

Biology and cultivation of coconut

K. Samsudeen

ICAR-Central Plantation Crops Research Institute, Kasaragod, Kerala- 671124, India.

Coconut served man through ages. Originated even before continental drift, coconut survived many vagaries of nature outliving all its relatives to develop in to the monotypic genus *Cocos* with the sole species *nucifera*. Place of origin of *Cocos nucifera* L. is an enigma even today. One school of thought is that coconut originated in Central American region while another says it is from South East Asia. Fossil records from New Zealand indicate that small, coconut like plants grew there as long as 15 million years ago. Even older fossils have been uncovered in India. An origin for the whole Cocoeae tribe in western Gondwanaland seems most compatible with the present day distribution. It has been hypothesized that the tribe probably differentiated shortly before the break up of that super continent. With its ability to float the coconut became independent of plate tectonics for its dispersal. The wild type evolved by floating between the volcanic islands and atolls where these fringed the continental plates and not on the lands masses at all. It is further postulated that the coasts and islands of the Tethys Sea could have been the ancestral home of the coconut, from where it dispersed by floating to other islands in the Indian Ocean and from there into Pacific Ocean. Wherever originated, coconut is well adapted to coastal ecosystems of tropical world. Today, coconut is found from tropic of cancer to tropic of capricorn in the cultivated form without any wild relatives.

Cocos nucifera, a monoecious perennial monocotyledon, is placed in Arecaceae family (formerly Palmaceae) and the sub family Cocoideae which includes a total of 27 genera and 600 species. Before 1910 many South American palm genera were classified as *Cocos* but now *Cocos nucifera* is considered monospecific, despite the pantropical distribution of this palm. The coconut palm, *Cocos nucifera*, the most important of all cultivated palms, is essentially an oil crop but is also ranked as an important food crop. The palm not only supplies food, drink and shelter, but also provides raw materials for a number of important industries. The palm is referred to as 'The Tree of Wealth' and 'The Tree of Life, as it provides all the necessities of life.

Coconut is cultivated in 11.93 million hectares in 94 countries producing 60.5 million tons of nuts equivalent of 10 million tons in copra or six million tons in oil. In India, coconut is cultivated in 18 states and three Union Territories under 2.16 million ha for the production of 15.08 million tons. The four southern states, Kerala, Karnataka, Tamil Nadu and Andhra Pradesh account for 90% of area under coconut and 93% of production. Rest of the production comes from Maharashtra, Orissa, Pondicherry, Andaman & Nicobar, Lakshadweep, Gujarat, Goa, West Bengal and non-traditional states like Bihar, Assam, Tripura, Nagaland, Manipur, Meghalaya, Arunachal Pradesh and Chhattisgarh.

Botany

The coconut palm is a tree sans branches, with a single stem topped by a cluster of long pinnate leaves. The palm with indeterminate growth has only one apical meristem that gives rise to leaf and inflorescence primordia. The inflorescences emerge from leaf axils.

Root

The palm being a monocot has an adventitious root system. Roots emerge from the base of the stem (bole). Number of roots in a palm varies with the variety, age of the palm, bole size, and management and ranges from 1500-7000. The main roots form a number of secondary roots that branch into many rootlets, which help the plant absorb nutrients from the soil. The growing root is initially yellowish white in colour and gradually turns light brown and subsequently becomes reddish-brown with age. The tender growing tip of the root is protected from injury by a root cap. The rootlets, however, are short lived and are frequently replaced. From the main roots and rootlets, numerous pneumatophores develop, facilitating gaseous exchange between the roots and the atmosphere.

Stem

The coconut palm has a single, straight stem, greyish in colour, culminating in a crown of leaves. The palm has a single terminal bud that produces a succession of leaves and is well protected by the young unopened leaves. The stem is marked by leaf scars. The thickness of the stem is determined by the environment, in addition to varietal differences. In certain varieties, the base of the stem is swollen and is referred to as the bole. The stem of the coconut palm becomes visible once the bole reaches the full stage of its development. In the initial years, the stem gradually becomes thick and once the maximum size is reached, there is no further appreciable change in the girth of the stem. The length of the stem is determined by the age of the palm, variety, environmental conditions and cultural practices.

