COCONUT CULTIVATION TECHNOLOGY

Editing : **K.U.K. Nampoothiri**
H.P. Singh
Text : **S. Arulraj**
C. Thamban

Coconut Development Board
Ministry of Agriculture
Govt. of India
Kochi - 682 011

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FOREWORD

Agriculture in the twentieth century was characterised by technological innovations which spread to different corners of India under "Green Revolution". This revolution in biological, chemical and mechanical technology ensured that agricultural production grew at a fast pace to cope with the demand for food in the wake of a rapidly growing human population. The impressive growth of agricultural productivity that transformed a food deficit nation into a self-sufficient one is a major accomplishment. Notwithstanding this achievement, the basic problems of food security, poverty, equity and sustainability continue to be important. These are some of the important challenges before us to be reckoned with in the coming years.

A similar increase is noticed in the production of coconut palm, which is the most useful cultivated palm in the world. As an edible food, oilseed, beverage and as a source of natural fibre and timber, coconut enjoys an unique status among horticultural crops. It contribues more than Rs. 7000 crores to the GDP and sustains nearly 10 million families besides earning foreign exchange to the tune of Rs. 238 crores through various coconut products. However, as the yield frontiers are relatively limited, meeting the future demand has to be mainly through crop productivity enhancement, using technological changes and their adoption by farmers. Needless to mention, such productivity enhancement measures have to be eco-friendly and cost-effective.

Knowledge and know-how have always played a critical role in agricultural and environment systems. As a step towards enhancing the knowledge level of users of coconut technologies, the present publication is being brought out. This publication gives a brief account of the new coconut varieties, coconut crop production and protection technologies as well as pre and post-harvest technologies. It also gives information on the services offered to the coconut growers by various research and development agencies. Presentation of information supported by a large number of colour plates on various coconut technologies will enable the readers to understand the intricacies of the technologies for correct adoption.

The efforts of the scientists of Central Plantation Crops Research Institute (CPCRI) and Chairman, Coconut Development Board in bringing out this publication are commendable. I am sure the publication would be of immense benefit to researchers, growers and all those concerned with coconut development and would go a long way in improving the productivity of coconut.

(Bhaskar Barua)

PREFACE

Coconut plays an important role in the economic, social and cultural activities of millions of people in our country. We have made significant achievements in enhancing coconut production and productivity, mainly because of the concerted efforts of the farmers, extension personnel and research workers engaged in the coconut research and development programmes. Currently India ranks first in the world map of coconut production and productivity. Through the systematic research conducted during the last few decades, a substantial number of viable technologies related to crop improvement, production, protection and cropping/farming systems have been evolved for enhancing coconut production. However, the gap between the average yield from the farmers' holdings and the yield obtained in research farms is wide and immediate steps are needed to bridge it. Thus the necessity for implementing an effective technology transfer strategy assumes significance to enable the coconut farmers make use of available technologies to their benefit. As a major factor influencing coconut productivity, correct adoption of technology assumes considerable significance. This book is the outcome of the need to make available the details on the different coconut cultivation technologies in as comprehensible a manner as possible to cater to the information needs of farming community. The photographs and illustrations add to the quality of the book to help the reader for a better understanding of the concepts discussed. All the aspects of coconut cultivation are described in a simple manner leaving no grounds for ambiguity. We hope that the publication will be useful to the coconut farmers in their endeavour to increase productivity and ultimately the net profitability which are essential to sustain the farmers' interest in the crop. We thank all our professional colleagues who have rendered valuable help during the different stages of preparation of this book.

AUTHORS

CONTENTS

COCONUT CULTIVATION TECHNOLOGY

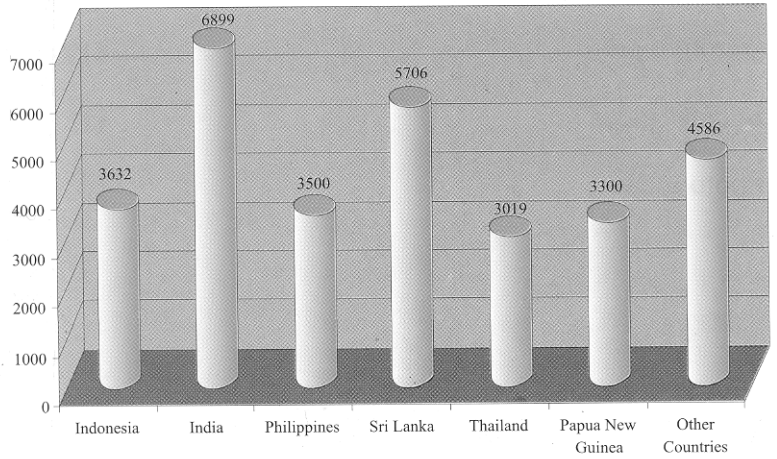
1. COCONUT SCENARIO

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 other. It provides food, drink, shelter and materials for industries. Coconut is cultivated in India since ages and it plays an important role in the social, economic and cultural activities of the people.

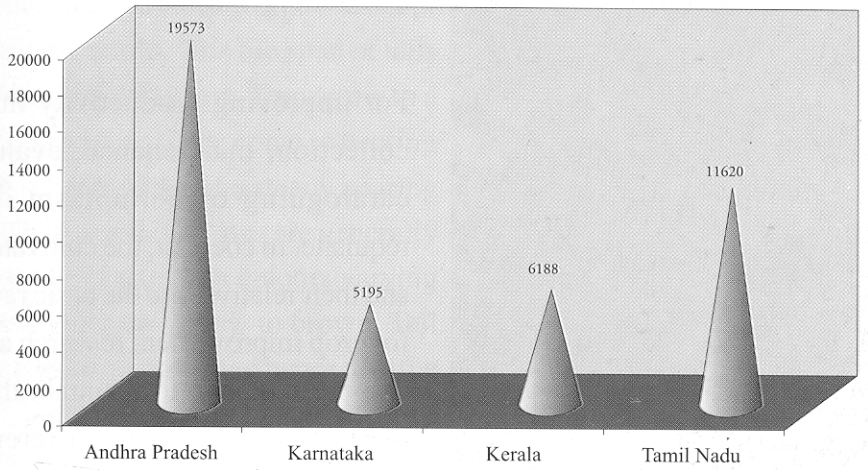
Progress made in increasing the production and productivity of coconut in the country is unprecedented. This has been made possible due to the efforts of coconut cultivators, development personnel and research workers.

