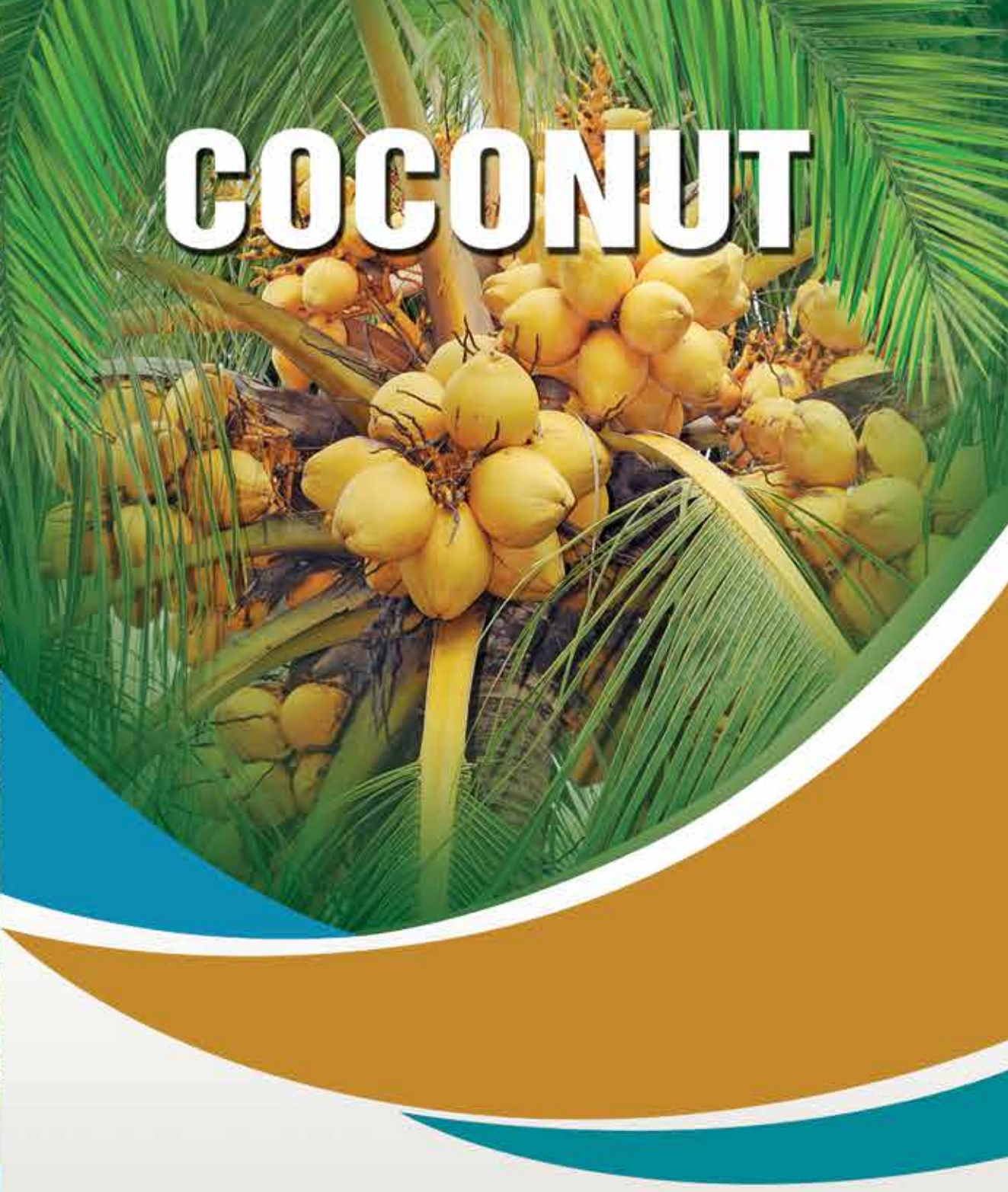

ICAR-CENTRAL PLANTATION CROPS RESEARCH INSTITUTE
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COCONUT

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Introduction

The coconut palm is referred to as 'Kalpavriksha' – the '*tree of heaven*' as each and every part of the palm is useful in one way or the other. Ten million people in India depend on coconut for their livelihood either directly or indirectly. India ranks third in area and first in production of coconut in the world. As per the latest statistics available (2016-17), the annual coconut production in India is 23.90 billion nuts from an area of 2.08 million ha with an average productivity of 11481 nuts/ha. The four southern states *viz*., Kerala, Tamil Nadu, Karnataka and Andhra Pradesh are the major coconut producing states in India, accounting for more than 90 per cent of the area and production. It has been demonstrated that a four-fold increase in yield can be achieved by adopting scientific technologies in coconut cultivation as compared to the unscientific practices. Thus, there is great scope for enhancing the productivity of coconut through adoption of scientific cultivation technologies as given in the succeeding pages.

Climate and soil

The coconut palm is grown under varying climatic and soil conditions. It is essentially a tropical plant, growing mostly between 20° N and 20° S latitudes. The ideal mean temperature for coconut growth and yield is 27±5°C and relative humidity more than 60 per cent. Very high humid conditions right through the growth of palms is not considered good. The coconut palm grows well up to an elevation of 600 m above mean sea level. However, near the equator, productive coconut plantations can be established up to an elevation of about 1000 m above mean sea level. The palms tolerate a wide range in intensity and distribution of rainfall. However, a well distributed rainfall of about 2000 mm per year is the best for proper growth and high yield. In areas of inadequate rainfall and uneven distribution, irrigation is needed. The palm requires plenty of sunlight and it does not grow well under shade or in too cloudy regions. About 2000 hrs of sunshine in a year is considered necessary for the healthy growth of the palm. The natural habitat of coconut is the coastal belt of the tropics where sandy and red sandy loam soils are predominant. The cultivation of coconut has slowly extended to inland areas, even to the hill tops, having varied soil conditions. It grows well in almost all types of soils including sandy, laterite, swampy, alluvial, black and saline soils, provided they have proper drainage system, permitting unrestricted root development, aeration and absence of rock or a hard substratum within 2 m of the surface. It tolerates salinity and a wide pH ranging from 5.0-8.0.

Varieties and hybrids

Enhancing productivity through cultivation of improved varieties including hybrids is one of the major strategies suggested to make coconut farming more remunerative. The extensive research conducted on coconut improvement at ICAR-Central Plantation Crops Research Institute (CPCRI) and State Agricultural / Horticultural Universities has resulted in the release of

49 improved varieties having high yield potential and other desirable traits such as resistance to biotic and abiotic stress and suitability for tender nut purpose. Twenty-nine improved varieties of coconut suitable for different agro-climatic zones have been developed through selection and released till date, which includes 18 tall and 11 dwarf varieties. Besides these, 20 hybrid varieties including 8 Dwarf x Tall and 11 Tall x Dwarf hybrid and one Tall x Tall hybrid have also been released for cultivation in different agro-climatic regions. The released hybrid varieties of coconut have a yield potential of 2.79 to 6.28 tonnes of copra per ha per year in comparison to 2 tonnes of copra yield realized by the tall cultivars which are predominantly cultivated by coconut farmers.

Tall cultivars

The tall cultivars are most commonly cultivated in all coconut growing regions of the world. The productive life span of tall cultivars is about 60 years. They grow to a height of 15 to 18 m. Tall palms are predominantly cross pollinated and hence do not breed true to type. They produce copra of good quantity and quality with fairly high oil content. It takes around 5-7 years for the first bearing after planting. The tall cultivars commonly grown in India are the West Coast Tall (WCT), Tiptur Tall (TPT) and East Coast Tall (ECT).

Dwarf cultivars

Dwarf varieties are shorter in both stature and life span. They grow to a height of 5-7 m with an average economic life span of about 40 years. It takes around 3-4 years for the first bearing after planting. They are predominantly self pollinated. The nuts are smaller and the copra is thin, leathery and low in oil content. The dwarf cultivars are generally grown for tender nuts and also used for hybrid seed production. The common dwarfs available in India are Chowghat Orange Dwarf (COD), Chowghat Green Dwarf (CGD) and Gangabondam Green Dwarf (GBGD).

The details of tall and dwarf varieties released from ICAR-CPCRI for cultivation in the different states of the country are given in Table 1.

Table 1. Improved varieties of coconut released by ICAR-CPCRI

Variety	Nut yield (nuts/ palm/year)	Copra (yield kg/ palm/year)	Oil yield (kg/palm/ year)	Area for which recommended
Tall varieties				
Chandra Kalpa	100	17.60	12.67	Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra
Kera Chandra	110	20.79	13.72	Kerala, Karnataka, Konkan region (Maharashtra), Andhra Pradesh, West Bengal

Kalpatharu	117	20.50	13.96	Kerala, Karnataka, Tamil Nadu
Kalpa Pratibha	91	23.25	15.50	Kerala, Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra
Kalpa Dhenu	86	20.81	13.63	Kerala, Tamil Nadu & Andaman & Nicobar Islands
Kalpa Mitra	80	19.25	12.80	Kerala & West Bengal
Kalpa Haritha	118	21.25	14.13	Kerala, Karnataka
Kera Keralam	109	19.18	13.05	Kerala, Tamil Nadu, West Bengal
Kalpa Shatabdi	105	28.65	18.34	Kerala, Tamil Nadu, Karnataka
Dwarf/Semi-tall varieties				
Chowghat Orange Dwarf	112	14.34	9.46	All coconut growing areas
Kalpasree	90	8.64	5.75	Root (wilt) disease prevalent tracts
Kalparaksha	87	11.94	7.83	Kerala & root (wilt) disease prevalent tracts
Kalpa Surya	123	22.88	15.33	Kerala, Karnataka, Tamil Nadu
Kalpa Jyothi	114	16.19	9.96	Kerala, Karnataka, Assam

Hybrids

Hybrids are the inter-varietal crosses of two morphological forms of coconut. They show earliness in flowering, higher nut yield as well as higher quantity and better quality of copra when compared to the parents. When the tall is used as female and dwarf as male, they are all called T x D hybrids, while the reciprocals are known as D x T hybrids. Hybrids perform well under good management conditions including nutrient, irrigation and crop protection.

The details of hybrids of coconut released by ICAR-CPCRI are furnished in table 2.

Table 2. Improved hybrids released by ICAR-CPCRI

Hybrid	Parentage	Nut yield (nuts/ palm/year)	Copra yield (kg/palm/ year)	Oil yield (kg/palm/ year)	Area for which recommended
Chandra Sankara	COD x WCT	110	25.00	16.82	Kerala, Karnataka, Tamil Nadu
Kera Sankara	WCT x COD	108	20.20	14.60	Kerala, Karnataka, Maharashtra, Andhra Pradesh
Chandra Laksha	LCT x COD	109	21.30	14.60	Kerala, Karnataka

Kalpa Samrudhi	MYD x WCT	117	25.72	17.33	Kerala, Assam
Kalpa Sankara	CGD x WCT	84	14.62	9.87	Root (wilt) disease prevalent tracts
Kalpa Sreshta	MYD x TPT	167	35.90	23.02	Kerala, Karnataka

Varieties and hybrids released by ICAR-CPCRI


Chandra Kalpa


Kera Chandra


Kalpatharu


Kalpa Pratibha


Kalpa Dhenu


Kalpa Mitra


Kalpa Haritha


Kera Keralam


Kalpa Shatabdi


Chowghat Orange Dwarf


Kalparaksha


Kalpasree

Kalpa Surya

Kalpa Jyothi

Chandra Sankara

Kera Sankara

Chandra Laksha

Kalpa Samrudhi

Kalpa Sankara

Kalpa Sreshta

Nursery agro-techniques

Selection of seed nuts and seedlings are very important in coconut cultivation as the performance of the new progeny can be known only several years after planting. If the seed nuts and seedlings happen to be of poor quality, the new plantation will be low yielding and uneconomic, causing considerable loss of time and money to the grower. The fact that, coconut is a cross-pollinated palm and it does not breed true, makes the selection of seed nuts and then of seedlings in the nursery all the more important. By means of a series of selections made at different stages, it is possible to eliminate poor quality seed nuts and seedlings.

Mother palm selection

In tall varieties, seed nuts should be collected from mother palms which should have attained an age of 20 years. Wherever possible, it is advisable to select middle-aged trees as they will be in their prime of life and it is easier to spot good yielder from mediocre/poor yielder. The important features are: a) straight stout trunk with even growth and closely spaced leaf scars, b) spherical or semi-spherical crown with short fronds, c) short and stout bunch stalks without tendency drooping, d) more than 30 leaves and 12 inflorescences carried evenly on

the crown, e) inflorescence with 25 or more female flowers, f) consistent yield of about 80 nuts under rainfed conditions and 125 nuts under irrigated conditions, g) 150 g per palm copra per nut and h) absence of disease and pest incidence. In dwarf varieties, seed nuts can be collected from mother palms which have attained an age of 12 years or more and yielding more than 60 and 100 nuts per year under rainfed and irrigated condition, respectively. Further, it should have a minimum of 30 leaves with a nut weight more than 400 g.

