of US$5–10 at smart restaurants and resorts (see Figure 10-8).

chapter 11

The wonder food

Since antiquity, coconut has been a staple food of many indigenous peoples. It was embraced by industrial society as a raw material for many products in the 19th century, but in the late 20th century an onslaught by competition saw its use decline.

There is both scientific and abundant anecdotal evidence coconut's great health benefits, including increased energy, weight loss through the burning of body fat, natural antibiotic activity, cholesterol reduction and insulin stabilisation.

A valuable staple since antiquity

Early European navigators visiting the tropical coasts of the Indian and Pacific oceans noted with surprise the outstanding fitness and good health of the indigenous people. The visitors learned that the inhabitants of these regions had been consuming coconut for thousands of years. King Manuel I of Portugal, upon learning from explorer Vasco da Gama of the great role that coconut played in the human economy in coastal west India, wrote in 1501:

> …from these trees and their fruit are made the following things: sugar, honey, oil, wine, vinegar, charcoal and cordage…and matting…and it serves them for everything they need. And the aforesaid fruit, in addition to what is thus made of it, is their chief food, particularly at sea.

In 1606, the Spanish navigator Torres explored the southern coastline of mainland New Guinea, encountering many native peoples who depended on the coconut as a major food item. He wrote of one group:

> Some of them are brown, well built and robust. They have very little variety of food, only having a few cocoanuts and roots. Their nourishment is from fish and shellfish.

Torres thus records that people whose diet comprised coconut, roots (probably yams) and a variety of seafoods were not just surviving on their island, but were strong and healthy.

In the 1930s, Dr Weston A. Price, an American dentist, visited the South Pacific to study the relationship of diet to both dental and general health. He found that people consuming traditional foods, which commonly meant a diet of at least 60% coconut, had excellent teeth with no dental caries, and were generally free from serious illness. On the other hand, among islanders who had moved to trade centres—adopting an urban diet high in processed carbohydrates and low in coconut—there was 26% incidence of dental caries and 'progressive development of degenerative disease'.

Coconut's market grows, then collapses

As I have detailed in Chapter 10, coconut oil played a key part in Europe's industrial revolution. Originally used in soapmaking, it was also needed for lighting and for cooking. Along with desiccated coconut, the oil became a staple shortening ingredient in biscuit and cake recipes.

The global depression that began in 1929 hit coconut producers hard, drying up investment capital. World War II in the Pacific (1941–45) disrupted the trade entirely, and manufacturers sought substitutes. A desperate, and impressively successful, agronomic and food processing research effort, especially in the United States, led to the ascendancy of soybean oil.

When the supply of coconut oil was restored after the war, the product faced a wholly new marketplace and could no longer sustain a competitive niche, despite its relatively low price. In order to protect a higher price for home-grown vegetable oil, a marketing strategy was designed that was intended to reduce the appeal of coconut oil, as well as of saturated animal fats.

Saturated and unsaturated fats

Marketers of unsaturated oils were able to place their products in opposition to saturated oils. It is worthwhile to understand a little of the chemistry of food oils.

Table 11-1 presents information about oils of different 'chain length'. This term refers to the number of carbon atoms that are strung together chemically to form the oil molecule. Medium-chain oils have 8–12 carbon atoms and long-chain oils have 14–22 carbon atoms.

In a saturated oil molecule, all the linking ability of every carbon atom is accounted for by stable, single-bond connections to neighbouring carbon atoms in the chain and to other chemical entities, mostly hydrogen atoms.

An unsaturated oil has one (monounsaturated) or more (polyunsaturated) double links between its carbon atoms. Rather than strengthening the linkage, this double bond is unstable, with one of the links readily combining with some external chemical entity. Such combination can cause the breakup of the fat molecule and the release of a 'free fatty acid', which is undesirable. Protection against such external influence by an antioxidant is needed to stabilise the unsaturated oil molecule.

Competitors play dirty

Following reports that experimental rats fed coconut oil as their sole fat showed increased cholesterol in blood serum, a hypothesis that saturated fat raised harmful cholesterol was promulgated and 'marketed' to the food industry. Both coconut oil and saturated animal fats, such as dairy fats, were maligned as unhealthy in an unrelenting campaign that included re-education of professionals throughout the entire health industry.