Research carried out by the Central Plantation Crops Research Institute (CPCRI), State Agricultural Universities and other organizations have resulted in the

Productivity of Coconut in Major Coconut Growing Countries (1998)



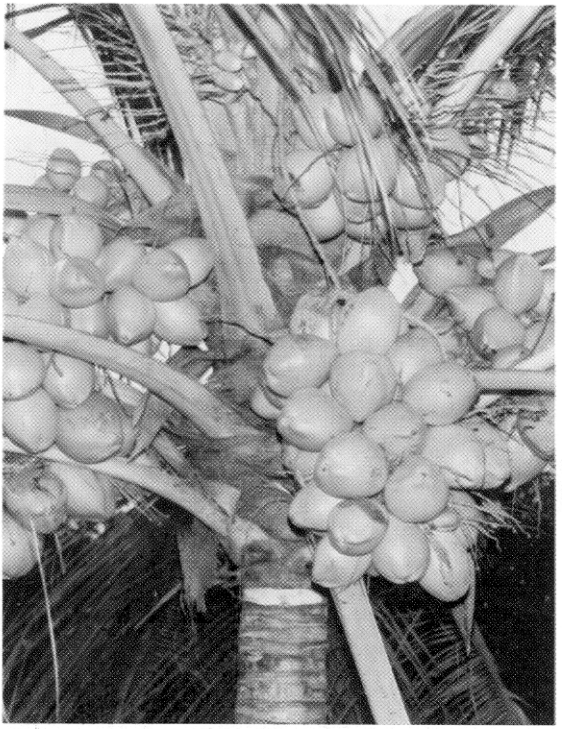
Productivity of coconut in different States
(1998-'99)



identification of high yielding cultivars and improved management technologies for improving the production and productivity of coconut. However, there exists still a gap between the productivity achieved at Research Stations and the end productivity in field. The national average of coconut productivity is 7,821 nuts/ha/year (during 1999) while that of the best managed garden is 27,300 nuts/ha/year. It has been demonstrated that an increase in yield by four folds can be achieved by adopting scientific technologies in coconut cultivation as compared to the unscientifically managed palms.

Thus there is a great scope for enhancing the productivity of coconut through the adoption of scientific cultivation technologies, which would result in many fold increase in production even from the existing area under cultivation.

The agricultural situation in India has been in the process of rapid change during the recent years. However, it has been reported by different social science researchers that farmers in India, as in the case of most of the developing countries, do not keep pace with the fast developing technology. Thus there is a great need for strengthening the programmes meant for the transfer of coconut cultivation technologies to the farmers' fields across the country. New technologies identified at different coconut research institutions on high yielding cultivars, crop management practices, pest and disease management etc. are described in the subsequent chapters. It is therefore highly desirable to harness the potential by adoption of improved technologies through a mechanism of effective transfer of technology in which the researchers, development workers and growers have to play a vital role.



Malayan Orange Dwarf -
An exotic collection from Malaysia

Sanramon – a cultivar with large sized nuts

2. VARIETIES AND HYBRIDS

Coconut germplasm

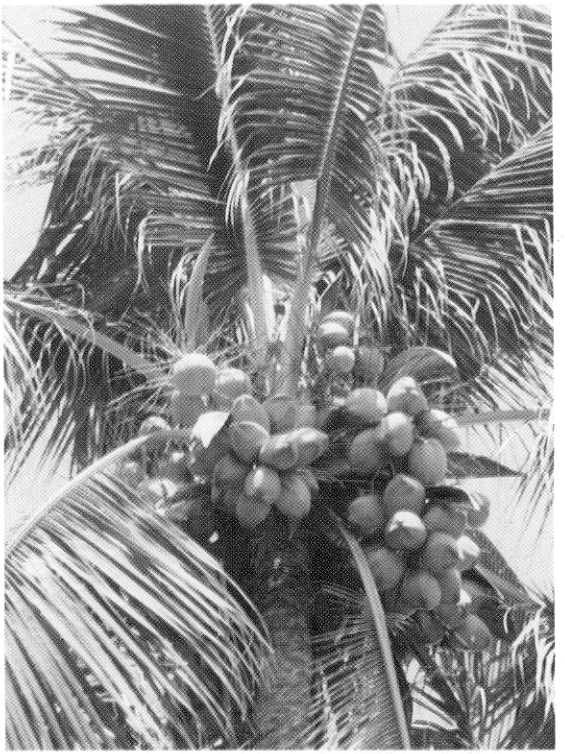
For improving productivity in any crop, collection, maintenance, evaluation and cataloguing of germplasm is the pre-requisite. In coconut, the cultivated varieties and their relatives are the basic raw materials for crop improvement research and hence it is a pre requisite to maintain them in live gene banks located at different centres. CPCRI holds the world's largest collection of germplasm of coconut consisting of 241 cultivars of which 101 are exotic and 140 are indigenous types.

The varieties available at the germplasm are under evaluation for morphological, yield and quality characteristics at various centres. Varieties selected based on the preliminary evaluation are further evaluated in multilocation trials at ten Co-ordinating Centres under the All India Co-ordinated Research Project on Palms and based on their superior performance, they are released for cultivation.

Basically coconut cultivars are classified into two groups viz., the tall and the dwarf cultivars.

Tall cultivars

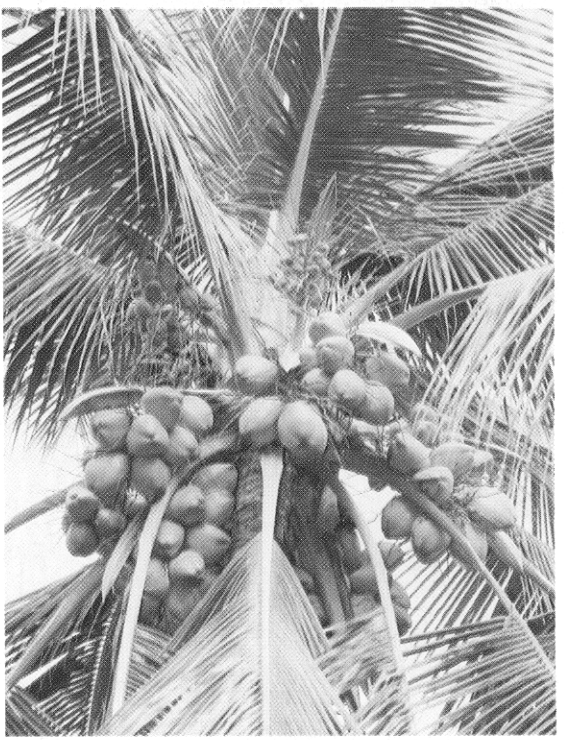
Tall varieties are the common type that occur through out the world. The life span of talls extends from 60 to 80 years. They grow to a height of 15 to 18 m. They come to bearing in about 6-7 years and attain steady bearing in about 12-15 years. The nuts are generally medium to big in size with colours varying from green, greenish yellow to brown. Tall palms are cross pollinated and hence not true to type. They produce good quantity of quality copra and have fairly high oil content as compared to dwarf cultivars. The characteristic features of promising tall cultivars are given below:



Fiji Tall – a drought tolerant germplasm

West Coast Tall (WCT)

West Coast Tall is the ordinary tall cultivar, cultivated extensively in the west coast region of India. It is a sturdy cultivar having an economic life span for about 75 years or more. It is a regular bearer producing about 12 inflorescences per year. The WCT palms normally come to bearing in about 6-7 years under favourable conditions. Under rainfed condition, it gives an average annual yield ranging from 40 to 100 nuts per tree with a mean yield of 80 nuts. Average copra content is 176g with an oil content of 68 per cent. It grows well in all types of soil and is fairly tolerant to moisture stress and recommended for large scale cultivation in the coastal regions of Kerala and Karnataka.