Collection of seed nuts

Seed nuts can be collected throughout the year. However, it is preferable to collect seed nuts during the period from January to May in the West Coast region, so that sowing can be taken up with the onset of south-west monsoon. In the East Coast region, seed nuts are collected during the period from May to September and are sown during October–November with the onset of north-east monsoon. Fully matured nuts *i.e.* about 12 months old should be harvested. Care should be taken not to damage the seed nuts while harvesting. Nuts which are too big or too small in the bunch and also the nuts of irregular shape and size should be discarded. Seed nuts of tall varieties are to be sown 2-3 months after collection, whereas dwarfs should be sown within 15-30 days after harvest.

Raising nursery

Well-drained, coarse-textured soil near dependable irrigation water source should be selected for raising the nursery. The seed nuts can be sown in flat beds if there is no drainage problem. The seeds are to be sown in raised beds, if water stagnation is a problem. Nursery can be raised either in the open with artificial shade or in gardens where the palms are tall and the ground is not completely shaded. The seed nuts should be sown in long and narrow beds at a spacing of 40 cm x 30 cm during May-June, either vertically or horizontally in 20-25 cm deep trenches. Advantage of Vertical planting cause less damage during transit of seedling. However, in delayed planting, when the nut water goes down considerably, adopt horizontal sowing it is good to go for horizontal sowing of seed nuts for better germination.

Seedlings in the nursery

Selection of seedlings

Only good quality seedlings are to be selected from the nursery for field planting. In tall varieties, vigorous seedlings which are one year old, more than 100 cm in height with 5-6 leaves and girth of 10 cm at the collar should be

selected for planting. In dwarf varieties, the girth and height of good quality seedlings should be more than 8 cm and 80 cm, respectively. Early splitting of leaves is another character preferred for selecting good seedlings. Generally, one year old seedlings are preferable for planting. However, for planting in water-logged areas, 1½ to 2 years old seedlings are to be preferred.

Polybag nursery

Seedlings in polybags

Good quality seedlings can be raised in polybags. Germinated seeds can be transplanted in polybags (500 gauge thickness) of 45 cm x 60 cm dimension with 8-10 holes at the bottom. The commonly recommended potting media are top fertile soil mixed with sand (3:1) or top fertile soil, sand or coir dust and well rotten and powdered cattle manure (3:1:1). Potting mixture containing sand + vermicompost (3:1) is also ideal for raising polybag seedlings. Recent studies show that coir pith can also be used as potting mixture. Application of 25 g each of biofertilisers such as *Azospirillum* spp. and Phosphobacterium *Bacillus* sp., to the polybags results in production of vigorous seedlings. Use of Plant Growth Promoting Rhizobacteria (PGPR) based bioinoculants, '*Kera Probio*', (talc formulation of *Bacillus megaterium*) @ 25 g/seedling and '*Ker*AM' (Arbuscular Mycorrhizal bioinoculant) @ 50 g/seedling also helps in producing robust coconut seedlings. The advantage of polybag seedlings is that, there is no transplanting shock since the entire ball of earth with the root system can be placed in the pits and the seedlings establish early and more vigorously. But the disadvantages include difficulty for transportation and higher cost of seedling production. Care should be taken not to throw away the polybags in the coconut plantation.

Plantation Establishment

Selection of the site

Soils with a minimum depth of 1.2 m and good water holding capacity are preferred for coconut cultivation. Shallow soils with underlying hard rock, low lying areas subject to water stagnation and clayey soils with impeded drainage are to be avoided. However, in lands reclaimed by heaping alternate layers of sand and clay, coconut thrives well. Proper supply of moisture either through evenly distributed rainfall or irrigation and proper drainage are essential for coconut.

Preparation of land and planting

Preparation of land for planting coconut depends to a large extent on soil type and environmental factors. If the land is uneven and full of shrubs, the shrubs have to be cleared and land should be leveled before digging pits. The depth of pits will depend upon the type of soil. In laterite soil with rocky substratum, deeper and wider pits, 1.5 m length x 1.5 m breadth x 1.2 m depth may be dug and filled up with loose soil, powdered cow dung and ash up to a depth of 60 cm before planting. In case of laterite soil, application of 2 kg of common salt will help in loosening the soil. In loamy soils with low water table, planting in pits of 1 m x 1 m x 1 m filled with top soil to height of 50 cm is generally recommended. The coconut seedlings are planted in the centre of the pit by making small hole within the pits and the soil around the seedlings must be firmly pressed, but soil should not be allowed to bury the collar region of the seedling or enter into the leaf axils. However, when the water table is high, planting at the surface or even on mounds may be necessary. While planting on the surface or mounds also, digging pits and soil filling has to be done. While filling the pits with soil, it is advisable to use top soil. Two layers of coconut husk (with concave surface facing up) can be arranged at the bottom of the pit before filling up. This will help in conserving the moisture. The seedlings, after field planting, are to be protected from heavy wind by staking and from sunlight by proper shading using plaited coconut leaves or palmyrah leaves or any other suitable shading materials.

Planting of coconut seedling

Providing shade using plaited coconut leaf

Underplanting

Generally underplanting is done in plantations where the palms have become senile, unproductive and uneconomic to the farmer. Old palms are removed in stages over a period of 3 to 4 years. First the area to be underplanted is peg marked. To start with, very poor yielders (less than 20 nuts per palm per year) and those trees which are very close to the peg marked point for underplanting are to be removed. Other trees are to be removed at the rate of one third each year during 2nd, 3rd and 4th year after underplanting. If the existing garden is irregularly spaced, old palms within 1 m radial distance from the newly planted seedlings are

to be removed in the first year of underplanting, 2 m distance in the second year, 3 m distance in the third year and the rest in the fourth year.

Spacing

For realizing better yield from coconut, optimum plant density must be maintained in the field. A spacing of 7.5 m x 7.5 m to 8.0 m x 8.0 m in the square system is generally recommended for coconut. This will accommodate 177 and 156 palms per ha, respectively. If the triangular system is adopted, an additional 25 palms can be planted. Hedge system can also be adopted giving a spacing of 6.5 m along the rows and 9.5 m between rows. For facilitating multiple cropping in coconut gardens, it is advisable to go for wider spacing of 10 m x 10 m so as to provide ample opportunity to accommodate a number of perennial and annual crops in the interspaces.

Time of planting

In well drained soils, seedlings can be transplanted with the onset of south-west monsoon during June or with the onset of north-east monsoon during October-November. In low lying areas subject to inundation during monsoon periods, it is preferable to plant the seedlings after the cessation of the monsoon.

Management of juvenile palms

Adequate care should be taken during the early years of growth of young palms for realizing high yield. The field planted seedlings should be shaded and irrigated adequately during the summer months. Irrigation with 45 litres of water once in 4 days has been found satisfactory in all soil types. If it is drip irrigation, daily 10 litres of water need to be provided. Provision of proper drainage is important in areas prone to water logging. The pits should be cleared of weeds periodically. Soil washed down and covering the collar region of the seedlings during the rainy days should also be removed. The pits should be widened every year before the application of manure. The pits should be gradually filled up as the seedlings grow. By fourth year, the basin should be fully prepared to a radius of 1.8 m from the trunk. The palms should be frequently examined for any insect or fungal attack and necessary remedial measures should be taken up promptly.

Nutrition

Regular manuring right from the first year of planting is essential for good vegetative growth, early flowering and bearing and high yield of coconut palms. It is always advisable to test soil in the coconut garden (once in 3 years) based on the results of which, type and dosage of chemical fertilizers can be decided.

Collection of soil and leaf samples from coconut based cropping system

For coconut, soil samples should be collected from the coconut basin, 1 m away from the bole of the palm and at two depths *viz.,* 0-30 cm and 30-60 cm. For shallow rooted intercrops, soil samples should be collected from the interspace at 0-15 cm depth. For deep rooted intercrops, samples should be collected from different layers of 30 cm soil depths vertically up to the extent of the active root zone of the crop. At the sampling point, the crop residue and other undecomposed plant tissue or foreign material in the surface should be removed. Spade can be used for sampling at 0-15 cm depth (shallow rooted annual intercrops). With spade, V-shape pit of 15 cm depth should be dug and uniform thick slice of soil should be collected from the exposed surface. A tube or screw type augur will be convenient to collect the soil samples from more than 15 cm depth. If the tools are not available, a pit of 30 cm depth can be dug and soil samples collected. Then dig further, for 30-60 cm depth to collect the soil. The soil samples collected should be then mixed thoroughly (by breaking the big clods by hand or wooden mallet) on a clean piece of cloth and reduce it to half a kg of soil by quartering method (**Quartering method**: thoroughly mix the soil samples, divide it into 4 equal parts, then reject the 2 opposite quarters and mix the remaining 2 portions; then again divide into 4 parts, reject the opposite quarters and then mix the remaining two parts; repeat the same process until the sample is reduced to half a kilogram). Then dry the samples in shade. The dried soil samples should be packed in separate clean, dry cloth bags and properly labelled.

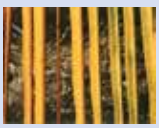
Quartering method of soil sampling

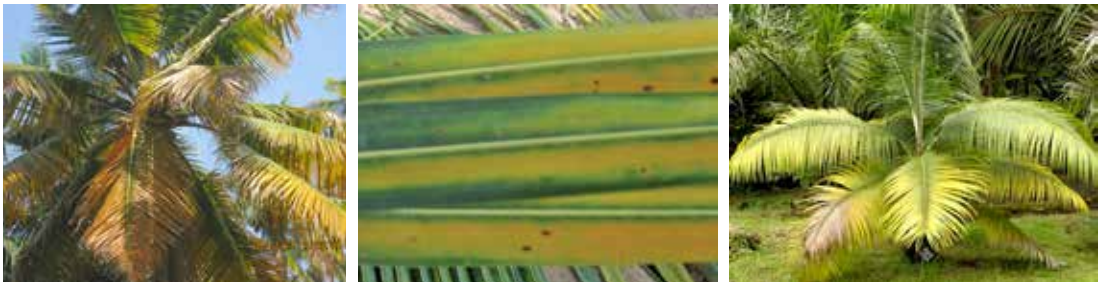
Leaf samples should be collected from the 14th frond (counted from the spindle leaf). The leaflets from two sides of the middle portion of the frond should be collected. The tip and bottom portion of the leaflets should be cut leaving the middle 10 cm length. The midrib should be removed. The leaf samples should be cleaned and dried in shade. The air dried samples can be packed and sent to the laboratory with proper labelling.

The soil and leaf samples should be labelled with full details like name of the farmer, sample number, depth, crop, cropping system, description of the field etc. along with the request for the fertilizer recommendation based on the soil test value for the specific crop/crops of interest.

Nutrient deficiency can be diagnosed based on visual symptoms and common deficiency symptoms in coconut are presented in Table 3. However, it is not advisalbe fertiliser application based on visual symptoms and it is often too late to correct the problem, especially with perennial crops. **It is always advisable to analyse the soil and leaf once in three years and based on the results, fertilizer application should be done.**

Table 3. Essential nutrients of coconut palm and deficiency symptoms

Nutrient	Deficiency symptoms
Potassium 	The first symptom of potassium deficiency is visible in the older functional leaves. They are characterized by yellowing of the leaflets with orange tinge, followed by necrosis. In severe cases, the necrotic spots coalesce, giving leaves a scorched appearance. In advanced stages, only a strip along the midrib remains green, widening towards the base of the leaflet. The same pattern can be observed in the entire leaf. When holding such a leaf against the light, a green triangle in the leaf with its base in the lowest leaflets, narrowing towards the tip of the leaf may be observed. A gradual reduction in the number of inflorescences, nuts and copra content affect the overall copra out-turn. The growth of the palm slows down, the trunk narrows and the internodes become shorter.
Boron 	Symptoms appear on newly emerging leaves, inflorescence and nuts. Leaf symptoms appear as leaf wrinkling and manifested as sharply bent leaflet tips, failure of the leaves to split, crown choke disorder, leaves have a serrated zigzag appearance, failure of newly emerging spear leaves to open normally. In a chronic stage, multiple unopened spear leaves may be visible at the apex of the canopy. Boron deficiency also occurs in inflorescence and nuts resulting in poor nut setting, increase in button shedding and immature nut fall. The inflorescence and nuts become necrotic leading to barren nuts.
Nitrogen 	Nitrogen deficiency begins as a uniform light green discoloration / yellowing (uniform chlorosis) of the oldest leaves. Yellowing starts from the tip to the base of the lower leaves and will proceed upwards. As the deficiency progresses, younger leaves will also become discoloured. Older leaves appear golden yellow in colour. Growth virtually stops when N deficiency is severe and shedding of leaves occur.
Magnesium 	Magnesium deficiency appears on the oldest leaves of palms as broad chlorotic (yellow) bands along the margins with the central portion of the leaves remaining distinctly green. In severe cases, leaflet tips may become necrotic. Older leaves become bronzed and give a dry appearance. Leaflets show necrosis and turn to reddish brown with translucent spots, yellowing starts at the tip and spreads to the base.
Zinc	Zinc deficiency is characterized by formation of small leaves wherein the leaf size is reduced to 50%. Leaflets become chlorotic, narrow and reduced in length. In acute deficiency, flowering is delayed. Zinc deficiency will also lead to button shedding. Its occurs mostly in saline soils.
Copper	Deficiency leads to coppery bluish leaf. Rolling of terminal leaves due to loss of turgor. Leaves appear to be bleached grey. Fail to produce flowers.