It only later became clear that any diet lacking in certain essential fatty acids (such as omega-3 alpha linolenic acid) will cause a rise in cholesterol as the health of the experimental animal deteriorates. Such fatty acids are not found in coconut oil or dairy fat (see Table 11-1) and are generally scarce in other saturated fats, but are normally found in other parts of a balanced diet. This proof of the lack of scientific soundness of the early dietary study on coconut oil was ignored by the marketers of the unsaturated fats that contained the essential fatty acids. The unqualified condemnation of saturated fats continued from the 1970s onwards.

Saturated fats from vegetable sources (such as coconut oil) and those from animal products (such as beef, mutton, pork and dairy milk) were both targeted. The combined marketing and political muscle of the unsaturated fat processors was so great that they persuaded health and food regulators to accept the 'saturated fat hypothesis'. The United States Food and Drug Administration, the American Heart Association, and the population at large, influenced by food journalists and medical practitioners, accepted as truth the claim that the saturated fats in coconut oil were harmful to health.

The reputation of coconut oil was destroyed, notwithstanding that hundreds of generations of coastal dwellers in South-East Asia and the Pacific had thrived on a diet of coconut, fish and small amounts of carbohydrates. Indeed, in the United States in the early 20th century, when fatty meat was common in the diet, heart disease was, according to Mary G. Enig in her book, Know your fats, practically unknown.

Table 11-1. Proportion of edible fatty acids in the oil of different natural products (%). Carbon atoms/molecule and number of

Source of oil	Caprylic 8	Capric 10	Lauric 12	Myristic 14	Palmitic 16	
Coconut	8	7	49	18	8	
Palm kernel	4	4	50	16	8	
Palm				1	45	
Cocoa					24	
Soy					11	
Olive					14	
Canola (regular)					4	
Canola (laurate)			37	4	3	
Sunflower (regular)					7	
Sunflower (high oleic)					4	
Corn					12	
Peanut					12	
Cotton				1	26	
Safflower (high linoleic)					6	
Safflower (high oleic)					5	
Sesame					10	
Almond					7	
Avocado					17	
Black currant					7	
Flax-seed					6	
Grapeseed					7	
Butter	1	2	3	12	26	
Poultry			1		23	
Lard				1	25	
Tallow				3	25	
Cod liver				4	14	

[a] includes 17% gamma linolenic; [b] includes 4% butyric; [c] includes 7% each of EPA (eicosapentaenoic) and DHA (docosahexaenoic)

double bonds are shown beside the name of each fatty acid.

	Stearic 18	Palmitoleic 16:1	Oleic 18:1	Linoleic 18:2	α Linolenic 18:3	Others
	2		6	2		
	2		14	2		
	5		39	9		
	35		38	2		
	4		23	53	8	
	2	1	71	10	1	
	2		59	23	10	2
	1		33	12	7	1
	5		19	68	1	
	5		81	8	1	
	2		28	57	1	
	5		46	31		6
	2		18	53		
	2		13	78		
	2		80	12		
	5		41	43		
	2		61	30	1	
		3	68	12	1	
	2		11	47	13	20[a]
	3		17	14	60	
	4		16	72	1	
	12	2	28	3	1	8[b]
	6	7	42	19	1	
	12	3	45	10	1	
	22	3	39	2	1	2
	3	12	22	1		44[c]

Explanation of Table 11-1

This table presents data from the book "Know your fats – the complete primer for understanding the nutrition of fats, oils and cholesterol" by Mary Enig (Bethesda Press, 2000. Silver Spring, Maryland).

The proportion of the various fatty acids that are found in the oil of the different crop products varies a little, but the values presented – which are the averages from extensive analyses, enable useful comparisons to be made. The mix of fatty acids in oils from animal sources, of which a few generic examples are shown, are more flexible than from crop sources, being usually much affected by the oil composition of the animal's diet.