West Coast Tall

Tiptur Tall

Benaulim Tall (Pratap)

Tiptur Tall

Tiptur Tall is a popular tall cultivar of Karnataka state. It resembles WCT in most of the morphological characters. Average yield is 86 nuts per palm per year. It has a mean copra content of 178g per nut with an oil content of 68 per cent.

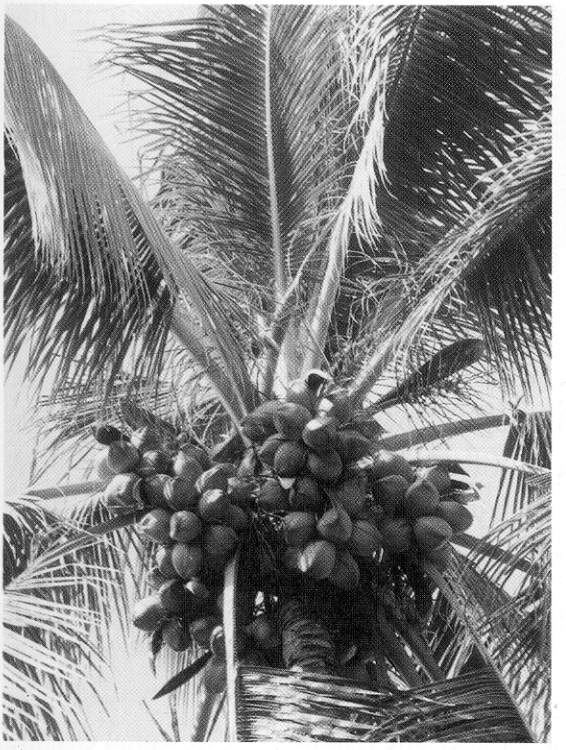
East Coast Tall (ECT)

East Coast Tall is a common cultivar grown extensively in the east coast of India. Morphologically it is similar to WCT. The palms take 6-8 years to start bearing. The average annual yield is 70 nuts per tree. It has a mean copra content of 125 g per nut and oil content of 64 per cent.

Benaulim Tall (Pratap)

Benaulim Tall is a popular tall cultivar in Goa, Konkan and coastal Maharashtra. It resembles West Coast Tall in appearance, but nuts are smaller and round. This variety comes to bearing in about 7-8 years. The bunches are heavy and attractive with closely packed round nuts. Average annual yield is 150 nuts per palm. It has a mean copra content of 152g per nut with an oil content of 64 per cent. This cultivar has been released under the name 'Pratap' for commercial cultivation in Maharashtra state.

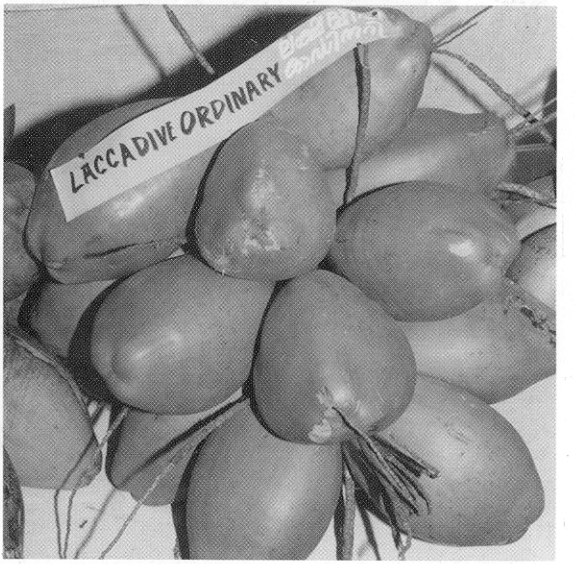
Lakshadweep Ordinary (Chandrakalpa)



Andaman Ordinary

Lakshadweep Ordinary (Chandra kalpa)

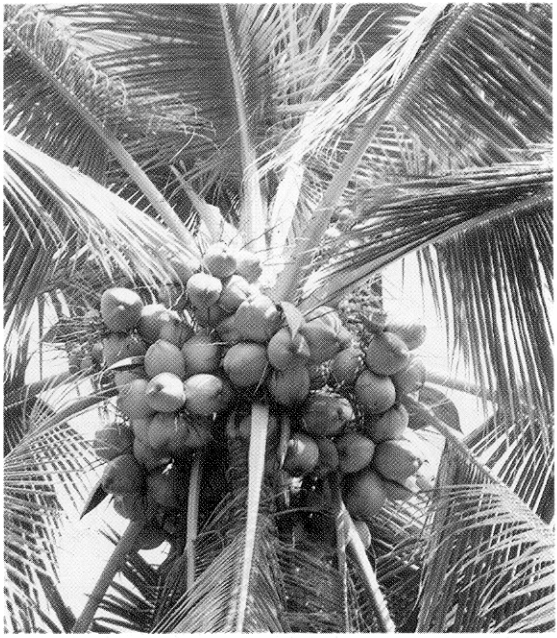
This cultivar is indigenous to Lakshadweep Islands. It resembles WCT except for the comparatively smaller nuts with three prominent ridges seen on the triangular nut. These palms are considered good for tapping sweet toddy. It has an annual average yield of 100 nuts per palm and has a copra content of 176g with 72 per cent oil content. CPCRI released this variety in 1985 in the name of 'Chandra kalpa' for large scale cultivation in Kerala, Karnataka and Andhra Pradesh.



Lakshadweep Ordinary

Andaman Ordinary

Andaman Ordinary is largely grown in Andaman and Nicobar Islands. The palms are tall, massive and comparatively more vigorous than WCT palms in vegetative growth. The nuts are fairly large in size with an average yield of 94 nuts per palm per year. Copra content is 169 g per nut with 66 per cent oil content.

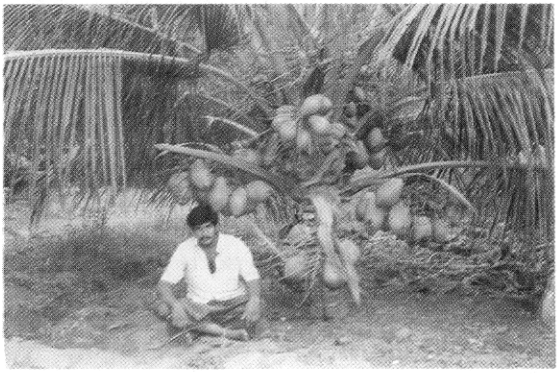


Philippines Ordinary

Philippines Ordinary

This is an exotic cultivar from Philippines which grows to a height of l0-12m. It is a good yielder with an average yield of 110 nuts per palm per year. The average copra yield is 189 g per nut with an oil content of 66 per cent. This variety is suitable for cultivation in the west coast including Konkan region, coastal Andhra Pradesh and West Bengal.