Potassium deficiency

Magnesium deficiency

Boron deficiency

Application of chemical fertilizers

The first application of chemical fertilizer should be done three months after planting and the quantity of fertilizer to be applied is approximately one tenth of the recommended dose of fertilizer for adult palms. During the second year, one third of the dosage recommended for adult palms may be applied in two split doses in May-June and September-October. This dosage may be doubled during the third year. From the fourth year onwards, fertilizers may be applied at the rate recommended for adult palms.

Application of 500 g N, 320 g P_2O_5 and 1200 g K_2O per palm per year is generally recommended for adult plantations. To supply the above quantity of nutrients for an adult palm, it is necessary to apply about 1 kg urea, 1.5 kg rock phosphate (in acidic soil) or 2 kg super phosphate (in other soils) and 2 kg of muriate of potash (MOP). It can be also applied through 700 g Di ammonium phosphate (DAP), 815 g of Urea and 2 kg of MOP. After the receipt of summer showers, in May-June, one-third of the recommended dose of fertilizers

may be spread around the palms within the radius of 1.8 m and forked in. Circular basins of 1.8 m radius and 20 cm depth may be dug during August-September and green leaf or compost or farm yard manure may be spread at the rate of 50 kg per palm basin. The remaining two-third of the recommended dose of fertilizers may be spread over the green leaf or compost and covered. Wherever irrigation facilities are available, it is advisable to go for more number of split doses, preferably four split doses (March, June, September and December).

Table 4. General fertilizer recommendation for coconut (g/palm)

Age of coconut palm	May-June			September- October		
	N	P_2O_5	K_2O	N	P_2O_5	K_2O
First year	Planting in May-June			50	40	135
Second year	50	40	135	110	80	270
Third year	110	80	270	220	160	540
Fourth year onwards	170	120	400	330	200	800

Drip fertigation

If there is drip irrigation facility, then the water soluble fertilizers like urea, DAP, phosphoric acid (commercial grade) and muriate of potash can be applied along with drip irrigation in 6 equal splits. Through fertigation, it is recommended to provide 91 g urea, 33 ml phosphoric acid and 170 g muriate of potash per palm per application. When DAP is used it is recommended to provide 70 g urea, 60 g DAP and 170 g muriate of potash for a single dose per palm.

When the recommended dose of phosphatic fertilizers are applied continuously, the available phosphorus in the soil goes up. When it is more than 20 ppm, application of phosphatic fertilizers can be skipped for a few years until the level goes below 20 ppm. If the level is 10 to 20 ppm, half of the recommended dose of phosphorus can be applied.

Application of soil amendments

In soils with acidic nature, in addition to the recommended level of fertilizers, 1 kg of dolomite or 1 kg of lime may be applied per palm per year. Dolomite/ lime may be broadcasted and incorporated in the basin one month prior to the application of chemical fertilizer. For coconut palms showing yellowing of leaves due to magnesium deficiency, 0.5 kg of magnesium sulphate can be applied in the basin along with other fertilizers during September-October. Deficiency of the micronutrients, especially boron, is also observed in coconut palms in certain localities. About 75 g of borax is to be applied at bi-monthly intervals till the symptom disappears.

Application of organic manures

Application of sufficient quantity of organic manure improves the soil characteristics and provides nutrients to coconut palms. Organic matter addition enhances moisture retention capacity and reduces the bulk density of the soils, thereby increasing aeration, drainage and water intake of soils. Organic manuring also helps in enhancing soil microbial activity and recycling of minerals. Organic manures such as farm yard manure, compost, green leaf manure or vermicompost can be applied to coconut palms. Circular basins of 1.8 m radius and 20 cm depth may be dug during August-September and green leaf or compost or farm yard manure @ 50 kg per palm may be spread in the basin.

Basin management with legume cover crops

An agrotechnique has been developed to generate significant quantities of organic manure and nitrogen in coconut gardens, utilizing the leguminous cover crops. It involves cultivation of leguminous plants having symbiotic association with efficient *Rhizobium* strains in coconut basins and interspaces during the monsoon period and incorporation of biomass generated to the palms at the maximum vegetative growth stage of legumes. Field experiments on basin management with legumes in adult coconut plantations have revealed the effectiveness of this technique to substitute nitrogen fertilizer for coconut up to 30 per cent. The effectiveness of the legume treatment as a component in the management programme for root (wilt) disease of coconut has also been well demonstrated. *Pueraria phaseoloides, Mimosa invisa, Calopogonium mucunoides,* cowpea (*Vigna unguiculata*), sunhemp (*Crotolaria juncea*), horse gram (*Macrotyloma uniflorum),* daincha (*Sesbania aculata*) and *Sesbania spinosa* are the species of legumes superior in biomass and nitrogen contribution in coconut basins. They contribute about 15-25 kg of biomass and 100-200 g of nitrogen in coconut basins during a growth period of 60-120 days in monsoon season. Pelleting of inoculated seeds with neutral or inert materials enhances nodulation by introduced *Rhizobia* in acidic soils.

Basin management through *Pueraria phaseoloides*

Cowpea as a cover crop in the coconut basin

Cover cropping

Cover cropping is recommended where inter and mixed cropping is not followed to prevent soil erosion in coconut gardens. This will also add organic matter to the soil. Leguminous crops such as Cowpea (*Vigna unguiculata*), *Sesbania aculeata, Mimosa invisa, Pueraria phaseoloides, Centrocema pubescens, Stylosanthes gracilis* and *Calopogonium mucunoides* are suitable for growing as cover crops in coconut garden. Green manure crops like sunhemp (*Crotolaria juncea*) and kolinji *(Tephrosia purpurea)* can also be raised and ploughed in, at the end of the monsoon. These crops can be sown in April-May when pre-monsoon showers are received.

Growing *Glyricidia* as green manure crop

Generation of large quantities of nitrogen rich biomass is also possible through the cultivation of fast growing perennial leguminous green leaf manure tree crop, *Glyricidia* in the coconut plantations. This can be easily grown along the borders of coconut plantation and can generate adequate amount of nitrogen rich green leaves.

Legume cover crops. *Pueraria phaseoloides*

Mimosa invisa

Sesbania aculeata

Crotolaria juncea

Vigna unguiculata

Glyricidia as alley crop

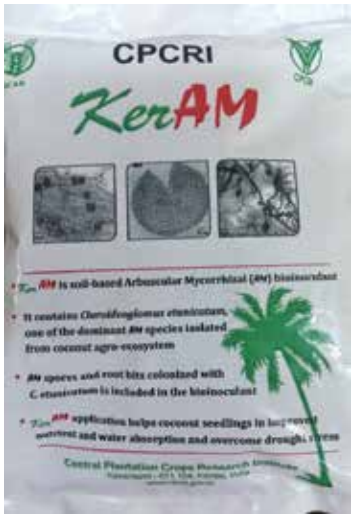
It can also be raised in littoral sandy soils where no other green manure can be established. The tree is propagated either through vegetative cuttings or seeds. One meter long stem cuttings or 3 to 4 month old seedlings raised in poly bags/raised beds can be used for planting. It is preferable that the planting season should coincide with the monsoon (South-West / North-East monsoon) for better establishment. Spacing of 1 m x 1 m can be adopted. Two rows of glyricidia can be planted along the boundary of coconut garden in a zig zag manner. Stem cuttings or seedlings can be in an upright position in pits of 30 cm x 30 cm x 30 cm. For better establishment, a basal dose of 50 g of rock phosphate per pit may be applied. Height of the plants when grow-up should always be maintained at 1 m by pruning. Pest and disease is not a major problem for glyricidia and hence, no plant protection measures are required. Pruning can be started one year after planting and should be done at least thrice a year. Studies conducted at ICAR-CPCRI have indicated that the best growth and biomass of leaves could be obtained with planting of three rows of Glyricidia at 1 m x 1 m spacing between two rows of coconut and pruning of leaves during February, June and October. This could produce around 8 t of biomass annually. Application of Glyricidia prunings could supply around 90%, 25% and 15% of the requirement of N, P_2O_5 and K_2O, respectively.

Bioinoculants

Bioinoculants are carrier-based preparations containing beneficial microorganisms in a viable state intended for seed or soil application and designed to improve soil fertility and help plant growth by increasing the number and biological activity of desired microorganisms in the root environment Bioinoculant formulations containing *Azospirillum* spp. and Phosphate solubilising bacteria having 10^8 colony forming units of bacteria prepared in carriers such as talc or vermicompost are to be applied @100 g per palm. '*Kera Probio*', a talc formulation of *Bacillus megaterium*, effective for raising robust coconut seedlings has been developed at ICAR-CPCRI. Similarly an Arbuscular Mycorrhizal Fungal (AMF) bioinoculant, '*Ker*AM', has been developed at ICAR-CPCRI, which is a soil based AMF bioinoculant for coconut seedlings. The bioinoculant contains *Claroideoglomus etunicatum*, one of the dominant AM species isolated from coconut agro-ecosystem with high potential to increase the growth parameters

of coconut seedlings. The bioinoculant should be mixed with one kg vermicompost and applied to soil and incorporated. Care should be taken to use only biofertilizer containing adequate number of living micro organism and before the expiry period mentioned in the packet. It has been observed that in many instances desired results are not obtained due to the use of preparation not containing the required number of metabolically active micro organism. Optimum soil moisture is essential after biofertilizer application to ensure the survival of the introduced microbial inoculum in the soil. Hence, biofertilizer application should coincide with the onset of monsoon, especially when the palms are maintained under rainfed condition. However, under irrigated conditions, it can be applied at any time, since maintaining optimum moisture is not a problem.

Kera Probio bioinoculant packet



*Ker*AM bioinoculant packet

Vermicomposting using coconut leaves

Fallen coconut leaves in the coconut garden can be effectively converted into rich verimcompost using the earthworm *Eudrilus* sp. Vermicompost preparation can be done in cement tanks or in trenches made in the coconut garden or in the coconut basin itself. The weathered coconut leaves collected from the garden should be kept for two weeks after sprinkling with cowdung slurry. Cowdung should be used at the rate of one tenth of the weight of the leaves. Afterwards earthworms (*Eudrilus* sp.) are to be introduced at the rate of one kg for one tonne of the material. Care should be taken to provide sufficient moisture for the decomposing material by frequent sprinkling of water. Adequate shade also should be provided to avoid direct sunlight. Vermicompost will be ready in about 2½ - 3 months. Watering should be stopped one week before collecting the compost. On an average, 70 per cent recovery of vermicompost is obtained. Nucleus cultures of the local strain of *Eudrilus* sp. capable of composting coconut plantation wastes are being supplied from ICAR-CPCRI at a nominal cost. These worms can be multiplied fast in a 1: 1 mixture of cowdung and decayed leaves, mulched properly with grasses.

Vermicompost is a finely divided peat-like organic material with excellent structure, porosity, aeration, drainage and water holding capacity. It has appearance and many characteristics of peat. It can influence a number of soil physical, biological and chemical processes which have their bearing on plant growth, development and yield and is a better source of organic matter than other composts. Application of vermicompost improves the soil aggregation, aeration, and water holding capacity; root growth, microbial activity and the overall crop production capacity of the soil. The vermicompost produced from coconut leaves using the technology developed at ICAR-CPCRI is now available by the trade name 'Kalpa Organic gold'

Coconut leaf vermicomposting tank

Earthworms

Vermicompost

Kalpa Organic gold

Vermicomposting using coconut leaves

Composting of coir pith

Coir pith is a lignocellulosic waste biomass which accumulates around coir processing factories as a waste material. Though coir pith has a number of beneficial properties, its direct utilization as manure is not advisable as it contains large amounts of lignin and phytotoxic polyphenols. A simple technology has been developed at ICAR-CPCRI for conversion of coir pith having a C:N ratio of 100:1 to acceptable manure. Large scale composting of coir pith can be done by the heap method in a shaded place. Coir pith (900 kg) obtained from coir processing units are treated with poultry manure (100 kg), lime (5 kg), rock phosphate (5 kg) and after proper mixing, it is spread evenly in an area of 4 x 2 x 1 m (l x b x h) dimensions. Water is sprinkled regularly over this mixture. The watering helps the whole coir pith heap to remain sufficiently moist. Over wetting and drying should be avoided. The heap is covered with dry grass to prevent moisture loss. The whole heap is to be turned once in 15 days enhances the speed of decomposition indicated by colour change of reddish brown raw coir pith to dark brown colour. After 45-60 days, the coir pith will become dark brown to black colour indicating the completion of composting process. The final product can be shade dried and packed for sale or farm use. The coir-pith compost produced by ICAR-CPCRI

Raw coir pith

Composted coir pith

Kalpa Soil Care

technology is dark coloured with *p*H in the range of 6.1 to 6.9 with a C:N ratio of 21 to 22 and having up to 500% water holding capacity. The N, P and K content ranges between 1.3 to 1.4, 0.9 to 1.2 and 1.3 to 1.6%, respectively, and is a good source of micronutrients as well. Composted coir pith @ 25 kg /palm can be applied in the basin of coconut palm during the month of August-September. The urea-free coir-pith compost produced using this co-composting technology is available at ICAR-CPCRI under the brand name 'Kalpa Soil Care'.