Six saturated fatty acids are shown in the first six columns, two mono-unsaturated fatty acids are next, and then the two most common polyunsaturated fatty acids, the omega-6 linoleic and the omega-3 alpha linolenic. Coconut, palm kernel, lauric canola and butter stand apart through having many components in the short and medium-chain fatty acid group (six to fourteen carbons per molecule). The other two saturated fatty acids, palmitic and stearic are found in all oils though in greatly varying proportion. Likewise the mono-unsaturated oleic acid is present in all sources, with highest values in olive, regular canola, almond, avocado, and transgenic sunflower and safflower.

Poly-unsaturated linoleic is found in all oils, but there is only 1% in cod liver oil. It is an essential fatty acid that is transformed by "elongase" enzymes into the omega-6 forms of EPA and DHA found within the living cell. Similarly alpha linolenic is transformed into omega-3 EPA and DHA. A proportion of linoleic higher than three to four times the level of alpha linolenic monopolises the transforming enzymes in the system, resulting in reduced transformation of the essential omega-3 fatty acid. When there is substantial saturated fatty acids present however the transformation of alpha linolenic is protected from the interference of excess linoleic.

For an adequate daily supply of essential fatty acids Mary Enig recommends that the diet should contain 1 to 1.5% of total energy as alpha linolenic acid and 2 to 3% of total energy as linoleic. Even then transformation to EPA and DHA can be erratic. Cottage cheese and high sulphur yoghurt are known to improve the transformation process. Alternatively 2 to 3 grams of fish oil per day will meet the need for EPA and DHA. Fish species differ greatly in oil content with herring, mackerel and sardines at the high end with around 3 g EPA and DHA per 100 g of flesh, while many tropical fish have less than 1 g per 100 g flesh. A problem for coconut, palm kernel and butter is that they contain nil or negligible essential fatty acids. This has led top their vilification by processors of those oils which are rich in essential fatty acids whose promotions have erroneously targetted the saturated fatty acids as unhealthy. These saturated oils combine well in the diet with sources of the essential fatty acids.

Oils that are high in unsaturated fatty acids pose a hazard as cooking oil, because transformation to trans forms of fatty acid occurs at high temperature. Multiple use of poly-unsaturated oil for cooking is not recommended, whereas cooking oil with predominantly saturated components is highly stable – for example coconut and palm kernel. Oleic (mono-unsaturated) is less susceptible to conversion to trans fatty acid than the polyunsaturated fatty acids.

A major transformation employed in the food industry for decades has been the partial hydrogenation of unsaturated fatty acids to a "saturated" form known as trans fatty acid. This process, applied especially to soy, canola, corn, cotton and safflower oils, which are all high in linoleic acid, raises the melting point, (thereby making it solid at ordinary temperature) enabling the manufacture of margarine and shortening. Many serious health problems including cardiovascular abnormalities, stroke and carcinomas have been linked to the consumption of a high proportion of trans fatty acid in the total dietary fat intake. Trans fatty acid is a manufactured saturated form of fatty acid but its non-natural molecular form invokes quite different dietary consequences from the natural saturated fatty acids, which in turn are an important component for a healthy diet.

Independent researchers in the United States attribute the success of the campaign to demonise saturated fats and oils, with special attention being paid to tropical oils, to a combination of several elements. Marketers of home-produced unsaturated oils engaged in aggressive advertising and exerted political influence on the decisions of regulatory authorities. It also seems that they were able to sideline the publication of unfavourable research findings about their own products (about trans fats, for example, until the late 1990s) whilst vigorously publicising any information that might damage rival products.

The marketers of coconut oil for export, scattered throughout the mostly small economies of the less-developed world, were too fragmented and too poorly resourced to mount any effective retaliation in the national media of their principal customer countries.

Marketers demolish reputations, invoke obesity

When the relatively new palm oil also entered the American food market, it too was marked for denigration and exclusion. The unrelenting campaign against saturated fats also brought about huge collateral damage to the market for foods containing animal fats, which are mostly saturated. However, there was little retaliatory reaction by the United States dairy industry, because it shared processors with the vegetable oil industry. The processors accepted the lowering of the value of one group of their products, apparently considering this an unavoidable compromise. It was the necessary trade-off to maintain a high price for vegetable oils and their derivatives, and to fend off competition from imported oils. Condemnation of the saturated group of fats led, by the early 1980s, to broadly accepted dietary 'wisdom' that a diet low in fat—any kind of fat—was the best.