Dwarf varieties have shorter trunks than tall varieties. Palms under excessive shade and very close planting exhibit rapid stem elongation. In rare instances, branching of coconut palms is observed, due to damage to the terminal bud, and up to five branches have been reported.

The stem of the coconut palm, being more fibrous in nature, combines stiffness with flexibility and hence is capable of withstanding a good amount of lateral strain, even when exposed to severe winds/cyclones.

Leaf

The top of the coconut palm bears a crown of leaves, comprising of opened leaves as well as unopened leaves in various stages of development surrounding the growing terminal bud. The number of leaves in the crown varies with the variety, growing environment and management. An adult palm normally has about 25-35 opened leaves on the crown. Once the leaf emerges, it has an average life span of about 2-3 years.

The leaves are long, measuring about 3-6 m in length depending on the variety, age of the palm, vigour of the tree and environmental and management conditions. In general, tall varieties have longer leaves, while dwarfs have relatively shorter leaves. The individual leaf consists of a strong petiole, extending to form a rachis with numerous leaflets inserted on either sides of the rachis. The petiole accounts for about one-fourth of the total length of the leaf, but varies with the variety. A short and stout petiole is able to better withstand vertical pressure exerted by the developing bunch in its axil. The number of leaflets in a mature leaf ranges from 150 to 250. The first leaflets at the base are short, followed by a gradual increase in length of the subsequent leaflets with the maximum length being achieved at about one-third of the midrib followed by a gradual decline in length towards the top of the leaf.

The midrib of the leaflet is a very strong structure. The stomata are first formed about

a year prior to the emergence of the leaf. Stomata are confined to the lower surface of the leaflets, are elliptic with two guard cells containing large starch grains and a small opening. Normally, a leaflet contains about 170-220 stomata/mm². Stomatal density is a varietal character and higher density has been reported in dwarfs than in tall varieties.

The young leaves have stipules at their bases, which tend to form a fibrous sheath that more or less encompasses the trunk. As the leaf becomes older, the stipules dry and fall away. In some of the young palms, the stipules tend to persist till the leaf dry and fall.

The progression of leaf development from bud to leaf takes several years, and the average time taken from initiation to final abscission is almost five years. Various workers have studied the stages in development of the leaf and sequence of events in differentiation of leaf primordia into adult leaf. The time taken from differentiation of the leaf primordium to emergence from the leaf sheath is almost 28-32 months. Once the leaf emerges, it has an average life span of about 2-3 years. The season and also soil conditions influence the process of leaf maturing and shedding. The rate of leaf opening appears to be more dependent on the temperature rather than the rainfall. Under favourable growth conditions the leaves remain on the crown for longer period, up to three and a half years after emergence. A higher rate of leaf production, coupled with higher number of leaves on the crown has been observed in heavy bearers. Normally, one year old seedlings have about 7-11 leaves depending on the varieties, with majority of them having eight leaves. Generally, the number of leaves on the crown increases up to 28-38 and an adult tree on an average has got about 30 leaves.

The leaves on the coconut crown are arranged in spirals, running either in the clockwise or anticlockwise direction, or in such a way as to ensure maximum light availability to each leaf. Hence, the 6th leaf is located over the 1st leaf, the 11th leaf over

the 6th and so on. The spirality in a palm can either be right-handed (bunches hang towards the right of the petiole), or left but remains the same throughout the life of a particular tree. The two types of spirals are distributed almost equally in a population.

Flowers

The coconut palm is monoecious, with male and female flowers borne on the same inflorescence. The inflorescence emerges from the leaf axils, with one inflorescence produced every month from successive leaf axils, in adult palms under favourable conditions of growth. The age at initial flowering varies with the variety and environmental conditions. The inflorescence is at first visible as an oblong flat structure and is referred to as a 'spadix'. Subsequently, when the spadix is fully mature, the spathe ruptures and exposes the inflorescence.

The length of the inflorescence ranges from 60 cm to 200 cm, depending on the variety, age, nutrient status of the palm and the cultural conditions. The central axis is referred to as peduncle and bears about 30-35 spikelets. The spikelets carry numerous male flowers and a few female flowers (generally 1-2, and occasionally more). The female flowers are borne near the base of the spikelets, while the male flowers are closely set, and borne above the female flowers.