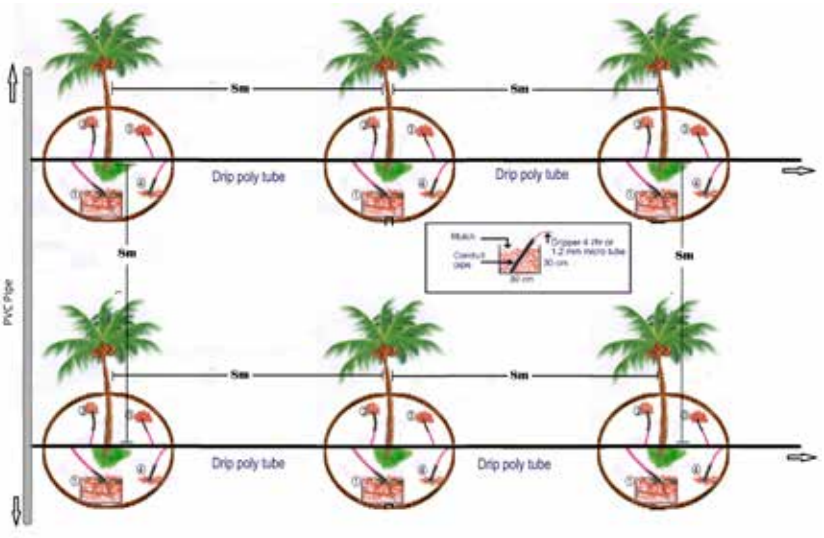
Intercultivation

Tillage operations like digging the garden with spade and making shallow basins with a radius of about 2 m at the beginning of monsoon and filling up at the close of monsoon are beneficial to the palms. Generally two ploughings can be undertaken per year during pre and post monsoon period. In sandy soils, which are generally of low fertility and do not have a luxuriant growth of weeds, regular intercultivation may not be necessary, but in other soils which permit quick growth of weeds, intercultivation will be necessary to keep weeds under control. Method of intercultivation (ploughing and digging) will depend upon local conditions, availability of labour, size of holding, soil type, topography and distribution of rainfall.

Irrigation methods

Irrigation methods commonly adopted in coconut gardens are flooding, basin irrigation, sprinkler or perfo-sprays and drip irrigation. In certain areas of Tamil Nadu, East and West Godavari Districts of Andhra Pradesh where adequate supply of water is available, coconut gardens are flood irrigated. There is considerable wastage of irrigation water under flood irrigation. In addition flood irrigation leads to poor aeration especially in clay soil leads to water stagnation and spread of disease like *Ganoderma*. Hence flood irrigation for coconut is not advisable and should be avoided. In basin irrigation, water is applied in the basins of 1.8 to 2.0 m radius which is the active root zone of coconut. Irrigation channels are provided in between two rows and each basin is connected with the channel. In this method there will be some loss of water due to deep percolation, seepage and evaporation. However this loss is reduced when basins are irrigated through hose pipes. This is being advocated to reduce water loss

in transit. Still, there is loss due to deep percolation and surface evaporation. ICAR- CPCRI recommends application of 200 l of water once in four days. For the WCT palms in red sandy loam soils on the west coast, perfo irrigation with 20 mm water, when cumulative pan evaporation is 20 mm is found to be the best irrigation schedule.



Drip irrigation layout in the coconut basin

Sprinkler irrigation or perfo sprays are most suited for inter or mixed cropping systems where the entire surface requires wetting. The quantity of water applied should be at least 75 per cent of open pan evaporation (Eo). Drip irrigation is ideally suited for widely spaced crops like coconut as it saves water, energy and labour and the WUE is high. Drip irrigation is a micro irrigation system in which the water is applied to the root zone at the rate at which the palm can take up. It is ideal considering the advantage of water saving. Four pits with a size of 30 x 30 x 30 cm have to be dug one meter away from the bole of the palm at equidistance and the pits filled with raw coir pith. The water has to be delivered to the pit through conduit tube placed in slanting position. Based on a study conducted at ICAR- CPCRI, it was concluded that yield of coconut with drip irrigation daily @ 66% of the Eo from December to May was adequate (32 liters/palm/day when the evaporation rate is 4 mm day) and comparable to basin irrigation @ 200 litres per palm once in four days. Thus, there is 34 per cent saving of water in drip irrigation. This is applicable to varieties and hybrids and also in different soil types. The number of dripping points should be six for sandy soils and four for other soil types. The rate of water application should be 2-4 litres per hour per emitter.

Soil and water conservation

Proper soil and moisture conservation practices are essential for ensuring sustainable production especially when coconut is grown under rainfed condition with undulating terrain and sloppy conditions.

Mulching

In order to conserve soil moisture in the coconut plantations, mulching with various types of organic materials can be practiced. The best time for mulching is before the end of the monsoon and before the top soil dries up. For mulching, cut coconut leaves into two or three pieces. To cover 1.8 m radius of coconut basin, 10 to 15 fallen coconut leaves are required and can be spread in two to three layers.

Mulching with composted coir pith to 10 cm thickness (approximately 50 kg/palm) around coconut basin is also an ideal method to conserve moisture. Coir pith can hold moisture five times its weight. Due to its fibrous and loose nature, incorporation of coir pith considerably improves the physical properties and water holding capacity of soil. The applied material may last for about 1 to 2 years. Coconut husks are also used as surface mulch around the base of the palm. It can hold moisture to the tune 3 to 5 times of its weight. Approximately 250 to 300 husks will be required for mulching one coconut basin. Mulching is usually done up to a radius of 2 m leaving approximately 30 cm near the palm. Two layers of husk may be buried in the coconut basin with the concave side facing upwards. These layers facilitate absorption of moisture. Above this, another layer of coconut husk is placed with the convex side facing upwards to arrest evaporation. Effect of this mulch lasts for about 5-7 years.

Coir pith mulching

Coconut leaf mulching

Husk mulching

Husk burial

Burial of husk in trenches in between the rows of palms is also effective for moisture conservation in coconut gardens. Husk burial is to be done at the beginning of the monsoon, in linear trenches of 1.2 m width and 0.6 m depth between rows of palms with concave side of husks facing upwards and each layer is to be covered with soil.

Catch pit filled with coconut husk

Catch pits can be constructed at slopes to conserve soil and water. Though there are no standard dimensions for catch pits, catch pits of 1.5 m length x 0.5 m width x 0.5 m depth can be constructed. A bund is to be made at the downside using the excavated soil and pineapple suckers may be planted on it. This pit is also to be filled with coconut husk.

Contour trench filled with coconut husk

This measure is to be taken up where the land slope is high. Trenches of 50 cm width x 50 cm depth and convenient length are to be made in between two rows of coconut palms. These trenches are to be filled with coconut husk. Coconut husks need to be filled in layers with the bottom layers facing up and top layer facing down. A bund of 20 cm height and suitable width (>50 cm) is made at the downstream using the excavated soil. Two layers of pineapple plants are to be planted on the bund with a spacing of 20 cm x 20 cm. Pineapple plants would stabilize the bund and provide additional income to the farmer. The runoff water from the upper side would be collected in the trenches. Soil particles would also get deposited in the trench along with the runoff water. Coconut husk retains the moisture and makes it available for plants during summer months.

Half-moon bund around coconut basin reinforced with pineapple

This measure is to be taken up where there is mild slope (15-20%). Here a flat basin with a slight inward slope towards upstream is made by excavating soil from the upstream side and filling the excavated soil at the downstream side. After making the basin, a bund of 30 cm

Half moon bund with pineapple border

Catch pit with pineapple border

Husk burial

Contour trench filled with coconut husk

height and >50 cm width is made at the downstream side of the coconut using the excavated soil. Two layers of pineapple plants could be planted with a spacing of 20 cm row to row and 20 cm plant to plant on the bund. The bund prevents runoff and water gets collected within the basin and percolates down. Pineapple would help to protect the bund and stabilize the same in addition to giving fruit yield.

Cropping/farming systems

Coconut based cropping systems by raising compatible subsidiary crops and/ or integrating with livestock enables to increase the productivity and net returns from unit area of coconut plantations. Farm resources like land, labour, sunlight, water and nutrients can be effectively utilized in such a system and higher productivity could be achieved as a result of synergistic interaction among the crop and crop-livestock components. Crop diversity involving a number of annual, biennial or perennial crops as inter/mixed crops in perennial stands of coconut also promote the productivity and sustainability of the system.

Coconut as a monocrop does not fully utilize the basic resources such as soil and sunlight available in the garden. The growth habit and planting methods of coconut make it highly suitable for intercropping in the interspaces of the coconut garden. Coconut palm like all monocots has a typical adventitious root system. Under favourable conditions, as many as 4000 to 7000 roots are found in the middle-aged palms. About 74 per cent of the roots produced by a palm under good management do not go beyond 2 m lateral distance and 82 per cent of the roots were confined to the 31 to 120 cm depth of soil. Thus, in a coconut garden the active root zone of coconut is confined to 25 per cent of the available land area and the remaining area could be profitably exploited for raising subsidiary crops. The orientation of leaves in the coconut crown helps penetration of sunlight into the soil and provides opportunities for exploitation of land and solar energy for inter/mixed cropping. Inter/ mixed crops are to be selected based on the age of the palms, size of the crown, availability of sunlight in the garden and agro climatic condition of the growing region.

Coconut offers scope for intercropping in the initial stage of the growth of palms and mixed cropping in the later part of life of palms. A variety of intercrops like tubers and rhizomatous spices (tapioca, elephant foot yam, sweet potato, greater yam, lesser yam, chinese potato, colocasia, ginger and turmeric), cereals and millets (paddy, sorghum, maize, pearl millet and finger millet), pulses and oilseeds (cowpea, green gram, black gram, red gram, ground nut, soybean, bengal gram and sunflower), vegetable crops (pumpkin, ash gourd, chillies, potato, french bean, snake gourd, amaranthus, brinjal, bottle gourd, ridge gourd, *Coccinia* sp., *Dolichos* bean, annual moringa, curry leaf and tomato), fruit crops (banana, pineapple, and papaya), flowering crops (*Heliconia* sp., *Anthurium* sp. and *Jasminum* sp.) and fodder grass and legumes can be raised in coconut gardens upto 5 to 7 years.

During the second growth phase of palms, *i.e.*, 5-20 years of age, growing of other crops in the interspace may be difficult due to poor sunlight availability. However, crops like colocasia, some varieties of banana like Robusta, Grand Naine Palayamkodan *etc.*, fodder grass, shade loving medicinal plants *etc.* which can tolerate shade can be cultivated in this phase.

After the palms attain a height of 5 to 6 m (above 20 years) *i.e.*, in older plantations, the crops mentioned in the initial stage and perennials like cocoa, vanilla, black pepper, cinnamon,


Tapioca


Elephant foot yam


Diascorea sp.


Ginger


Turmeric


Banana


Pineapple


Sorghum


Bitter gourd


Gladiolous


Black pepper


Cocoa

clove and nutmeg, sapota and medicinal and aromatic crops like Chittadalodakam (*Adhatoda beddomei*), Karimkurinji (*Nilgirianthus ciliatus*), Nagadanthi (*Baliospermum montanum*), Vetiver (*Vetiveria zizanioides*), Indian long pepper (*Piper longum*) can be grown as mixed crops along with the intercrops. Perennials are recommended as intercrops in the third stage only when the spacing adopted for coconut is 7.5 to 8.0 m. However, perennials can be grown as intercrops from the initial stage onwards by planting coconut at a wider spacing of 10 m and above. In places where rainfall is not well distributed, irrigation is necessary during summer months. However, these crops are to be adequately and separately manured in addition to the manures applied to the coconut palms. Package of practices of intercrops should be followed as per the recommendation by Agricultural Universities of the region.