Twenty years later, it has become clear that this is a very unhealthy diet indeed, and that it has led, paradoxically, to an epidemic of obesity. The cause of this is complex, and involves an imbalance in the insulin mechanism that deals with carbohydrate, such that the appetite gets out of control and the victim craves relief through excessive food consumption.

After three decades of promotion of one type of vegetable oil as more healthy than another, and the unexpected aversion of diet consultants to all forms of fat, the market for food oils of all kinds has declined enormously. This is reflected in the price trend shown in Figure 10-2 (Chapter 10), which compares coconut, palm, soybean and peanut oils. Relatively, coconut oil has declined a great deal more than any other since 1960. When dietary sanity returns, it might be expected that the prices of all dietary oils will improve, especially prices of the saturated oils.

From 1960 onwards, the price of coconut oil fluctuated wildly in response to variable supply, but always showed an overall downward trend. Palm oil experienced similar price fluctuations, but producers countered the negative price trend with a successful yield-improvement effort. Palm oil had become the new tropical wonder crop, taking the place in investors' perceptions occupied by coconut oil almost a century earlier. Through both breeding and management advances, palm oil remained profitable.

The relative success of the oil palm gave rise to a belief that plant breeders should be able to do likewise for the coconut palm. It is now recognised, however, that coconut has a lower potential to produce oil than oil palm. It became especially clear in the 1980s that the main reason for the ailing price of coconut oil was the concerted assassination of its reputation by the processors of polyunsaturated food oils. What is also emerging however, is that the health of large communities, and indeed of the whole United States, has deteriorated greatly during the late 20th century compared with 100, or even 60, years earlier (Gary Taubes, 'What if it has all been a big fat lie?' New York Times Magazine 7 July 2002). The increasing longevity of the population relies on enormous use of medicines.

Some competitor products harm health

Recent damage to health, noticed also in several other industrial countries, has largely been attributed to three causes.

The first cause of declining health was the reduction in the proportion of saturated fats in the diet, which occurred in response to marketing claims that they induce disease, particularly coronary heart disease. Such disease was a relatively rare condition in America until the 1940s, when the campaign for dietary change, principally through reduction in the use of animal fat and coconut oil and their replacement with unsaturated fats, began in earnest. Promotion of unsaturated fats also paid no heed to the fact that the chemistry of the many saturated fats found in different items of food is actually highly diverse (Table 11-1). It is clear some decades later that it was extremely fanciful to label all saturated fats as posing similar risks—or any serious risk, for that matter—to any particular aspect of health.

There is evidence that the level of harmful cholesterol in the blood rises temporarily when some saturated fats are consumed. However, elevated cholesterol is but one factor in heart health, and a contentious one at that. Cholesterol moves back and forth between the body tissues and the bloodstream, its levels fluctuating widely. It is also an essential agent in the functioning of human cells and organs, transporting both protein and fats around the body. Only a small proportion of the cholesterol in the body is found in the bloodstream, so a spot check on blood cholesterol could be misleading as to the whole-body level, and is potentially influenced by the ingredients of a recent meal.

The second major cause of deteriorating health in industrialised countries has been the increase in consumption of trans fats—the fats produced by the process of partial hydrogenation of unsaturated oil. The very thin, or runny, polyunsaturated fats are converted by partial hydrogenation into firm, artificially saturated fats, in order to make margarine and shortening. Such trans fats, which are derived from soy, cotton, sunflower, canola and maize oils, do not occur naturally in any food consumed by humans (except for very small amounts of related but not identical forms in dairy fat), and therefore are 'foreign' molecules entering into the chemistry of the body. There is accumulating evidence that they are seriously harmful to health when consumed in excess of a safe daily amount (set at 12 grams per day for adults in the United Kingdom), and are linked to increased incidence of stroke, carcinoma (cancer) and obesity.