All the flowers are sessile/subsessile. A single inflorescence has about 8,000-10,000 male flowers, while the number of female flowers in an inflorescence varies considerably (0-400) depending on the variety, age of bearing, growing environment and management. However, in the spikeless/spicata type of inflorescence, the central axis is unbranched and male and female flowers (with a preponderance of female flowers) are directly borne on the peduncle.

The male flowers are about 8 mm in length and contain six perianth lobes arranged in two whorls and six stamens arranged in a single whorl. In the centre is a rudimentary/abortive pistil. Anthers are normally

yellowish in colour and attain a bluish green tinge on maturity. Flowering commences from the distal end of the spikelets and extends downwards. The flowers open throughout the day, but maximum blooming occurs from 8-10 AM. The interval between the opening of the first male flower and the shedding of the last male flower is termed as the male phase and lasts for 18-22 days, varying with the variety, age of the palm, season and cultural conditions.

The female flowers are larger, globular in structure and bracteolate with a diameter of about 13-25 mm. It contains six rounded, concave, imbricate perianth lobes with a staminodal ring at the base and a short style with three stigmas at the centre. Ovary is tricarpellary, syncarpous with a single anatropous ovule in each carpel. However, only one ovule is fertile. Generally, two small, fertile male flowers called accessory or axillary male flowers accompany each female flower. The female flowers remain receptive for 1-3 days after opening. Generally, the female flowers become receptive two to three weeks after the opening of the spathe.

Since the male and female flowers are separate, transmission of pollen from the male flower to the female flower for fertilization has to take place. In an inflorescence, the male flowers mature earlier than the female flowers and shed the pollen. Pollination in coconut palms is effected either through wind or insects. The possibility of cross as well as self-fertilization exists in coconut. If there is time interval between the opening of the last male flower and the opening of the first female flower, there is greater possibility of cross pollination. When there is no gap there is greater possibility of self-pollination. In majority of the tall coconut varieties, the time interval between the end of the male phase and commencement of the female phase is 2-3 days and hence pollination is effected through pollen from neighbouring trees (cross pollination). However in some trees, especially in Dwarf varieties, there is overlapping of the female and male phases in an inflorescence,

thereby resulting in self-pollination. Even in the absence of overlapping of the male and female phases in an inflorescence, self-fertilization can occur through overlapping of the male and female phases of successive inflorescences in a palm. In India, chances of inter spadix pollination is reported to be about 22% of the total spadices opened during the year, with maximum possibility in the summer months of March, April and May. Such inter spadix overlapping during the wet season has been reported in Philippines as well as Sri Lanka.

Fruit

The fruit of the coconut palm is a drupe, commonly referred to as the 'nut'. It contains an internal endosperm referred as kernel with embryo embedded in it and protected externally by a thick pericarp. The pericarp has three distinct regions, the outer exocarp/epicarp, middle fleshy mesocarp and hard endocarp.

The fruit starts developing upon fertilization of the female flowers. During the course of development, a large number of female flowers shed, leaving only a few on the bunch. The young fruits are initially yellowish in colour, but turn green, yellow or red (depending on the variety) on exposure to light. On reaching complete maturity, the fruits turn brown. The developing fruit attains its maximum size and weight about six months after pollination and remains so for another two months. Subsequently, there is a drastic reduction in fruit weight along with a slight decrease in the size of the fruit, due to loss of water.

The solid endosperm (kernel) begins to develop when the nuts are about six months old, and appears as a thin watery lining on the shell at the basal end, away from the eyes. As the endosperm formation increases, the meat at this end thickens and subsequently hardens. The solid endosperm reaches its maximum thickness when the nuts are

around nine months old. The fruits are ready for harvest 10-12 months after pollination, depending on the variety.