High Density Multispecies Cropping System

High density multispecies cropping system (HDMSCS) involves growing a large number of crops to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash. This is ideally suited for smaller units of land and aims at maximum production per unit area of land, time and simultaneously ensuring sustainability. This system includes annuals, biennials and perennials. The crops selected include cash crops, food crops and fodder crops. The biomass other than the economic part is recycled within the system. From the experimental plot on HDMSCS maintained at CPCRI Kasaragod, which involves coconut and other crops like banana, pineapple, pepper, clove and nutmeg, it is observed that an average annual net income of 5 to 6 lakh rupees can be obtained per ha. Besides, 25 tonnes of organic wastes are also made available per ha which can be recycled and applied to the crops as vermicompost. In HDMSCS if organic recycling is effectively carried out, we can reduce the chemical fertilizer input for coconut to two third of the recommended dose.

Coconut based HDMSCS

Coconut based integrated farming system

Coconut based integrated farming is an ecologically sustainable system which helps the farmer to realize more income. Sustainability is the objectivity of the integrated farming system where production process is optimized through efficient utilization of inputs in safeguarding

the environment with which it interacts. Mixed farming by raising fodder grasses such as hybrid Napier or guinea grass along with leguminous fodder crops such as *Stylosanthes gracilis* in coconut gardens has been found to be profitable. Raising the above crops in one hectare of coconut garden can support five to six dairy animals. However, if Hybrid Bajra Napier (Co 3, Co 4 or Co 5) is grown as intercrop in coconut garden about 120 tonnes of green fodder per hectare per year can be obtained through which 12 animals can be maintained. In addition to cattle, poultry, pisiculture, goattery and apiculture may also be integrated depending upon the farmer's interest. The cattle and poultry manure generated from the system when applied to coconut garden improves the soil fertility considerably. Maintaining milch cows and other components in coconut garden helps the farmer to enhance his income and provide additional employment to the family. A net income of 6.0 to 6.5 lakhs rupees per year can be obtained from a one hectare coconut based mixed farming unit comprising of components such as 10 milch cows, 6 batches of poultry birds of 100 per batch and Co 3 Hybrid Bajra Napier fodder grass, 1000 fingerlings and 20 does and 2 bucks in goattery unit. Employment generated from such a unit is about 900 man days per year. By maintaining one coconut based integrated farming system more than 70 tonnes of FYM is produced from the system and cow urine more than 1 lakh liters and these if recycled in to the system can result in improvement of soil physical, chemical and biological properties and ensure the sustainability of the system. More than 75 per cent of the N and k requirement can be substituted through on farm resources and entire phosphorus requirement can be met internally.

Coconut + Grass +Pepper

Dairy

Gobar gas unit

Poultry unit

Pisciculture

Goat unit

Coconut based integrated farming system

Pest suppression

The major pests of coconut palm are rhinoceros beetle (*Oryctes rhinoceros*), red palm weevil (*Rhynchophorus ferrugineus*), leaf eating caterpillar (*Opisina arenosella*), eriophyid mite (*Aceria guerreronis*), rugose spiralling whitefly (*Aleurodicus rugioperculatus*), coreid bug (*Paradasynus rostratus*) and root eating white grub (*Leucopholis coneophora*).

Rhinoceros beetle, *Oryctes rhinoceros* Linn.

This ubiquitous and cosmopolitan pest has currently become the greatest impediment in the early establishment of juvenile palms causing more than 20% damage through collar entry. Beetles bore into the collar region of the young palms resulting in dead heart, twisted spindle with elephant-tusk like symptoms and perverted leaflets. In adult palms, the beetle bores into the unopened fronds/spindle region/spear leaf/spathes/nuts. The affected frond shows the characteristic diamond shaped cuts (V-shaped) upon unfurling as well as exposing chewed up fibres from the feeding site. Infestation on spathes often destroys the inflorescence and thus prevents production of nuts. Of late, the beetle was also found to cause damage in tender nuts.

The beetle breeds on a variety of materials such as decaying organic debris, farm yard manure, dead coconut stumps, logs and compost and mostly seen during the months of February to April. The life cycle of this pest is about six months and afterwards it undergoes pupation for a period of 14-29 days and the adult black beetle emerges finally. The infestation will be severe during the months of June to September. Attack by rhinoceros beetle will lead to infections by bud rot and leaf rot, besides damage by red palm weevil.

Leaf damage by rhinoceros beetle

Life stages of rhinoceros beetle

Management

- Maintenance of farm sanitation in coconut gardens by proper disposal of decaying organic debris and upkeep of palm hygiene by annual crown cleaning.
- Regular monitoring and looking out for any damage on the spindle region of the juvenile palms or seedlings at collar region.
- Extraction of beetles with GI hooks mechanically without causing further injury to the growing point of the palm and any such wounds should be dressed with fungicide suspension.
- The top most three leaf axils may be filled with powdered neem cake/marotti cake/ pongamia cake @ 250 g/palm + fine sand (250 g) per palm during pre and post monsoon months (May, September, December) as a prophylactic measure or
- Filling the innermost three leaf axils with 12 g of naphthalene balls and covered with sand at 45 days interval or
- Placement of three perforated sachets containing chlorantraniliprole a.i. 0.4% (5 g) or fipronil (3 g) or three botanical cake (2 g each) developed by ICAR-CPCRI during monsoon phase. During dry period, 100 ml of water may be poured over the sachet for effective release of the molecule.
- Incorporation of the biomass of the weed plant *Clerodendron infortunatum* Linn. @ 10 per cent w/w in the compost pit.
- The *Oryctes rhinoceros* nudivirus (OrNV) can be used for the biological control of rhinoceros beetle and release of virus inoculated beetles @ 10-12 per ha brings down the pest population.
- The breeding sites may be treated with green muscardine fungus (*Metarhizium anisopliae).* The fungus can be mass multiplied on local materials such as coconut water, cassava chips and semi-cooked rice. Spraying of fungal culture at a population of 5 x 10^{11} spores diluted with 750 ml water per cubic meter in the breeding site helps to reduce the pest population.
- Use of PVC pheromone traps 'Oryctalure [ethyl 4 methy octonoate]' (1/ha) and field delivery using nanomatrix @ 1 trap / ha in farmer participatory community mode is an innovative method in pest suppression. Avoid installation of traps in gardens with juvenile palms.
- An ecologial engineering with intercrops in coconut planations would emanate different volatile cues disorienting rhinoceros beetle from attacking palms.

Extracting beetles with GI hooks

M. anisopliae infected grubs of rhinoceros beetle

Packets containing *M. anisopliae* multiplied in semi-cooked rice

Red palm weevil, *Rhynchophorus ferrugineus* Olivier

Red palm weevil is a fatal enemy of coconut palm. Young palms of less than 20 years of age succumb to severe damage when infested by this pest. Dwarf varieties are highly susceptible to red palm weevil. Palms infected by bud rot, leaf rot *etc*. and attack by rhinoceros beetle are the pre-disposing factors for red palm weevil infestation. Adult beetles lay the eggs in the injured parts of trunk or collar region. Grubs will emerge after 3 to 4 days and enter into the wounded portion of trunk or collar region. Yellowing of middle whorls (1-2 fronds) can be a sign of attack due to impairment in nutrient translocation. Leaf splitting at base due to improper growth of trunk may also occur. Being an internal feeder, it is very difficult to detect the damage caused by red palm weevil at an early stage. Wilting of the central spindle, presence of chewed fibers and cocoons in the trunk, presence of holes in the trunk with brown fluid oozing out are the important symptoms of red palm weevil attack. The symptom of the infestation becomes clear in advanced stages, by which time the crown of the affected palm topples. Gnawing sound of grubs can be heard through the trunk similar to the crushing of sugarcane during juice extraction.

The grubs of red palm weevil moult into ten different instars in a period of 36-78 days. It further undergoes pupation for a period of 22 to 25 days and afterwards the adult weevil will emerge. Adult has a life span of 60 to 70 days. The weevil multiplies abundantly in young

Life stages of red palm weevil

Crown toppled juvenile palm

Feeding grubs

coconut plantations, causing loss to an extent of 1-3 per cent. Entire life stages of the pest are observed within the infested palms on all occasions.

Management

- Avoid causing injury to palms, as they would attract the weevils to lay eggs. Injuries caused by rhinoceros beetle, mechanical injury during cutting of leaves or steps cut on the trunk for climbing give a favorable condition for egg laying. Infection by fungal disease is also a pre-disposing factor. Mechanical injury if any, caused should be treated with coal tar.
- While cutting fronds, petiole to a length of 120 cm is to be left on the trunk to prevent the entry of weevils into the trunk.
- Removal and burning of palms at advanced stage of infestation would aid in destruction of various stages of the pest harbored inside the trunk.
- Prophylactic leaf axil filling is suggested to ward off damage by rhinoceros beetle.
- Spot application of 0.02% imidacloprid 17.8 SL (@1.12 ml per litre of water) or 0.013% spinosad 2.5 SC (5 ml per litre of water) or 0.04% indoxacarb 14.5 EC (2.5 ml per litre of water) was found effective in the suppression of the pest.
- Installing traps with aggregation pheromone helps to mass trap and destroy the weevils. The weevils are trapped using a plastic bucket of 5 litres capacity with four windows (5 x 1.5 cm) made below the rim of the bucket. Coconut fiber/jute sack is wound over the bucket to provide grip to the alighting beetles. The commercially available pheromone lure (Ferrolure+) is hung inside on the lid of the bucket. The bucket is filled with 150 g banana, 2 g yeast and 2 g fipronil in 1 litre of water. Instead of banana, pineapple can also be used. The traps are tied on separately erected poles at about 1.5 m above the ground level. Placing a single trap per hectare was found ideal. This technology would be successful if taken up on community basis. The pheromones lures have an extended life of 6-8 months if nanomatrix is used for delivery. A farmer-participatory community approach is required for area-wide implementation.
- Adoption of intercropping in coconut garden reduces the incidence of red palm weevil attack.

Coconut eriophyid mite, *Aceria guerreronis* Keifer

It is an invasive pest introduced into the country during 1998. Coconut gardens in India are seriously affected by this non-insect pest. These mites infest by sucking sap from the soft meristematic tissues beneath the tepals on buttons. In the initial stages, symptoms are seen as triangular patches close to perianth. Later because of the continuous sucking of sap by

Progression of eriophyid mite damage

Eriophyid mite attacked nuts

various stages of mites present beneath the inner bracts of perianth, brown coloured patches are formed. As the nuts grow in size, the injured patches become warts and then develop into longitudinal splits on the surface of nuts. The damage thus caused affects the quality of husk and de-husking becomes difficult.

Management

- Removal of dried spathes, inflorescence parts, fallen nuts *etc.* and burying them in the soil or burning them reduces the pest inoculum and consequent infestation. Crown cleaning should be taken up as and when necessary.
- Root feeding azadirachtin 10,000 ppm @ 10 ml + 10 ml water.
- Spraying with neem oil-garlic-soap mixture @ 2 per cent concentration (neem oil 200 ml, soap 50 g and garlic 200 g mixed in 10 litres of water) is effective.
- Spraying neem formulations containing 1 per cent azadirachtin @ 4 ml per litre of water during April-May, October-November and January-February.
- Along with the recommended dose of chemical fertilizers and 50 kg cowdung or compost, 5 kg neem cake per palm should be applied. Recycling of biomass or raising of green manure crops in coconut basins and *in situ* incorporation during flowering, summer irrigation and moisture conservation by appropriate measures are also recommended for the management of the pest.
- Three sprayings of palm oil (200 ml) and sulphur (5 g) emulsion on the terminal five pollinated coconut bunches during January-February, April-May and October-November reduces mite incidence drastically.
- Kalpa Haritha (a tall selection from Kulasekaram green dwarf) recorded lowest mite incidence in the field and could be a preferred choice in endemic zones.
- Application of talc based preparation of *Hirsutella thompsonii* @ 20 g / l/ palm containing 1.6×10^8 cfu with a frequency of three sprayings per year reduces mite population.

Leaf eating caterpillar, *Opisina arenosella* Wlk.

Leaf eating caterpillar, another serious pest of coconut, commonly occurs in the coastal and backwater tracts. In recent years, they have assumed severe proportions in interior tracts as well. The caterpillars live on the under surface of leaflets inside silken galleries and feed voraciously on the chlorophyll containing functional tissues. This adversely affects the health of the palm by reducing the photosynthetic area and results in yield reduction. The severity of infestation by this pest will be marked during the summer months from February to May. With the onset of southwest monsoon, the pest population begins to decline. In severe outbreaks of leaf eating caterpillar, the older leaves of the palms are reduced to dead brown tissue and only three or four younger leaves at the center of the crown remain green. In the year following the outbreak, the nut yield and crop canopy may be reduced to half. In case of severe infestation, the whole plantation presents a scorched appearance.