The third cause of health problems has been the reduction in the diet of lauric, caprylic and capric oils, which are found in abundance in coconut oil. These oils are now known to play a powerful role in fighting many pathogens in the body. This applies to viral, bacterial and protozoan pathogens, including a bacterium active in stomach ulcers, some sexually transmitted disease agents, and human immunodeficiency virus (HIV). Laboratory tests and clinical case studies have shown that including coconut oil in the diet helps combat these pathogens. During digestion, lauric, caprylic and capric fatty acids form monoglycerides, which are active and evidently powerful germicidal agents. Part of the great benefit in breastfeeding babies arises from the presence of lauric oil in human breast milk, which provides protection for the infant against infections.

Coconut helps overcome obesity

Coconut oil, despite being a dietary 'fat', appears not to contribute to obesity, unless consumed in quite excessive amounts. Coconut oil in the diet is absorbed into the 'portal' blood (that part of the circulatory system that deals with uptake of readily available energy sources in the food passing through the digestive system) and carried to the liver in the same way that soluble carbohydrates, such as sugar, are delivered by the insulin mechanism. From the liver, coconut oil is rapidly 'burned', which explains why people eating a substantial amount of coconut in a meal often experience a more noticeable rise in body temperature than after a meal without coconut. Coconut oil thus increases the body's energy needs, sometimes requiring deposited fat to be burned to meet those needs. Far from contributing to obesity, coconut oil can assist weight loss.

Anecdotal evidence suggests coconut oil is also a deterrent to excess fat intake, because a quite moderate amount induces a feeling of fullness or satiety when consumed, thereby providing another mechanism for achieving weight loss by limiting intake of energy. There is also some remarkable anecdotal evidence that coconut oil has proved to be a dismal failure as a commercial fattening agent when added to the diet of pigs. Pig farmers in the United States, attracted by the low price, attempted to fatten their animals using coconut oil—but the pigs evidently remained lean and highly active! However, when animals are fed unsaturated fat, including trans fat, they gain weight rapidly. While this is a boon to the farmer, it changes the animal's fat composition for the worse, making it less healthy for the consumer.

Racehorses fed a coconut 'cake', containing about 10% coconut oil, obtain a high energy level and maintain their lean physique. Trainers in Australia are showing increasing interest in coconut oil because of the improved performance of horses using it. Could human athletes get the same results by including coconut oil in their diets? Research in this area has recently been undertaken, but no results are available yet.

Table 11.2. Summary of coconut assets

Issue	Detail	Comments
1. Principal oil components	50% lauric; 15% shorter-chain; total medium-chain oils = 65%. Less than 10% unsaturated.	Highest proportion of medium-chain components of any oil. Over 90% saturated components. High melting point; solid below 24°C.
2. Outstanding stability in storage and use	Saturated components withstand high temperature – prolonged use deep frying without change.	Most stable of all the cooking oils. Others have more unsaturated components – oxidation at high temperature spoils flavour.
3. Uptake path in human body	Moves to liver in portal blood supply; rapid burning for body energy.	All long-chain fats (saturated or not) are carried directly to lipid deposits, accumulating as body fat.
4. Nil demand for antioxidants	Saturated fats have no double bonds at risk of oxidation, and do not need protection from it.	Unsaturated fats need protection from oxidation; if protection is inadequate, harmful free radicals are released.
5. Lowers harmful cholesterol	Dominant medium-chain oils do not enter into lipoprotein (cholesterol) formation; low presence in atheromas.[a]	Erroneous perception that coconut oil raises cholesterol due to selective tests with flawed diets; not suited as sole dietary oil as it lacks essential fatty acids.
6. Stimulates thyroid function	Depression of body vigour often reversed by adding coconut oil to the diet.	Evidence that excess unsaturated oil and trans fatty acids suppress thyroid function.
7. Counteracts obesity	Consistent dietary dose of 50 g per day raises energy 'burning', lowers appetite, consumes more stored fats.	All forms of long-chain oils are readily accumulated in the body, being 'burned' only when energy intake is deficient.
8. Induces an antibiotic effect on pathogens	Derivatives of lauric and capric oil suppress bacterial, fungal and viral pathogens of humans, including HIV.	Coconut oil is also widely used in 'heartland' cultures on skin wounds. HIV suppression is promising, and study continues.
9. High general attraction as food	Myriad possibilities for use: kernel (fresh, roasted, flakes, shreds, powder, flour); cream and milk; virgin or RBD[b] oil.	Coconut flavour combined with chocolate, ice-cream and sugar favoured by most consumers; health benefits are a bonus.