The fruit of the coconut palm contains an internal endosperm with embryo embedded in it and protected externally by a thick pericarp. The pericarp has three distinct regions, the exocarp/epicarp, mesocarp and endocarp. The exocarp/epicarp is the outermost layer of the fruit and is a tough fibrous skin, the colour of which varies from green to red to yellow to brown, depending on the variety. The mesocarp is the fleshy portion immediately beneath the epicarp (husk). In the tender fruit, this has an astringent taste but in rare instances, it is sweet and edible. As the fruit matures, this region becomes more fibrous. The thickness of the mesocarp varies from 2 cm to 15 cm, depending on the variety. Immediately below the mesocarp is the endocarp, which develops into a hard shell as the fruit matures. The shell, on its basal side has three pores (eyes) representing the three carpels of the ovary. One of the eyes is soft while the other two are quite hard. The fibre over the soft eye is generally softer and less compact than elsewhere in the fruit. The seed/kernel is present beneath the hard shell and is therefore well protected. The thickness of the endosperm (meat) generally is around 1.3 cm. However, depending on the variety this may vary from 0.8 to 2.0 mm. The embryo is situated below the soft eye. In between the endocarp and the albuminous endosperm is a thin layer of testa/seed coat. The testa is brown in colour and adheres to the endosperm. In the middle of the endosperm is a cavity filled with sweet water and referred to as the liquid endosperm. In the unripe fruit, this central cavity is completely filled with water. However, as the fruit ripens, the quantity of water reduces gradually and gets completely absorbed by the nut on storage for a few months, after harvest. Once the nut water is exhausted, the ability of the fruit to germinate is lost.

Variability

The coconut palm, in spite of being a monotypic species with no known wild relatives, exhibits considerable variability in forms with several distinct populations and ecotypes, widely differing from each other in morphological characters, particularly with respect to plant habit and fruit characters.

Plant habit

Coconut palms are broadly classified into two groups based on plant habit viz., the tall and the dwarfs. Tall palms are the most commonly cultivated in all coconut growing regions of the world. Tall palms grow to a height of 20-30 m, have a sturdy stem, commence flowering 6-10 years after planting and continue bearing up to the age of 80-100 years. Tall palms are normally cross-pollinated and hence highly heterozygous. The fruits are generally medium to large in size and produce good quantity and quality of copra with fairly high oil content. Among the indigenous tall cultivars, West Coast Tall, East Coast Tall, Benaulim Tall, Tiptur Tall, Andaman Ordinary Tall and Laccadive Ordinary Tall are popular. Some popular exotic tall cultivars are Fiji Tall, Philippines Ordinary Tall, Sri Lankan Tall, West African Tall, Panama Tall, Malayan Tall, Jamaican Tall and San Ramon Tall.

Dwarf palms have gained importance in recent times due to tender nut qualities and resistance to certain diseases. They are of shorter stature, 8-10 m high when 20 years old and start bearing about 3-4 years after planting and have a short productive life of about 40-50 years. The dwarf palms are more homozygous than tall, due to a high degree of self pollination. They produce fruits, which are generally small to medium in size. The dwarfs are presumed to have originated from tall either through mutation or by inbreeding or by both. The popular dwarf cultivars grown in India are Chowghat Green Dwarf, Chowghat Orange Dwarf, Kenthali Orange Dwarf and Gangabondam Green Dwarf.

Among the exotic dwarf cultivars, Malayan Yellow Dwarf, Malayan Orange Dwarf and Malayan Green Dwarf have become popular in all coconut growing countries of the world.

The tall and dwarf types have been utilized for development of hybrid varieties, combining the early flowering trait of dwarfs with the hardiness and high yielding character of tall parents and also exploiting hybrid vigour.

Fruit characters

Considerable diversity is observed in the size, shape and colour of fruits of coconut palm. The colour of the fruits varies from yellow, shades of green and brown to red (orange). The variations in shapes of the coconut fruit are broadly classified as round, oblong or elliptic. Further, based on the equatorial view, the shape of coconut fruits can be classified as angled, round or flat based on the curvature of the fruit and the presence of ridges on the fruit. Variations are recorded in shape of the nut inside the fruit and these are broadly categorized as round, oval and oblong.

Grouping of varieties

Plant habit, fruit colour and other fruit characteristics are presently the most convenient for grouping of the varieties. In most cases, the size of the fruit is genetically determined and not solely the effect of environment. However, further refinements of this technique can be undertaken for a more fool proof classification system. Molecular marker studies have classified the present day coconut populations into two major groups: the Pacific group with five sub-groups (Southeast Asia, Melanesia, Micronesia, Polynesia and the Pacific coast of Central and South America) and the Indo-Atlantic group. The Pacific group includes the domesticated coconut while the Indo-Atlantic group, includes NiuKafa (wild) coconut types. However, human intervention through migration and cultivation has brought the different forms together and the resulting opportunity for cross pollination

has allowed the development of intermediate forms through introgression.