Life stages of leaf eating caterpillar

Palm damage by leaf eating caterpillar

Goniozus nephantidis parasitizing leaf eating caterpillar

Management

- Cutting and burning the heavily infested and dried outer most 2 - 3 leaves helps to prevent the spread of the pest.
- Improving soil and infested palm health through application of balanced dose of chemical fertilizers and organic manures.
- Since a very rich natural enemy fauna is associated with the pest in the field, chemicals are generally not encouraged for management of *O. arenosella.* As this pest is subject to parasitism by a good number of indigenous larval and pupal parasitoids, biological suppression is a feasible and viable approach. Augmentative release of stage-specific parasitoids *viz.,* the larval parasitoids *Goniozus nephantidis* (Bethylidae) @ 20 parasitoids/palm, *Bracon brevicornis* (Braconidae) @ 20 parasitoids/palm, the pre-pupal parasitoid, *Elasmus nephantidis* (Elasmidae) @49/100 pre-pupae, and the pupal parasitoid *Brachymeria nosatoi* (Chalcididae) @32/100 pupae at the appropriate time was found effective in the sustainable management of the pest. Combined release of the parasitoids is required in multi-stage prevalence of the pest in the field. Conditioning of parasitoids on larval frass before release enhances the field level parasitism.

Rugose spiralling whitefly, *Aleurodicus rugioperculatus* Martin

During 2016, gradient outbreak of rugose spiralling whitefly (*Aleurodicus rugioperculatus*), an invasive pest of Neotropical origin, was first reported on coconut palms from Pollachi, Tamil Nadu and Palakkad, Kerala. It was found to feed and breed profusely from the under surface of the palm leaves, numbering more than 10 live colonies on a leaflet. As rugose spiralling whitefly (RSW) is a highly polyphagous invasive species, a biosecurity alarm was sounded to monitor its spread and extent of damage caused. Though RSW initially created panic by its expansive mode of ovipositional damage in different crops including banana, bird of paradise, custard apple, jack, *Heliconia* sp., *etc.,* it could not sustain feeding on other crops successfully compared to coconut and relatively to some extent, on banana, which are its most favoured host plants.

RSW could not cause greater economic damage, however, it produced enormous quantities of honeydew on coconut and other intercrops in the palm system, resulting in heavy deposition of sooty mould (*Leptoxyphium* sp.) on affected plants. On coconut, sooty mould deposition was confined to the upper surface of coconut leaves including midrib impairing photosynthesis. Sooty moulds are black-coloured fungi that grow as secondary to infestation by honeydew producing insects such as aphids, whiteflies, and Coccoidea and have no interrelationship with the host plants associated with. Presence of black sooty mould is one of the characteristic symptoms of feeding damage by RSW and that also ascertained the presence of RSW in the palm system.

Eggs laid in spiralling mode

Nymphs

Adult rugose spiralling whiteflies

Management

- Application of 1% starch solution on leaflets to flake out the sooty moulds.
- In severe case, spray neem oil 0.5% and no insecticide is recommended.
- Installation of yellow sticky traps on the palm trunk to trap adult whiteflies.
- Encourage build up of the aphelinid parasitoid (*Encarsia guadeloupae*) and re-introduce parasitized pupae to emerging zones of whitefly outbreak.

- Conserve the natural population of the green lacewing, *Pseudomallada* sp. and other lady beetles to suppress the pest population.

- *In situ* habitat conservation of the sooty mould scavenger Leiochrinid beetle, *Leiochrinus nilgirianus* and introductory bio-scavenging/biological control in new areas of RSW emergence.


Green lacewing predator


Encarsia guadeloupae



Sooty mould feeding beetle *L. nilgirianus*

White grub, *Leucopholis coneophora* Burm

The soil inhabiting white grubs cause damage to the roots of coconut. Besides coconut, it infests tuber crops like tapioca, colocasia, and sweet potato grown as intercrops in coconut gardens. In coconut nursery, the grubs feed on the tender roots and tunnel into the collar region resulting in drying up of the spear leaf followed by yellowing of the outer leaves and gradual death of the seedling. In older coconut plantations continuous infestation by the grub results in yellowing of leaves, premature nut fall, delayed flowering, retardation of growth and reduction in yield. Beetles lay eggs in the soil and after 3 weeks grubs will emerge. The grubs initially feed on organic materials and roots of intercrops then it starts feeding on coconut roots. The total life cycle is one year. The adults will emerge from the soil during the month of June. After sunset the beetle will emerge for about 30 minutes.

Management

- Repeated ploughing during September to January once in a month for about 4-5 times

- Hand picking of beetles daily in the evening for 2 weeks commencing from the onset of south west monsoon in Kerala.


White grub


Adult beetles


Summer ploughing

- Application of neem cake in the coconut basin @ 5 kg/palm regenerates new roots.
- Drenching the root zone with 15 l insecticide solution per palm containing chlorpyrifos 20 EC @ 2.5 ml/l or imidacloprid 17.8 SL @ 0.27 ml/l or bifenthrin 10 EC @ 5.0 ml/l during May-June and September-October are found effective in the management of root grubs of coconut.
- Soil application of aqua suspension of entomopathogenic nematode, *Steinernema carpocapsae* in the interspaces at 5-10 cm depth with 1.5 billion IJ/ha and need based repeated application is found effective in the bio-suppression of white grubs.

Coreid bug, *Paradasynus rostratus* Dist.

Coried bug occurs in coastal areas and high ranges of Kerala. The incidence is at a higher side in Trivandrum, Waynad and Kasaragod districts of Kerala. Apart from coconut it feeds on tamarind, cashew, cocoa, and guava. The peak population occurs during post monsoon period. Nymphs and adults puncture the meristematic regions of tender buttons (1-3 months old) injecting toxin around the feeding site causing necrosis. Feeding punctures develop into necrotic lesions and these spindle-shaped depressions could be visible when the perianth of shed button is removed. Female flowers are attacked prior to pollination and such flowers get dried and can be seen attached to inflorescence on the crown resulting in production of barren nuts. Most of the infested buttons and tender nuts are shed. Retained nuts on the bunch develop furrows and crinkles on the husks and are malformed. In many cases, gummosis can be seen. Emergence of coreid bug is usually associated with increased population densities resulting from ecological changes consequent to alterations in the environment. Population build up starts from first rainy period (last week of May or first week of June) and there is a steady increase in the population reaching a peak during October-December.

Management

- Crown cleaning to destroy eggs and immature stages of the pest.
- Spraying of azadirachtin 10000 ppm (Nimbecidene) @ 0.004% (4 ml/L) reduces the pest incidence. Two rounds of azadirachtin spray on 1-5 months old coconut bunches during

Spindle shaped feeding lesion

Feeding nymphs

Damaged nuts

May-June and September-October are essential for satisfactory control of the pest.

- Among the natural enemies, the weaver ant, *Oecophylla smaragdina* is found to be the most efficient predator of coreid bug.
- Two egg parasitoids, namely *Chrysochalcissa oviceps* and *Gryon homeoceri* are identified as potential egg parasitoids. Forty per cent parasitism was observed in the egg mass collected from the field due to these parasitoids.
- Spraying lambda cyhalothrin 5% EC @ 1ml/l on the pollinated bunches in case of severe outbreak.

Slug caterpillars, *Contheyla rotunda, Parasa lepida*, *Darna nararia*

Early-instar caterpillar feeds on undersurface of coconut leaflets by scrapping the surface tissues giving a glistening appearance on the feeding area. Leaf spot-like black halo marking develops on the feeding areas which later coalesce and form bigger lesions. Early-instar caterpillars consume only the epidermis of leaf tissue, leaving the adaxial surface intact and the grown-up caterpillars feed voraciously on the leaf tissues leaving only the midribs. Feeding damage is often exacerbated by grey leaf blight fungus, *Pestalotiopsis palmarum* which may infect leaf tissue breached and damaged by early larval instars. Scorched / burnt appearance of leaves is the characteristic symptom observed in the field due to severe infestation. In severely infested palms, all functional leaves are dried up leaving only the

Infested coconut garden | Slug caterpillar | Silken pupa

Glistening feeding damage by early instar larvae | Aggregation of feeding caterpillars

inner leaves, thus affecting the photosynthetic efficiency of the palm. Premature drooping of leaves and shedding of nuts are also observed in heavily infested gardens bringing drastic reduction in nut yield.

Management

- Establishment of light traps in endemic tracts could help in monitoring of the pest as well as reducing the population of moths.
- Larvae of *D. nararia* are parasitized by *Eurytoma tatipakensis* Kur., *Euplectromorpha natadae* Kur. and *Secodes nararіae* Kur. under natural condition.
- Good nutrition as well as irrigation is required to recoup the infested palms, which takes about 20-24 months.

Rodents, *Rattus rattus wroughtoni*

Rats damage tender nuts and cause severe crop loss in many places. Damaged tender nuts contain a small hole about 5 cm diameter near the stalk region scooped by the rats and these damaged nuts are retained in the bunch for 2-6 days. Shed tender nuts with characteristic holes can be observed at the base of the affected palms. Three to six months old tender nuts are mostly preferred by this mammalian pest. Rats also damage leaf stalks, unopened spathe, female flowers and mature nuts in the field as well as in the stored nuts. In extreme cases, nests are constructed on coconut crown using coconut leaflets and other palms parts.

Management

- Rats can be controlled by providing mechanical barriers (bands), poison baits and traps. Wrapping the trunk of coconut trees using polythene sheets was found to reduce the damage by rats in Minicoy.
- G.I sheet bands, 40 cm wide, fixed around the trunk of palms at a height of 2 m from the ground serve as mechanical barriers for rats.
- Planting coconut seedlings in correct spacing as well as destruction of fallen fronds and other palm residues at regular intervals to ward off the rat activity from coconut gardens.
- Poison baiting with 10 g bromadiolone (0.005%) blocks two times at an interval of 12 days on the crown of one palm out of every five palms is recommended for effective control of black rat. This method is highly cost-effective. If the damage is restricted to certain palms, only such palms require baiting.
- Poison baiting at the ground level does not have much effect in controlling the rats since

Rat damaged nuts

Rat

they seldom come to the ground. If there are residential buildings within the plantations, rat control should be undertaken in both the places to check re-infestation. The best period to adopt the field operation to control the rat is late summer.

Disease management

The coconut palm is affected by a number of diseases, some of which are lethal while others gradually reduce the vigour of palms causing severe loss in yield.

Bud rot

Causal organism: *Phytophthora palmivora*

Symptoms

The earliest symptom is the yellowing of one or two younger leaves surrounding the spindle. The spindle withers and droops down. The affected spindle leaf turns brown, hangs down and can easily be pulled out as the basal portion of the spindle is completely rotten emitting a foul smell. Subsequently younger leaves next to the spindle also fall away one by one leaving only outer whorl of matured leaves in the crown. The bud rot pathogen also causes

Initial stage bud rot affected palm

Mortality of the palm due to bud rot

Rejuvenated palm after treatment

water soaked lesions on nuts, quite independent of bud rot, and nut fall commonly called as 'Mahali'.The disease kills the palm if not controlled at the early stages. Palms of all ages are liable to be affected but normally young palms are more susceptible. The disease is more prevalent during monsoon when the temperature is low and humidity is high.

Management

Integrated disease management strategies should be adopted for effective management of bud rot disease. Dwarf varieties of coconut are highly sensitive to bud rot compared to local ecotypes or tall varieties and more emphasis on bud rot management is required in the orchards with dwarf palms.

- **Phytosanitation:** Remove all the dead palms or palms in the advanced stage of bud rot disease from the orchard and destroy the crown. Burn all disease affected tissues removed from the palm.

- Regular monitoring of the palms for bud rot symptoms will help in diagnosing the disease in early stage and can be cured.

- **Prophylactic management:** Crown cleaning and application of Bordeaux mixture (1%) to palms in disease endemic areas before the onset of monsoon preferably in the last week of May or first week of June. About 300 ml Bordeaux mixture (1%) or chlorothalonil solution (3 g in 300 ml water) may be poured in the base of the spindle. In heavy rainfall endemic area, one more application is required after 45 days. Or place two perforated plastic sachets containing fungicide chlorothalonil (3 g) in the inner most leaf axil.

- **Curative treatment:** In the early stage of the disease, remove the spindle leaf by pulling it out and cut and remove the infected tissues completely. Two or three healthy leaves adjacent to the spindle may have to be removed if necessary for easy removal of all rotten portions and thorough crown cleaning. The wound should be treated with Bordeaux paste (10%) or chlorothalonil solution (3 g in 300 ml water /palm). Bordeaux paste (10%) can be prepared by dissolving 100 g of copper sulphate and 100 g of lime separately in 500 ml of water in a plastic mug and mixing the solutions. The treated wound should be covered with polythene cover to prevent entry of rain water and this protective covering should be retained till normal shoot emerges. The diseased tissues should be burnt after their removal.

- Besides integrated disease management techniques, nutrient management practices for the affected palms are important for improving the health and vigour of the palms for higher yield.

- Rhinoceros beetle attack predisposes the palm to bud rot infection. Hence prophylactic measures to prevent beetle infestation have to be undertaken in bud rot endemic area

Root (wilt) disease

Root (wilt) disease has been prevalent in the state of Kerala for nearly 130 years and is believed to have made its appearance after the great floods of 1882. It has now established itself almost contiguously in eight southern districts of Kerala *viz*. Thiruvananthapuram, Alappuzha, Kollam, Kottayam, Pathanamthitta, Idukki, Ernakulam and Thrissur. It has also made its sporadic appearance in the districts of Malapuram, Palakkad, Kozhikode, Wayanad and Kannur and in some groves in the neighbouring states of Tamil Nadu, Karnataka and Goa.