A germplasm plot with dwarf cultivars



Ganga Bondam - a dwarf parent

Dwarf cultivars

Dwarf varieties are shorter in stature and life span. They grow to a height of 5-7 m with an average life span of 40-50 years. They start bearing from 3-4 years after planting. They are self pollinated and hence true to type. The nuts are smaller and the copra soft, leathery and low in oil content. The dwarf cultivars occur with orange, yellow or green nut colours. Chowghat Orange Dwarf, Chowghat Green Dwarf, Malayan Yellow Dwarf, Malayan Orange Dwarf, Malayan Green Dwarf and Ganga Bondam are the common dwarf varieties grown sparsely in India. Dwarf varieties are mostly cultivated for tender nuts, ornamental value and for production of hybrids. The characteristic features of Chowghat Orange Dwarf are given below:

Chowghat Orange Dwarf (COD)

Hybrids

Hybrids are the intervarietal crosses of two morphological forms of coconut. They show earliness in flowering and give increased yield, higher quantity and better quality of copra and oil when compared to the parents. The first coconut hybrid in the world was produced in India during 1930's with West Coast Tall (WCT) as female parent and Chowghat Green Dwarf (CGD) as male parent. In Tall x Dwarf (TxD) hybrids, Tall cultivar is used as the female parent and Dwarf as the male parent. In Dwarf x Tall (DxT) hybrids, Dwarf is the female and Tall is the male parent. Inter varietal hybrids like Tall x Tall and Dwarf x Dwarf are also produced.

Chowghat Orange Dwarf (COD)

This indigenous dwarf cultivar is sparsely cultivated in the west coast region of India particularly in the Chavakkad area of Thrissur district in Kerala. It is known as 'Gowrigathram' or 'Chenthengu' in Kerala and 'Kenthali' in Karnataka. The palm has a thin stem, small and compact crown with orange coloured leaf petioles, inflorescence and nuts. It starts flowering from 3-4 years after planting. The average annual yield is 65 nuts per palm. It has a mean copra content of 150g per nut with an oil content of 66 per cent. This variety is ideal for tender nut purpose. The tender nut water is sweet with a total sugar content of 7 per cent, 20 ppm (ppm – parts per million) of sodium and 2000 ppm of potassium. This cultivar is recommended as a tender nut variety by CPCRI for commercial cultivation in Kerala and Karnataka.

Assisted pollination using a pollen applicator

In India, so far 11 coconut hybrids are released for commercial cultivation. Salient characteristics of these hybrids are briefly presented here:

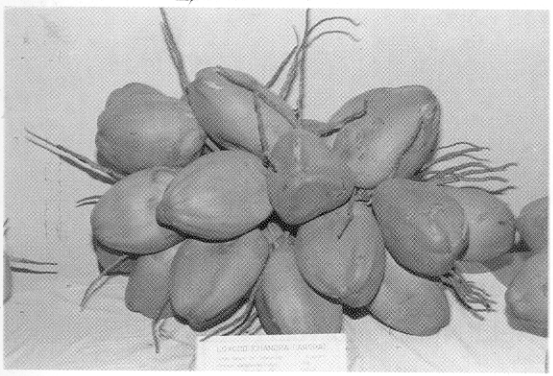
Name of hybrid : **Chandra sankara**
Parentage : COD x WCT
Yield(Nuts/palm/year) : upto 222
Copra yield(g/nut) : 215
Copra yield(kg/palm/year) : 24.9
Oil content : 68%
State for which released : Kerala

Chandra sankara (CODxWCT)

Name of hybrid : **Kera sankara**
Parentage : WCT x COD
Yield(Nuts/palm/year) : upto 211
Copra yield(g/nut) : 187
Copra yield(kg/palm/year) : 20.2
Oil content : 68 %
States for which released : Kerala, Coastal Maharashtra and Coastal Andhra Pradesh

Kera sankara (WCTxCOD)

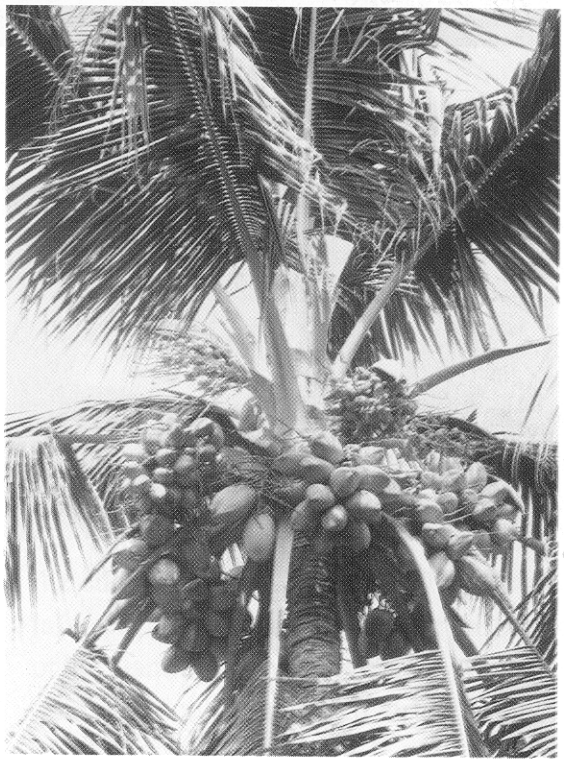
Name of hybrid : **Chandra laksha**
Parentage : LO x COD
Yield(Nuts/palm/year) : upto 171
Copra yield(g/nut) : 195
Copra yield(kg/palm/year) : 21.3
Oil content : 69 %
State for which released : Kerala



Chandra laksha

Chandra laksha (LOxCOD)

Name of hybrid : **Laksha ganga**
Parentage : LO x GB
Yield(Nuts/palm/year) : upto 186
Copra yield(g/nut) : 195
Copra yield(kg/palm/year) : 21.1
Oil content : 70%
State for which released : Kerala

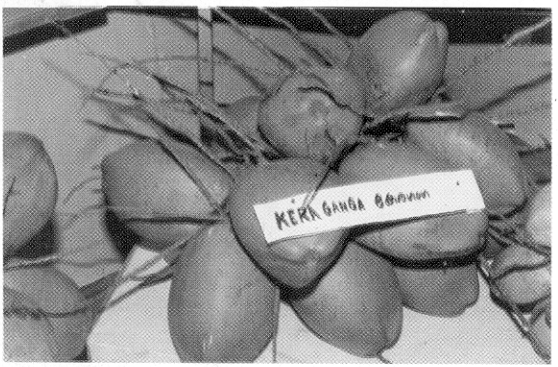


Laksha ganga (LOxGB)

Kera ganga (WCTxGB)

Name of hybrid : **Ananda ganga**
Parentage : AO x GB
Yield(Nuts/palm/year) : 95
Copra yield(g/nut) : 216
Copra yield(kg/palm/year) : 20.5
Oil content : 68 %
State for which released : Kerala

Name of hybrid : **Kera ganga**
Parentage : WCT x GB
Yield(Nuts/palm/year) : 100
Copra yield(g/nut) : 201
Copra yield(kg/palm/year) : 20.1
Oil content : 69 %
State for which released : Kerala



Kera ganga

Name of hybrid : **Kera sree**
Parentage : WCT x MYD
Yield(Nuts/palm/year) : 130
Copra yield(g/nut) : 216
Copra yield(kg/palm/year) : 28.1
Oil content : 66 %
State for which released : Kerala