Harries (1978) put forth a method for classification of coconut varieties as NiuKafa and NiuVai, on the basis of fruit characters and seed-germination traits. NiuKafa and NiuVai types of coconuts were suggested to denote wild and domesticated coconuts, respectively wherein NiuKafa fruits are thick husked, angular and lengthy with smaller inner cavity and late seed germination while NiuVai fruits are round or oblong having large inner cavity and early seed germination. Harries did not include the dwarf varieties under NiuVai and NiuKafa types as these evolved much later and can survive only under cultivation.

In addition to the variation described above, variation in coconut endosperm texture and quality has been reported in natural coconut populations. One such is the Makapuno type from the Philippines where the endosperm is buttery soft and almost fills the nut cavity and is used in delicious preparations. Similar soft endosperm types are reported from other coconut growing areas also. In India these types are called ThayirThengai and have been reported from Andaman Islands. Besides, sweet kernel type called Mohacho Narel and sweet tender husked type called Kaithathali have also been reported from India and are conserved in field gene banks. Another variant is the aromatic coconut, wherein the tender nut water and solid endosperm have a pleasant aroma, similar to the scented rice aroma, as seen in the Klapawangi of Malaysia, Aromatic Dwarf of Philippines, Nam-hom of Thailand, Aromatic Green Dwarf of Philippines, etc. A few other exceptional types are: palms producing thick shelled nuts (Poropol of Sri Lanka, Tutapaen of Philippines, thick shelled types observed in India, China, Indonesia etc.), thin husked fruits (Kelapa Bawang/Onion Coconut of Indonesia, Lupison of Philippines) and pink husked fruits (Ran Thembili of Sri Lanka, Guelle Rose of Mauritius, pinkish

mesocarp types observed in India, China, Fiji and Indonesia, etc.). Another oddity in coconut is the persistence of leaf bases and inflorescences, as seen in certain other palm species like Palmyra palm. These types are known to occur in many different coconut populations.

Besides these, a number of abnormalities have been reported from different coconut growing regions. These abnormalities, listed below, are freaks of nature and not distinct varieties, from the botanical point of view. The abnormalities include variations in stem (polyembryony, branching, suckering), vegetative parts (albinism, rosette seedling, chimera, fused leaflets/plicata, forked leaves, twin leaves, fused leaves, multi-leaf type), inflorescence (double spadix, multispathe, partial suppression of spikes, secondary branching of spikes, unbranched spikes, fasciated spikes, foliation of the spadix, terminal inflorescence, vivipary), flower (hermaphrodite flower, variation in number of pistillodes, stamens and perianth) and fruits (horned nuts, double ovary, mono, bi and tetracarpic fruits).

Uses of coconut

Coconut serves humanity by providing each and every part for one or the other uses. It is used as source of food, medicine, nutrition, toiletries and cosmetics. In addition, it provides construction materials, innumerable products from coir and activated carbon from shell. The parts and their contribution to various uses are discussed below.

The root has medicinal properties and can be used to treat gall bladder and urinary infections as well as kidney related diseases. It is useful for treating eczema and fibrosis. It helps melt clotted blood. The roots can also be used to treat heartburns. Coconut trunk is a time tested building material used as timber to make houses, boats, bridges and canoes. The treated coconut wood is used for making furniture. Coconut leaves are used as a thatching material, used to wrap rice for storage, used to make toys, used to

make decorative crafts and to make brooms. Toothpicks are made out of the midribs of the leaflets. Coconut leaves are also used to produce good quality paper pulp, hats and mats, fruit trays, fans, lamp shades, bag, and utility roof materials.

Coconut spathe is traditionally used to make caps and handbags. The whole inflorescence is used to prepare decoction that has medicinal properties. Coconut inflorescence is also used to produce neera by incising and tapping. The fermented neera is known as toddy or tuba (Philippines) or tuak (Indonesia and Malaysia). Fermented neera or toddy is distilled to produce arrack. In the Philippines, this alcoholic drink is called lambanog or 'coconut vodka'. The inflorescence sap can be reduced by boiling to create a sweet syrup or candy. It can be reduced further to yield coconut sugar also referred to as palm sugar or palm jaggery.