Causal organism : *Phytoplasma* is the causative agent of the disease. The disease is transmitted by lace bug *Stephanitis typica* and the plant hopper *Proutista moesta*.

Symptoms

The important visual diagnostic symptoms of the disease are abnormal bending or ribbing of the leaflets termed as 'flaccidity', a general yellowing and marginal necrosis of the leaflets

RWD affected palms

and unopened inflorescence. The nuts are smaller and the kernel is thin. The oil content of copra is also reduced. Since the disease is not lethal but debilitating and no curative measure is known at present, the approach will be to manage the disease in the already infected gardens. Palms of all age groups are affected. However, palms contracting the disease in the pre bearing age may not come to flowering and bearing. The disease also causes several internal changes in the palm.

To reduce the loss due to the disease, the strategy would be to contain the disease in the eight southern districts of Kerala for which the following measures are recommended.

Management

Management strategies for root (wilt) disease have been formulated separately for heavily diseased areas and mildly diseased areas. In the heavily diseased area, the yield of palms can be sustained or improved through adoption of integrated management practices as detailed below

Cultural practices: Cutting and removing palms with advanced disease and those that yield less than 10 nuts per palm per year; growing green manure crops – cowpea, sunhemp (*Crotalaria juncea*), *Mimosa invisa*, *Calapagonium mucunoides*, *Pueraria phaseoloides*, *etc*. which may be sown in coconut basins during April–May and incorporated during September–October; irrigating the coconut palms with at least 250 L water once in four days; adopting suitable inter/mixed cropping in coconut gardens; providing adequate drainage facilities in coconut garden.

Management practices: The integrated disease management technology module includes removal of all disease advanced and uneconomic palms with annual yield of less than 10 nuts, replanting with disease tolerant varieties or elite seedlings from high yielding disease free palms located in hotspot endemic areas, application of organic manure (25 kg farm yard manure or 10 kg vermicompost), biomass recycling by application of leguminous green manure crops and glyricidia leaves, soil test based application of fertilizers (500g N, 300 g P_2O_5,1250 g K_2O and 1kg $MgSO_4$/palm/year) in two splits, application of soil amendments, irrigation with 200-250 L of water/palm/week, soil moisture conservation, adequate drainage, inter cropping and mixed farming coupled with recycling of organic matter and adopt recommended management strategies for leaf rot disease, rhinoceros beetle and red palm weevil.

Use of tolerant varieties

As root (wilt) disease is not amenable to conventional plant protection measures, cultivation of tolerant varieties is the most ideal method for management. The tolerant varieties Kalparaksha

(selection from Malayan Green Dwarf), Kalpasree (selection from Chowghat Green Dwarf) and the hybrid Kalpa Sankara (Chowghat Green Dwarf x West Coast Tall) released from ICAR- CPCRI are suitable for cultivation in root (wilt) disease endemic tracts.

Kalpa Sankara, a root (wilt) tolerant hybrid

Leaf rot

Leaf rot disease commonly occurs on coconut palms already affected by root (wilt) disease. Infection by this disease is the major reason for the low productivity of root (wilt) affected palms.

Causal organism: *Colletotrichum gloeosporioides, Exserohilum rostratum* and *Fusarium solani* are the major pathogens causing leaf rot.

Symptoms

Leaf rot symptoms initially appear as minute water soaked reddish brown lesions on the spindle leaves. These lesions enlarge and coalesce freely resulting in extensive rotting. If the leaf rot infection happens in the early period of spindle leaf emergence, expansion of lesions would be rapid and the rotting may progress to the interior of the spindle also. Often the tips of the rotten leaflets of the spindle stick together while the bases of the leaflets are open. Later the affected portion breaks off in bits giving the infected leaves a fan like appearance. The rotten portion of leaflets dry up, turn black and shriveled and may fall off leaving the midrib alone. If no protective measures are taken, each new leaf of the diseased tree gets infected with the result that a stage is soon reached when all leaves of the tree show disease symptoms.

Management

- The integration of leaf rot management with pest management and general cultivation practices is very effective in improving the health of the palms and thereby increasing the yield.
- Cut and remove rotten affected portions of the spindle and the adjacent two innermost fully opened leaves. By pruning the rotten portions, the fungal inoculum load in the crown is much reduced.
- Mix hexaconazole 2 ml in 300 ml water and pour into the well around the base of the spindle leaf or apply talc based formulation of *Pseudomonas fluorescens* or *Bacillus subtilis* singly or in consortium @ 50 g in 500 ml/ palm. In disease endemic areas, treat all palms in the plantation (healthy and diseased) twice a year, i.e. in April-May and October-November as prophylactic measure. To make this operation more economical the treatment should be given along with harvest of nuts before and after the monsoon

Leaf rot affected leaf

Leaf rot affected palm

- Undertake prophylactic measures to prevent rhinoceros beetle attack.
- Palms in the early stages of disease will recover totally with two or three applications. Palms in the advanced stages (with an index of more than 50%) would take three years to recover fully. To prevent the recurrence of the disease, the treatment needs to be continued.

Stem bleeding disease

Stem bleeding disease is prevalent in all the major coconut growing states in India.

Causal organism: The fungus, *Thielaviopsis paradoxa,* is the primary causative agent. Growth cracks on the trunk, severe summer followed by sudden wetting, imbalanced nutrition, excess salinity etc. are the predisposing factors.

Symptoms

The disease is characterized by the exudation of dark reddish brown liquid from the longitudinal cracks in the bark generally at the base of the trunk. The tissues beneath the lesions show decay. The bleeding patches spread throughout as the disease advances. The liquid oozing out dries up and turns black. The tissues below the lesions rot and turn yellow first and later black. Leaves in the outer whorl turn yellow rather prematurely, droop and dry. Production of bunches is affected. Nut fall also is noticed. The trunk gradually tapers at the apex and crown size becomes reduced. In advanced stages, infestation with *Diocalandra* weevil can be seen which quickens the deterioration of the palms.


Palms infected with stem bleeding

Management

- Remove completely the disease affected tissues using a chisel and smear the chiseled portion with hexaconazole (0.2%) or carbendazim (0.2%) and apply coal tar after 1-2 days on the treated portion. Destroy the chiseled diseased tissues by burning.
- Apply a paste of talc based formulation of *Trichoderma harzianum* (Isolate CPCRI TR 28) on bleeding patches.
- In severely infected palms where bleeding patches spread top towards crown, root feeding with hexaconazole (2 ml in 100 ml water) or carbendazim (5 g per 100 ml) and drenching of the basin with 40 l of 0.2 % hexaconazole or carbendazim.
- Apply recommended dose of fertilizers (N (500 g), P_2O_5 (320 g) and K_2O (1200 g) in two equal splits during June-July and December–January) and provide irrigation (45 to 50 L per palm per day) during summer.
- Apply neem cake (5 kg/palm) enriched with *Trichoderma harzianum* (CPTD 28) during September-October.
- Avoid any type of injury to the trunks as wounds predispose the palms to infection. Care should be taken not to injure the stem base while ploughing the garden with tractor.

Basal Stem Rot disease/ *Ganoderma* disease/ Thanjavur wilt

Ganoderma wilt was first observed in Thanjavur district of Tamil Nadu during 1952 hence termed as Thanjavur wilt. In Karnataka it is known by the popular Kannada name 'Anabe

roga'. In Andhra Pradesh, the disease is mainly prevalent in lighter soils in the coastal districts than in heavy soils. Widespread occurrence of the disease is noticed in the maidan tracts of Karnataka especially in sandy soils of the southern region.

Causal organism :The disease is caused by *Ganoderma applanatum* and *G. lucidum*. The pathogen can be isolated from the infected roots.

Symptoms

In the initial stage of disease development, symptoms are characterized as, yellowing of the leaves of lowest leaf whorl and death and decay of fine roots. Later bleeding patches appear at the base of the stem near the ground level; the lesions gradually extend upwards, roots decay extensively and there is no new bunch production. As the disease advances, bleeding patches extend in the stem, leaves droop in the outer whorl followed by heavy button shedding and barren nuts. As stem decay traverses upwards, outer leaf whorl dries and droops off; other leaves also droop except the spindle leaf and surrounding two or three young leaves which remain erect and healthy. Ultimately all the leaves droop and fall off, leaving the decapitated stem.

In the middle or late stages of disease sometimes the scolytid beetle, *Xyleborus perforans* and the weevil, *Diocalandra stigmaticollis* may be found sometimes infesting the stem in large numbers at the bleeding patches from which powdery material is thrown out. The insects accelerate the death of the palm.

Ganoderma disease infected palm

Management

Ganoderma wilt can be effectively managed by following an integrated management practices listed below.

- Removal of dead palms, palms in advanced stages of the disease and destruction of the bole and root bits of these palms.
- Isolation of diseased palms from healthy palms by digging isolation trenches of 1 m depth and 30 cm width.
- Regular basin irrigation during summer months or moisture conservation by coconut husk burial (250 husks/palm).
- Avoiding flood irrigation or ploughing in infected gardens to prevent spread of the inoculum.
- Addition of 50 kg of farmyard manure or green leaves or 200 kg tank silt per palm per year.
- Application of *Trichoderma* (CPCRI-TR28) enriched neem cake@ 5 kg neem cake per palm per year and irrigating thte palm once in 4 days and mulching around the basin.
- Raising banana as intercrop wherever irrigation is possible.
- Root feeding of hexaconazole @ 2% (100 ml solution per palm) at quarterly intervals for one year and soil drenching @ 0.2% (40 l solution per palm) or 1% Bordeaux mixture.
- If *Xyleborus* attack is found in the stem, smearing with heptachlor may be done.

Grey leaf spot or grey leaf blight

Grey leaf blight of coconut is a wide spread disease found in almost all the coconut growing countries of the world. However the severity of the disease and extent of damage or loss they cause is seasonal and depends on climatic factors, nutritional status and varieties.

Symptoms

In adult coconut palms, initially, symptoms develop only on the outer whorl of leaves, especially on older leaves. Minute, yellow spots, each surrounded by a grayish margin, appear on the leaflets. Gradually, the spots turn grayish white in the centers and develop dark brown margins with yellow halos. Many spots coalesce into irregular, gray, necrotic patches. Complete drying and shrivelling of the leaf blade occur, giving a blighted or burnt appearance. The disease causes considerable damage and loss when appears in nursery or young juvenile palms.

Grey leaf spots in initial stage

Grey leaf spots coalesce and blight appears in later stage

Causal organism: *Pestalotiopsis palmarum*

Management

Remove severely affected older leaves and burn. Spraying with Bordeaux mixture (1%) or propiconazole (0.025%) or root feeding of Thiophanate-methyl or carbendazim (2.0 g in 100 ml of water). Follow recommended integrated nutrient management practices along with sufficient irrigation

Lasiodiplodia leaf blight

Lasiodiplodia leaf blight is an emerging problem in Coimbatore, Erode, Dindigul, Tirunelveli and Kanyakumari districts of Tamil Nadu. Though leaf blight is present in coconut growing areas of other states of India, the disease is not a serious problem

Causal organism: *Lasiodiplodia theobromae*

Symptoms

Affected leaflets start drying from the tip downwards and exhibit a burnt appearance. The leaves in lower 3 to 4 whorls are affected. Leaf blight induces apical necrosis of lower leaves with an inverted "V" shape, and symptoms similar to those induced by drought (water deficit) and other stresses. The leaflets have extensive necrotic lesions with defined edges and without transition areas between the necrotic and healthy tissues. The pathogen can internally colonize the rachis, inducing internal necrosis that moves upward toward the stem (systemic invasion). The necrotic tissues develop exposed cracks that release gums under the leaf


Leaf blight affected palms and leaflets

rachis and at petiole insertion. On nut, small black sunken region appear near the perianth of immature nuts. The eryiophyid mite attacked nuts are infected by the pathogen and cause immature falling of nuts and rotting. When nearly mature /mature nuts were infected the infection spread internally into mesocarp without any external symptoms. The affected nuts are desiccated, shrunk, deformed and drop prematurely causing 10 to 25 % loss in nut yield.

Management

Remove and burn the severely affected leaves to avoid further spread. Spraying with Bordeaux mixture (1%) or propiconazole (0.025%) or root feeding of carbendazim (2.0 g in 100 ml of water) or hexaconazole (2 ml per 100 ml water) at quarterly intervals.

Immature nut fall

Immature nut fall is a major problem in coconut and several factors are associated with this. Selection of good yielding mother palm is very important for collection of seed nuts since the poor quality/ genetic nature of mother palm is one of the prime reasons for button shedding in coconut. Poor pollination is another major factor responsible for button shedding. It has been reported that in some coconut palms, the production of plant growth regulators is not optimum and in such palms, the nut fall is high when compared to other palms. Very high soil acidity or salinity/alkalinity, drought condition and sudden changes in soil moisture also lead to high percentage of button shedding and immature nut fall. Imbalance (excess nitrogen) or deficiency of nutrients such as potassium and boron also leads to nut fall.