Name of hybrid : **Godavari ganga**
Parentage : ECT x GB
Yield(Nuts/palm/year) : 140
Copra yield(g/nut) : 150
Copra yield(kg/palm/year) : 21.0
Oil content : 68 %
State for which released : Andhra Pradesh

Kera sowbhagya (WCT x SSAT)

Name of hybrid : **Kera sowbhagya**
Parentage : WCT x SSAT
Yield(Nuts/palm/year) : 116
Copra yield(g/nut) : 196
Copra yield(kg/palm/year) : 22.7
Oil content : 65%
State for which released : Kerala

Name of hybrid : **VHC-1**
Parentage : ECT x DG
Yield(Nuts/palm/year) : 98
Copra yield(g/nut) : 135
Copra yield(kg/palm/year) : 13.2
Oil content : 70 %
State for which released : Tamil Nadu

Name of hybrid : **VHC-2**
Parentage : ECT x MYD
Yield(Nuts/palm/year) : 107
Copra yield(g/nut) : 152
Copra yield(kg/palm/year) : 16.3
Oil content : 69%
State for which released : Tamil Nadu

It would be ideal, if the farmers could select appropriate coconut varieties/hybrids depending on the agro-climatic situation prevailing in their area and the suitability of the cultivar to their holdings. They should take special precaution regarding the quality of the planting material especially when they opt for the cultivation of hybrids.

A mother palm

3. PLANTING MATERIAL

Being a perennial crop, the performance of coconut palm can be judged only after 15 years of planting. If inferior seednuts are used, the new plantation will prove to be uneconomic, causing considerable loss of time and money to the farmer. Hence use of quality planting material is of utmost importance. Further, being a cross pollinated palm, coconut does not breed true and makes the selection of seednut and seedling more difficult and important.

Mother palm selection: For obtaining good quality seednuts, trees with the following characteristics should be selected as mother palms:

- Attained an age of 20 years
- Regular bearer with an annual yield of more than 80 nuts per palm per year and free of any disease
- Have medium sized nuts with average per nut husked weight of 600 g and copra weight 150 g and above
- Have at least 30 fully opened leaves having leaf orientation in all directions ie; umbrella shaped crown
- Have short strong petiole with wide leaf base firmly attached to the stem
- Bunch stalk should be short, stout and strong and should not show any tendency to droop down or buckle

Palms which produce barren nuts or those shedding large number of immature nuts should be discarded. Avoid palms of very old age ie., above 60 years. Also avoid

Selection of seednuts

Sowing of seednuts

Watering the seedlings

Weed control

palms growing in very favourable conditions eg. trees near manure pits. Palms showing alternate bearing tendency also should be avoided.

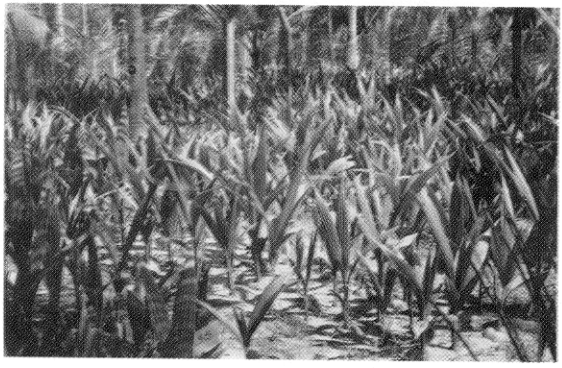
Collection of seednuts

Seednuts can be collected during the period January – April and sown in June in the west coast region. In the east coast region, nuts are sown during October-November. Only fully matured nuts ie., about 12 months old should be harvested. Nuts should not be damaged while harvesting. Discard nuts having irregular size and shape and improper development. Harvested seednuts should be properly stored in shade or in pits taken in soil in layers for preventing the drying of nut water until the time of sowing in nursery.

Raising nursery

- Select well drained, coarse textured soil near dependable water source for irrigation
- Prepare raised beds if water stagnation is a problem during rainy season
- Against white grubs and termites, apply phorate @10g/sq.m. or chlorpyriphos at 0.05% concentration.
- Nursery site should have partial shade only; excess shade should be avoided.
- Sow the seednuts in beds of size 1 m width and convenient length at a spacing of 40 x 30 cm either vertically or horizontally in 20-25 cm deep trenches.
- There is a possibility of damage to the seedlings during transportation if the

Plant protection



Coconut nursery

Select only good seedlings

seednuts are sown horizontally in the nursery.

Nursery care

- Provide shade if the nursery is in the open area.
- Practise mulching for moisture conservation in the nursery.
- Keep nursery free of weeds.
- Irrigate once or twice in a week if there is no rain.
- Regular surveillance for any incidence of pest and disease.
- Remove those nuts which have not sprouted even after five months of sowing.

Seedling selection

Only good quality seedlings, germinated early are to be selected from the nursery for field planting. The vigorous seedlings which are one year old, having minimum of six leaves and girth of 10 cm at the collar should be selected for planting. Early splitting of leaves is another character preferred for selecting good seedlings. Recovery of good seedlings will be 60 to 65 per cent of total seednuts sown.

Polybag nursery

Raising seedlings in polybags helps to produce vigorous seedlings with better root system resulting in better establishment and early bearing. The advantages of polybag nursery over conventional nursery are:

- Reduced transplanting shock due to the absence of root damage
- Ease of irrigation and fertilizer application in the bag
- The improved water holding capacity of the potting medium helps to maintain required moisture for early germination

Polybag nursery

In polybag system, seednuts are allowed to germinate in a pre-nursery bed, sown very closely and transplanted in polybag when the sprouts are 8-10 cm long. The bags are made of black polythene of 500 gauge thickness and 60 x 40 cm size for bigger nuts and 40 x 40 cm for smaller nuts. The bottom portion of bag should be provided

Fertilizer application in polybag

with 8 to 10 holes for draining excess water. The commonly recommended medium is the usual potting mixture or top soil mixed with sand in the ratio of 3:1.

The germinated nuts are picked out from the nursery once a week until 80 per cent of nuts are germinated or up to 5 months after sowing whichever is earlier. The germinated nuts are placed in the half filled bags with the sprout planted vertically at the centre of the bag and enough potting mixture is added to fill the bag up to two-third portion and the sides slightly pressed to keep the nut firm so that the nut is not bared during watering. Care must be taken not to cover the collar region of the young seedling. The size of the polybag nursery bed can be 3x6 m with about 1.5 m spacing between beds. Each bed can accommodate 115 seedlings and these bags are arranged in a triangular manner with 60 cm space between bags.

A polybag seedling

Care of polybag nursery

- For proper growth of seedlings, provide regular irrigation.
- Keep the nursery weed free.
- Fertilizers can be applied in polybag nursery @ 20 g ammonium sulphate and 25 g muriate of potash per bag after two months of germination and 45 g ammonium sulphate and 45 g muriate of potash after four months of germination per bag. Water the seedlings after fertilizer application.