Coconut fruit has different layers like outer husk, middle shell and inner endosperm that is both liquid and solid. Each one of these layers has various uses to mankind. Coconut liquid endosperm or coconut water can be used as tender coconut water when it is from 6-8 month old coconut fruit. Tender coconut water is a health drink used by man from prehistoric times. It is a good source of sugar, fibre, antioxidants, proteins, vitamins and minerals making it a popular sports drink providing energy, hydration and endurance. It helps restore any electrolyte imbalances caused by diarrhea, vomiting and after exercising. It is the only natural liquid that can be directly administered intravenously due to its ability to mix with blood. It is attributed to have antiseptic, antibacterial, anti-fungal, and anti-viral properties. It is used to replace lost fluids in cases of influenza, typhoid, malaria, and is said to dissolve kidney stones. Mature coconut water is used to produce vinegar. It is also used to make *nata de coco*, a jellylike food.

Mature endosperm is the source of coconut oil, desiccated coconut, coconut milk and coconut chips. In addition to the common use

in cooking, coconut oil is used in medicine and cosmetics and as lubricant. Cosmetic uses of coconut oil are as natural skin softener and moisturizer. It reduces fine lines, puffiness and dark circles under the eyes, it prevents skin infections, it has anti-wrinkle properties, it soothes sunburn and treats blisters and burns. It improves skin tone, elasticity and age spots. It conditions hair, prevents split-ends and treats dry flaky scalp including dandruff.

Coconut oil is attributed to have many medicinal uses. It eases acid reflux and gives relief in gall bladder disease, stabilizes blood sugar levels and insulin production, kills viruses causing flu and other infectious diseases, protects against cancers in the colon, breast and digestive tract, protects against intestinal disorders, reduces pain and inflammatory conditions such as arthritis, strengthens liver, protects against Alzheimer's disease, improves calcium and magnesium absorption promoting strong bones, helps stabilize female hormones and prevents hot flushes and vaginal dryness during menopause. Coconut milk is another product from endosperm that has many uses. It is used in a variety of ways in seafood dishes and in baking instead of animal fat. Coconut milk is used regularly, nearly as a staple ingredient in Southeast Asia and forms the base of curries. It is used to make a home brew in Rendell Island (Solomon Islands) where it is fermented with sugar and yeast and left for a week. The milk can be used to produce virgin coconut oil by controlled heating and collection of the oil fraction. The coconut meat or the fresh endosperm is eaten and used fresh. The meat is used in deserts and confectioneries. It is also an essential

ingredient for many curries and savory dishes throughout the world.

Other delicacies from coconut include palm cabbage and haustorium. Apical buds of adult plants known as 'palm cabbage' or heart of palm are edible. They are considered a rare delicacy, as harvesting the buds kills the palms. Hearts of palm are eaten in salads, sometimes called 'millionaire's salad'. Coconut haustorium, a spongy absorbent tissue formed from the distal portion of the embryo during coconut germination, is also edible.

Coconut shell is the strongest part in coconut fruit and it covers endosperm. The shell is used to produce various handicrafts. Coconut shells are also used to make charcoal which is used as fuel and is far better than other charcoals. Coconut shell charcoal is widely used to produce activated carbon. Coconut shell charcoal is widely used in purification industry and other industries.

Coconut husk is the source of coir which is the most industrially used part. Coir is the fibre on the husk and is used to make ropes, door mats, potting compost, mattress stuffing, brushes, mats, rugs and sacks and as joint sealer for boats (caulking).

The coconut palm is grown throughout the tropics and defines the landscape of many regions in the world adding value to the environment. It is known all over the world for its many culinary and other uses; virtually every part of the coconut palm can be used in some manner or the other and has significant economic value. Coconuts' versatility is sometimes noted in its naming. In Sanskrit, it is 'kalpavriksha' (the tree which provides all the necessities of life). In the Malay language, it is 'pokokseribuguna' (the tree of a thousand uses). In the Philippines, the coconut is commonly called the 'tree of life'.