Issue	Detail	Comments
10. High melting point, around 22–24°C	Excellent ingredient in ice-cream, which maintains firmness longer in a warm situation.	Solid in a cool kitchen, and safe against spillage, but like butter should be sold in a tub; readily softened using microwave.
11. Outstanding fuel oil	Coconut oil substitutes for diesel either directly (warm climate), or mixed with diesel or esterified (cool climate).	Especially valuable on isolated tropical islands, where mineral fuel supply is erratic, expensive and polluting.
12. Popular cosmetic and massage oil	Facial skin responds by remaining soft and healthy; oil keeps scalp free of parasites and beautifies hair.	Widely used in 'heartland' cultures; chemical stability allows global distribution with no loss of potency.

[a] An atheroma is an accumulation of material on the artery wall that usually contains a high proportion of unsaturated fat molecules. Blood flow is slowed by atheromas, triggering coronary disorders.

[b] RBD refers to the industrial procedures for standardising the quality of coconut oil derived from copra: R = refined; B = bleached; and D = deodorised.

Diabetes and hypothyroidism

As coconut oil quickly converts to heat energy, it can substitute for sugars as a ready source of energy without stimulating the release of insulin. A diet in which coconut oil is substituted for sugars can avert extremes in blood sugar concentration (hypoglycaemia and hyperglycaemia) in diabetes sufferers. It would also delay the development of the resistance of muscle cells to a rising insulin level that triggers mature-onset diabetes, a common ailment of late middle-aged and elderly folk in industrial societies, and increasingly suffered by young people who are obese.

The enhanced energy release, accompanied by a rise in body temperature, attributed to the use of coconut stimulates the thyroid gland, which governs the body's metabolism. If we think of the body as a motor vehicle, the thyroid gland acts as the body's carburettor, controlling the idling speed of the engine. Coconut oil is being widely tested by individuals suffering from hypothyroidism, in which thyroid activity is low and the sufferer experiences a debilitating lack of energy.

Restoring the status of coconut oil

The struggle to gain widespread recognition of the many great benefits of coconut oil is far from over, and indeed, in the light of the negative messages spread so widely by competing marketers, it appears to have only just begun. Until recently, there were few voices raised in defence of coconut as food. Those lipid chemists and health researchers who did speak out often suffered attacks on their credibility and loss of funding for their research, particularly in the United States. Such is the power of large industries eager to dominate the marketplace, and such is the dilemma of the scientific research community, which seeks to gain significant funding from industry to continue its work.

The polyunsaturated fat producers' domination of the market was at times so thorough that coconut consumption fell, even in traditional coconut cultures like those of southern India. Interestingly, the rate of coronary heart disease rose!

Coconut consumers are now regaining confidence, as the negative messages about coconut oil's threat to health are systematically discredited. This generates the hope that coconut oil and all its associated food forms will again become widely used worldwide, to the health and gastronomic benefit of all, as well as the economic benefit of the coconut's producers and processors.

The time will come when coconut products are freed from the opprobrium that has been heaped upon them in recent decades by those promoting other vegetable oils. In industrial countries, which have an enormous media devoted to food, coconut is bound eventually to receive its due acclaim.

A coordinated effort to promote coconut products by industry authorities and political leaders in producing countries would give renewed hope to the hundreds of millions of coconut farmers. All that is asked of the countries and industries that compete with coconut products is a 'fair go' for the coconut. That is all that is needed for the coconut to quickly reclaim its true status as a wonder food for all.





ACIAR