4. GARDEN ESTABLISHMENT

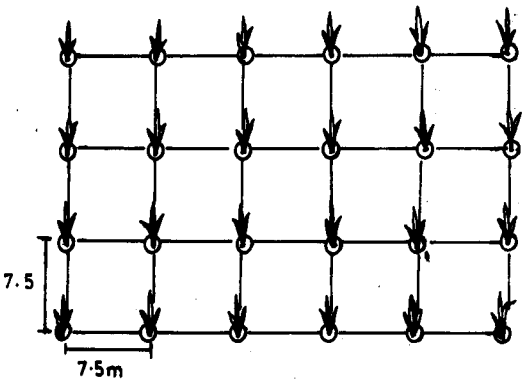
Site selection

Coconut palm is highly adaptable and performs well under a wide range of environmental conditions of climate, altitude and soil. However, best yields from coconut gardens are realized under the following conditions.

a. Temperature	:	Mean annual temperature of 27°C with a diurnal variation of 5-7°C is ideal
b. Rainfall	:	1,800 to 2,500 mm per year, well distributed. Can withstand very high rainfall in well drained soils. Irrigation is required in low rainfall and poor distribution. Can withstand occasional water logging.
c. Insolation	:	120 hrs of sunshine per month; 2000 hrs or more per year
d. Humidity	:	80-90 per cent Relative Humidity (RH) is ideal. RH below 60 per cent affects the growth.
e. Altitude	:	Generally up to 600 m. Can be grown at higher elevations if nearer to equator.
f. Soils	:	Comes up well in a variety of soils ranging from littoral sand to clay loam or clay; performs well in soils rich in organic matter with good water holding capacity. Depth of soil should be at least 1.0-1.5 m. Soil should be well drained.

Time of planting

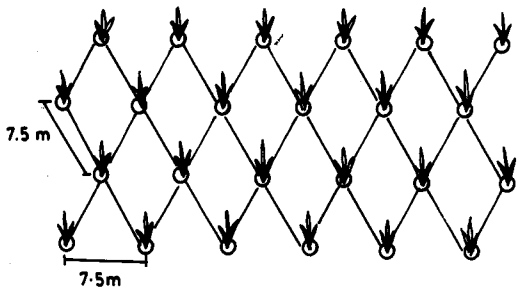
Generally seedlings can be transplanted with the beginning of southwest monsoon ie., June. If irrigation facilities are available, planting can be done a few weeks earlier so that the seedlings get well established before the onset of heavy rains. In low lying areas where water stagnation is a problem, seedlings can be transplanted after the heavy rains.



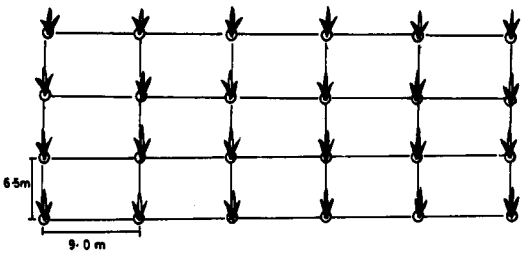
Square system of planting

Planting system

Spacing adopted for planting is an important factor affecting the productivity of coconut palms. For realizing better yield from coconut, an optimum plant density must be maintained in the field. A spacing of 7.5 x 7.5 m is generally recommended for coconut. Different systems of planting such as square, triangular or rectangular planting are followed. The plant density varies with the planting system adopted as given below:



Triangular system of planting



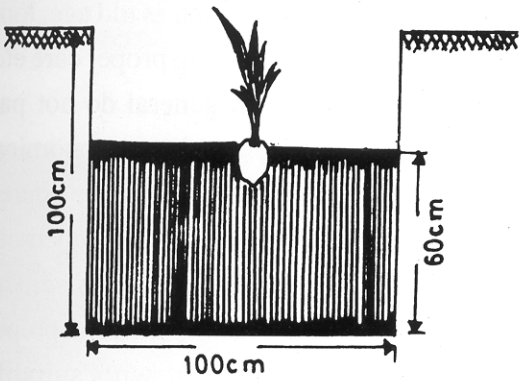
Rectangular system of planting

Spacing	System of planting	No. of palms/ha
7.5 x 7.5 m	Square	175
8 x 8 m*	Square	155
7.5 m	Triangular	205
8 m*	Triangular	180
9 x 6.5 m	Rectangular	170

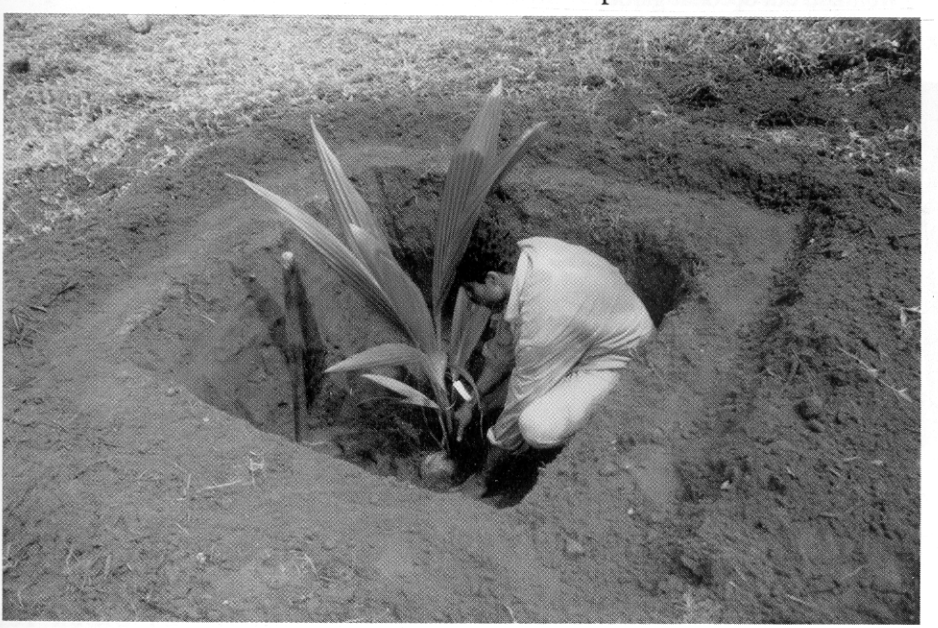
* As practised by farmers in some places of Karnataka state

Land preparation and preparation of pits for planting

Preparation of land for planting depends on the soil type and topography of the land. If the land is slopy and uneven, contour bunds or contour terraces are to be made. Once the planting system has been decided upon, the pits for planting should be dug out. The depth of pit depends on type of soil. In laterite soil with rocky substratum, pits of size 1.2 x 1.2 x 1.2m may be dug and filled up with top soil, powdered cowdung and ash up to a depth of 60 cm before planting. In loamy soils with low water table, planting in 1.0 x 1.0 x 1.0m pits filled up to 60 cm depth is recommended. In low lying areas where water table is high, planting can be done at the surface or on mounds. Arranging two layers of coconut husk with concave surface upward at the bottom of the pit



Pit for planting seedling


Planting seedling

before filling with soil will help in moisture conservation. In laterite soil, addition of 2 kg of common salt will be helpful to loosen the soil.