Eriophyid mite attack leads to immature nut fall and also provides entry points for pathogenic fungi causing rotting and nut fall. In certain cases, even though the mite infestation is negligible, the infection caused by fungal pathogen causes severe rotting and immature nut fall. Intensity of rotting and immature nut fall varies from locality to locality as well as from garden to garden.

Infected nut

Split open infected nut

Immature nut fall

Symptoms

Rotting starts from the point of on the nut surface near the perianth as dark brown to black discoloration and gradually extends to the entire surface area. The lesion also spreads deep into the internal tissues and when the lesion encircles the perianth region, the nut gets detached from the bunch and shed or remains on the bunch in between other nuts. The slight injury caused by mite paves way for the pathogen to enter and cause severe rotting. Thus in COD variety mite infestation is comparatively low but the incidence of rotting and immature nut fall due to fungal infestation is frequently observed. The fungal infection spreads to the kernel and leads to grayish black discoloration and rotting. In certain cases when the fungal infection starts in nearly mature nuts, it continues even after harvest and storage.

Etiology

Immature nut fall caused by *Phytophthora palmivora* is common in high rainfall areas during monsoon season. Though, *P. palmivora* and *Theilaviopsis paradoxa* are also found associated with mite infested nuts, *Lasiodiploida theobromae* is the main causal organism of rotting and immature nut fall in mite infested nuts.

Management

This disease can be controlled by spraying carbendazim 0.1% to bunches of the affected palms. If coconut is cultivated under the organic farming system, spraying of garlic bulb extract (10%) can be recommended for the management of the disease.

Harvesting

Usually 11-12 month old nuts are harvested. Coconuts are harvested at varying intervals in a year. The frequency varies depending upon the yield of palms. Usually, the nuts are harvested 6 to 10 times in a year. In well maintained and high yielding gardens, bunches are produced regularly and harvesting is done once in a month. Nuts which are 11 months

old give fibre of good quality and can be harvested in the tracts where husk is utilized for manufacture of coir fibre. Skilled personnel are traditionally employed for climbing palms for harvesting nuts. Nowadays, lack of availability of skilled climbers for harvesting operations is a serious problem experienced by coconut farmers. A simple palm climbing device invented by a farmer from Kannur district of Kerala is gaining popularity.

Post harvest processing and value addition

Traditionally the post harvest processing of coconut is confined to the production of edible and milling quality copra, coconut oil and coir and coir based products. Technological research has been successful in evolving appropriate processing technologies for the profitable utilization of some of the products and by-products of the coconut palm. To cope with the market fluctuations, there is a need for product diversification and by product utilization.

Production of quality copra using copra dryers

The conventional system of copra drying is by spreading the cups on any open surface for sun drying. It takes about 5-8 days for getting copra and the quality deterioration due to deposition of dirt and dust on wet meat is unavoidable. To overcome the disadvantages of conventional system of copra drying, CPCRI has developed a series of copra dryers with various sizes and capacities. The drying method of copra has been standardized through the principle of indirect hot air drying using these dryers. Of these dryers, the small holder's copra dryer and shell fired copra dryer are popular among the coconut farmers.

Small holders copra dryer

It is simple in design and safe to operate. Its capacity is 400 nuts per batch. Coconut shell, husk and any dried agricultural wastes can be used as fuel. Time required for drying is 34-36 hours. This dryer is useful during the monsoon season where sun drying is not possible. Small-holders dryer is available with the Kerala Agro-Industries Corporation @ Rs.8,000 per dryer.

Shell fired copra dryer

Shell fired copra dryer developed by CPCRI is a natural convection dryer with a unique furnace. Coconut shell is used as fuel. Its capacity is 1000 nuts per batch. It requires less fuel. Time required for drying copra is 24 hours. Once ignited, the shell produces heat for about six hours. The labour

requirement is less. Shell fired copra dryer will be made available through the Agricultural Technology Information Centre, CPCRI, Kasaragod. Shell fired copra dryer with capacity 500 nuts per batch is also developed by CPCRI.

Copra moisture meter

To estimate the moisture content accurately, CPCRI has developed a moisture meter which works on the principle of electrical conductivity. It is calibrated to read the moisture content upto 40% so that the moisture level at the different stages of drying can be found out.

Snow Ball Tender Nut (SBTN)

Snow ball tender nut is a tender coconut without husk, shell and testa which is ball shaped and white in colour. Coconut of 7–8 months age in which there is no decrease in quantity of tender nut water and the kernel is sufficiently soft. is more suitable for making SBTN The main steps involved in the making Snow Ball Tender Coconut are: removal of husk of 7–8 month maturity coconut in which the tender kernel thickness should be about 2 - 3 mm, making groove in the shell without breaking the kernel and scooping out the shell. For making the groove easily, a machine has been developed. Snow ball tender nut is sterile, nutritive and is a drink and a snack at the same time. Since there is no refuse after the consumption, there is no scope for littering of the premises. Since the snow ball tender nut can be individually packaged and refrigerated under hygienic conditions, the shelf-life of this product is prolonged up to 15 days. In ambient condition it can be stored for about 8 hours.

Coconut chips

The dehydrated coconut chips is in ready-to-eat form and can be used as snacks. It could also be used at any time just like fresh kernel after rehydration of the chips. Fresh kernel of matured coconut containing reasonable amount of water are to be used for the production of the sweet coconut chips. Important steps involved in the production of the sweet coconut chips are: dehusking, removal of shell, removal of testa, slicing of kernel, blanching of slices, osmotic dehydration of slices, drying of osmotically dehydrated slices in hot air dryer and then packaging in aluminium foil. The time of osmotic dehydration will be 40 minutes only.

The drying time in hot air dryer is six hours.

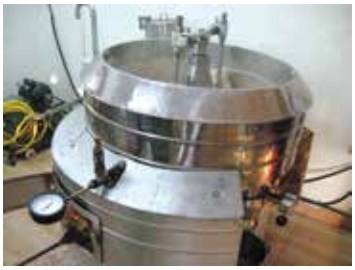
In a plastic basin, mix one kg of sugar and one tablespoon full of salt in one litre water. In a stainless steel vessel take three litre of water and heat upto boiling point. Take a dehusked coconut and scoop out the fresh kernel by using knife. By using the testa remover, remove the testa. Slice the white kernel pieces by using slicer. Wash the coconut slices in a clean water (two times). Transfer the slices to muslin cloth and then dip it in hot water for 2 minutes. Transfer the slices to the sugar solution (which was already prepared) and keep for one hour. Spread the soaked slices on the water absorbing paper for about 15 minutes. Dry the slices in the dryer for six hours. Pack the chips in the aluminium foil. For every coconut add 75 g of sugar in the sugar solution and reuse it.

The quantity of chips to be obtained is about 50 per cent of the fresh kernel weight. On an average, about 150 gram of chips can be obtained from a coconut.

Virgin Coconut Oil

Virgin coconut oil is the oil obtained from fresh, mature endosperm (kernel-meat) of the coconut by mechanical or natural means, with or without use of heat, no chemical refining, bleaching or de odorizing and maintains the natural aroma and nutrients. It is called “virgin” because the oil obtained is pure, raw and pristine. Virgin coconut oil is suitable for human consumption in its natural form. It is the purest form of coconut oil, crystal clear, contains natural vitamin E and with very low, free fatty acid content (0.1%). It has a fresh coconut aroma ranging from mild to intense, depending on extraction process.

The different processes involved in VCO production are Hot-processing method, Natural



fermentation method, Centrifugation process and extraction from dried grating (EDG) method. The choice of the technology to be adopted depends to a great extent on the scale of operation, the degree of mechanization, the amount of investment available and the market demand.

The modified hot process method for producing VCO also follows the same principle, except for controlled heating to prevent the oil from turning yellow and maintain the moisture content less than 0.2% to prolong its shelf life. Hot process comprises of two stages: extraction/ preparation of coconut milk and cooking the milk to get VCO.

In fermentation method, the VCO can be produced in a home-scale operation using ordinary kitchen utensils after extracting the coconut milk. The oil produced in this method is water-clear in colour. The VCO produced could turn sour if the fermentation period is prolonged and the fermentation process conditions are not controlled properly. Fermentation method comprises of two stages: extraction/preparation of coconut milk and fermentation of the milk for VCO production.

In centrifugation method, the coconut milk is subjected to mechanical phase separation process. Coconut milk and hot water is fed in a three-way centrifuge equipment where the oil separates out from the top and the water and sludge comes out through separate outlets. It produces the best quality oil with sweet coconut aroma and the oil produced in this method is water clear in colour. Centrifuge method comprises two stages: extraction/preparation of coconut milk and centrifugation of the milk for VCO production.

Kalparasa (coconut sap)

Kalparasa (coconut sap) or 'neera' in Sanskrit means life essence of coconut tree. It is the phloem sap extracted from the unopened inflorescence. From the cut end of the inflorescence the sap oozes out. The trickled sap is traditionally collected in earthen pot and during the process it gets fermented. Lime coating inside the collection pots to a certain extent prevents fermentation but not fully in the traditional technique. The coco-sap chiller technology developed by ICAR-CPCRI, wherein the sap is collected under low temperature keeps the sap a fresh and unfermented without addition of any chemicals. The sap thus

collected can be stored for any length of time under refrigerated condition (-1 to -3°C). Furthermore the sap collected in this closed container is free from contaminants like insects, ants, pollen, dust, etc. It can be directly sold as fresh juice, packaged and sold or processed into value added natural products like sugar, jaggery, honey, syrup, *etc*. without the addition of chemicals. The sale of neera as a fresh juice and its products has been demonstrated to improve the livelihood of farmers, tappers and those who are dependent on coconut sector.

Coconut sugar and jaggery

Coconut sap contains about 15% sugars and considerable amount of nutrients, which can easily be converted to various value added products. Coconut sugar and jaggery are obtained by evaporating the water of unfermented sap at 115°C. The viscous liquid, fairly thick hot (Brix 60 to 70°) is cooled to get coconut honey or syrup. Further, on heating the sap becomes more viscous and thicker in consistency, and is poured to moulds of either coconut leaf or steel to obtain jaggery. Some more heating with continuous stirring to avoid charring, changes the viscous syrup into crystal form and at this stage it is immediately cooled. While cooling, it is stirred continuously to break the lumps. The sugar thus obtained is sieved to get uniform particle size and to produce quality product.

Coconut sugar is also known as coconut palm sugar, coco sugar or coco sap sugar. Unlike cane sugar which supplies only calories, coconut sugar supplies calories and nutrients. It has high mineral content as compared to brown sugar and refined cane sugar, and is a rich source of potassium, magnesium, zinc and iron. In addition to this, it contains all essential amino acids required for protein synthesis, and rich

in B complex Vitamins like B1, B2, B3 and B6. When compared to brown sugar (prepared from sugarcane molasses), coconut sugar has double the amount of iron, four times the magnesium and over 10 times the amount of zinc.

A dark chocolate has been developed by using coconut sugar and cocoa cream and butter as main ingredients. A chocolate drink also has been developed with similar ingredients.

From the coconut kernel gratings after removal of coconut milk, a crispy food item, 'Kalpa Krunch' has been developed. It is a value added, healthy, ready to eat, extrudate product from coconut. It is possible to make Kalpa Krunch with different tastes and flavours.

Another product of coconut is the coconut frozen delicacy, which is a vegan ice cream. Tender coconut water, coconut milk and tender coconut pulp constitute 80% of this delicious product. It is a highly nutritious, premium product.

Mushroom cultivation using coconut by-products

Methods to cultivate mushroom using by-products of coconut as substrate have been developed at CPCRI, Kasaragod. Among the cultivated mushroom, Oyster mushroom belonging to *Pleurotus* spp. is the ideal one for cultivation on coconut by-products because of their ability to utilize lignin rich materials and the favourable climatic conditions in the coconut growing areas. Coconut bunch waste, leaf stalk, mixtures of leaf stalk + coir pith in 1:1 ratio and bunch waste + coir pith in 1:1 ratio were found to be better substrates for mushroom cultivation. On an average, mushroom yields of 590 and 570 g can be obtained per kg dry weight of leaf stalk and bunch waste in a cropping period of 73 and

60 days, respectively. Polybag method of cultivation could be followed using 3 per cent spawn applied by multilayering technique. Spawn run and cropping can be done in a low cost mushroom shed built exclusively with coconut materials such as plaited coconut leaves and coconut wood inside an adult coconut garden. Spraying of 1 per cent urea and 1 per cent super phosphate helps to reduce the interval between flushes. *Pleurotus eous, Pleurotus flabellatus, Pleurotus florida* and *Pleurotus sajor caju* are the suitable mushroom species for cultivation using coconut byproducts.

For further details on coconut cultivation and for technical guidance, please write to:

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