Well laid out coconut garden

A neglected garden

Replacement of unproductive palms

Coconut palms become uneconomical to manage due to reasons such as old age, long term neglect without giving proper care etc. Coconut cultivators in general do not pay much attention to replace the uneconomical coconut palms in time. This is considered as one of the reasons for the low productivity of coconut. Timely removal of senile, unproductive and diseased palms and proper planning to replace them with suitable varieties is essential to maintain high level of production.

There are two methods for the replacement of unproductive coconut palms viz., replanting and under planting.

Replanting

In replanting, seedlings are planted after complete removal of the old stand and hence uniformity in plantation is obtained. It provides for taking up intercropping profitably and allows change of planting system/palm density. Replanting is recommended for large scale plantations. It could be staggered over a period of time depending on the resources available by adopting block - by-block replanting approach.

Under planting

Under planting in a well spaced garden

Under planting

In under planting of a coconut garden, the seedlings are planted amongst the old palms, which are removed in stages over a period of about six years. The major advantage of underplanting is that the old palms give some income to the cultivator until the new plants start bearing. In a coconut garden in which no regular spacing is adopted, the following method of under planting can be taken up.

As a first step, the garden is peg marked. During the first year, the palms which come in right in the place of peg mark are removed and new seedlings are planted. During second year, the palms which fall upto 1 m from the peg mark are removed. Similarly in the third year, palms upto 2m and in fourth year, palms upto 3m from peg mark are removed. Within a period of six years, all the old palms are removed.

However in a garden where systematic planting is adopted, we can go for under planting exactly at the centre of the two palms at the same time and the old palms can be removed by fourth year.

Early underplanting as well as late underplanting should be discouraged. In early underplanting, when the palms are still young and yielding well, the underplanted seedlings may compete with the older palms for moisture and nutrients and reduce the

yields. Similarly, underplanting at a very late stage will result in very poor returns from the garden for a number of years until the underplanted seedlings reach the bearing stage.

After care

Proper care is to be provided to the young palms in the early years of growth for their better performance in later years.

- Provide shade and irrigation during summer months.
- In sandy soil, irrigate @ 45 litres of water once in four days.
- Provide proper drainage facilities in ill drained areas.
- Remove the soil particles from the leaf axils and collar region splashed during rainy season.
- Remove weeds from the pits periodically.
- Widen the pits every year before applying manure by slicing down from the edges of the pit.
- Fill up the pit gradually as the seedling grows.
- Adopt prompt plant protection measures against pest and disease incidence, if any.

Widening the pit

5. GARDEN MANAGEMENT

A well maintained garden

Cultivation of high yielding varieties and adoption of the recommended crop management technologies are the two primary requirements for obtaining better yields from any agricultural crop. To serve as a reference guide for ensuring the adoption of proper crop management practices in a coconut garden important technologies recommended for coconut are discussed here:

Intercultivation

Intercultural operations alone twice in a year, once at the starting of monsoon and second at the fag end of monsoon has been found to increase the coconut yield by 30-35 nuts/palm/year as compared to the neglected plots (27 nuts/palm/year). The response of West Coast Tall palms to different management practices proved that an yield

Intercultivation using power tiller

increase by four fold by cultivation and manuring is possible as compared to the neglected gardens.

Application of first dose of fertilizers

Forking the soil

Fertilizer recommendations for coconut – a summary

- Regular manuring right from the first year of planting is essential for good vegetative growth, early flowering and bearing and high yields of coconut palms.
- Quantity, type, method and time of application of manures and fertilizers are to be properly followed for improving the fertilizer use efficiency.
- The fertilizer dose generally recommended for an adult palm is 500g N, 320 g P_2O_5 and 1200 g K_2O per palm per year.
- Under rainfed conditions, fertilizers may be applied in two split doses. After the receipt of the summer showers, one third of the recommended dose of fertilizers may be spread around the palms within a radius of 1.8 m and forked in. Circular basins of 1.8 m radius and 25 cm depth may be dug in August-September and organic manure in the form of cattle manure, compost or green leaves @ 50 kg per palm may be spread in the pits. Two third of recommended dose of fertilizers may be spread over the green leaf or compost and the basins may be covered.
- Under irrigated conditions, the fertilizers

Fertilizer recommendation(g/palm/year)

	May-June			September-October		
Year	N	P_2O_5	K_2O	N	P_2O_5	K_2O
First year	—	—	—	50	40	120
Second year	50	40	125	110	80	275
Third year	110	80	250	220	160	550
Fourth year onwards	170	120	400	330	200	800

Basin opening

Application of green manure

may be applied in four or more equal split doses avoiding heavy rainfall season.

- Fertilizers can also be applied through drip irrigation. Water soluble fertilizers like urea, diammonium phosphate, phosphoric acid (commercial grade) and muriate of potash can be applied in 4 to 6 equal split doses through fertigation.
- First application of fertilizers should be done three months after planting @ one tenth of the recommended dose of adult palms.
- One-third of the recommended dose should be given in two splits ie; during May-June and September-October during the second year. Similarly, two-third of the recommended dose is to be applied during the third year.
- From the fourth year onwards, full dose of fertilizers should be provided to the palms.
- 1 kg urea, 1.5 kg Mussorie phos/rock phosphate and 2 kg of muriate of potash

Application of second dose of fertilizers

Covering the basin after fertilizer application

are required to supply the nutrients recommended per year for an adult palm

- When the recommended dose of phosphatic fertilizers are applied continuously, the available phosphorus level in the soil goes up. When it is more than 20 ppm, application of phosphatic fertilizers can be skipped off for a few years until the level goes below 20 ppm. If the level is between 10 to 20 ppm, half of the recommended P_2O_5 can be applied.
- In acidic soils, 1 kg dolomite or 1 kg lime and 0.5 kg magnesium sulphate per palm may be applied in addition to the annual recommended dose of NPK fertilizers. Dolomite or lime may be broadcast in April-May in the basins and incorporated into the soil by forking. Lime should not be applied with other fertilizers. Magnesium sulphate can be applied with other fertilizers in the basins during September.

Deficiency of nutrients

Optimum concentration of essential plant nutrients should be maintained in the soil through proper fertilizer management for ensuring proper growth and yield. The requirement of nutrients for coconut is in the order of potassium, nitrogen, chlorine, calcium, magnesium, sulphur, phosphorus, iron, manganese, zinc, copper, boron and molybdenum. The nutrient requirement of coconut can be determined by either soil

testing or plant analysis. Deficiency symptoms are generally observed in coconut palm for elements such as nitrogen, potassium, magnesium, boron, sulphur and chlorine.

Yellowing of palm due to nitrogen deficiency

Nitrogen

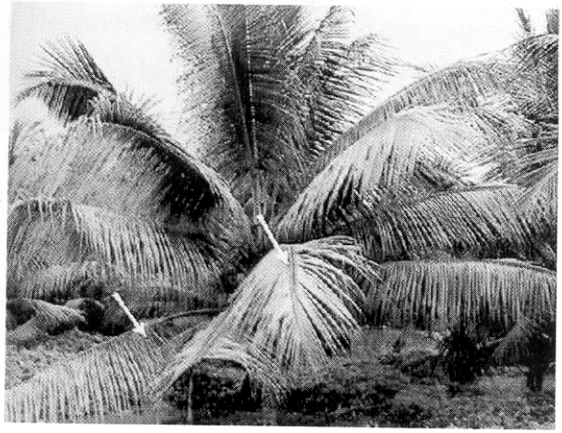
A nitrogen deficient coconut palm, exhibits a general yellowing of all leaves. In the advanced stage, many inflorescences are aborted and the number of female flowers is low. The tree is stunted in growth and stem tapers off in the 'pencil point' way. For nitrogen deficient coconut trees, apply nitrogenous fertilizers. Establishment of a good legume cover also helps to improve the condition of the trees.

Good legume cover to avoid nitrogen dificiency

Symptom of potassium deficiency

Potassium

In a potassium deficient coconut palm, rust coloured spots appear on leaflets on either side of the central rib. The rusting spots invade the whole leaflet and form large patches of irregular outline. Older leaves are affected first and show yellowing. General flaccidity and drying of leaf tips are also noticed. For potassium deficient coconut tree, apply potassium fertilizers.



Symptom of magnesium deficiency

Magnesium

Magnesium deficiency results in yellowing of older leaves. Yellowing of the leaflets starts from the tip moving up towards the petiole. This discoloration is worse in the parts exposed to the sun, the shaded parts remaining greener. Necrosis of the tips of leaflets is also observed. Application of magnesium sulphate or dolomite helps to correct magnesium deficiency.

Symptom of boron deficiency

Boron

Emergence of shorter leaves with deformed and crinkled leaflets is the first symptom of boron deficiency. Often, leaflets show severe tip necrosis. Affected leaflets do not unfurl properly and in many cases give a choked appearance to the frond. The inner leaves crowd around the bud and prevent normal unfurling of the flag leaf. Inflorescence emergence is hindered resulting in yield loss. Soil application of borax @ 50g per palm at the post monsoon period improves the condition of the boron deficient coconut palm.

Symptom of sulphur deficiency

Sulphur

Due to sulphur deficiency in young coconut palms, the leaves become yellow to orange which decay at the tips and become grey. In older trees, the foliage gets reduced and becomes completely decayed and hangs down the trunk. The tips of leaflets dry off prematurely. Copra becomes light in weight and leathery. Apply sulphur containing fertilizers to correct sulphur deficiency.

Chlorine

Deficiency of chlorine results in yellowing and/or orange mottling of the older leaves with a drying up of the outer edges and tip of the leaflets. Orange coloured spots are seen on leaflets. Chlorine deficiency can be tackled by the application of potassium chloride or common salt.

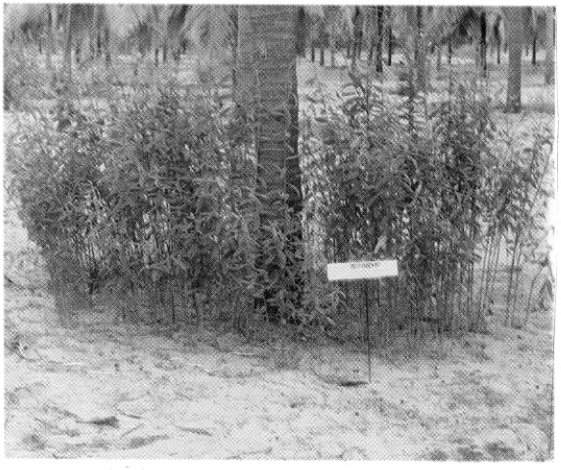
Avoiding nutrient deficiencies helps in better yields

Green leaf manuring to a young palm

Green manuring in coconut garden

The growing of a green manure crop *in situ* and its incorporation into the soil has been recognized as the easiest and the most economic method of augmenting the organic matter content in the soil. The leguminous green manure crops were found to improve the nitrogen status of the soils. Further, green manuring improves soil structure, releases plant nutrients present in the soil in an available form, conserves nutrients from leaching losses, regulates soil temperature and minimize soil erosion.

Sunnhemp (*Crotalaria juncea*), wild sunnhemp (*Crotalaria striata*) and cowpea (*Vigna unguiculata*) are the most suitable green manure crops for growing *in situ* in the coconut gardens. Under normal conditions, these green manure crops give a total out turn of about 5,000 to 10,000 kg of green stuff per ha. It has been observed that by the addition of phosphatic fertilizers to the green manure crop, the green matter yield can be substantially increased. A dose of 40 kg P_2O_5 per ha is recommended under normal soil conditions. On neutral or alkaline soil, superphosphate may be added while sowing the green manure crops at the rate of 250 kg per ha. On medium acidic soils, super phosphate may be replaced with bonemeal or basic slag at a level sufficient to give 40 kg of P_2O_5 per ha. On strong acid soils, the use of rock phosphate is more effective.



Basin management with sunnhemp in coastal sandy soil

To derive the maximum benefit from green manuring, the green manure crops should be incorporated at the correct stage of growth and when the soil moisture is sufficient enough to permit complete decomposition of the green matter.

If the growing of green manure crops *in situ* is found impracticable, plants like *Gliricidia maculata* and *Tephrosia candida* can be grown along the boundaries of the coconut garden and the green matter is cut and applied to the coconut palms. These bushes would serve as excellent sources of green matter for a number of years.

Organic recycling in coconut

Currently, the emphasis in agricultural production is on resource conserving technologies and practices. Such a sustainable production system aims at increasing production and at the same time enhancing the quality of natural resource base. Also worldwide, there is an ever increasing demand for organically grown agricultural produce and products. Perennial plants in general produce huge quantities of organic wastes throughout the year, in

A good cover of Calopogonium in coconut garden

A good cover of self-seeding Mimosa in coconut basin

addition to the economic produce. The growth habit of coconut makes it highly suitable for managing through organic farming. From a well-managed coconut garden, about 15 tonnes/ha/year of dry material becomes available in the form of leaves, spathe, bunch waste and husk. If fully recycled, these wastes can meet a major portion of nitrogen and a part of other nutrient needs of coconut plantations. Opportunities available for recycling of organic materials in a coconut garden are discussed here:

a) Organic recycling in coconut based farming system

Farming systems designed based on local resources and needs consider the whole farm as a single unit and all the components are given importance in the functioning of the system. As the biomass production per unit area will be very high, when the available organic wastes are recycled, soil health and coconut yields can be sustained even in the absence of external inputs.

b) Leguminous green manure plants for sustaining coconut yields

Leguminous green manure plants, either annual or perennial types, can add a lot of green matter rich in nitrogen to soil in the shortest time because of their ability to associate with atmospheric nitrogen fixing *Rhizobium* spp. This nitrogen-rich green matter will decompose easily and release the

bound nutrients fast. Growth of legumes also increases the availability of phosphates. Because of their deep tap root system, they absorb nutrients that have leached down beyond the root zone of coconut palms and make them available when the biomass is incorporated into soil. Leguminous cover crops grown in coconut plantations during the rainy season protect the soil from direct impact of heavy rains. Incorporation of legume biomass has also been found to enhance soil microbial population, population of VA mycorrhiza fungi, soil enzyme activity and carbon mineralization.

Basin management with Calopogonium in coastal sandy soil

Legume cover crops grown in basins can generate about 15-20 kg green biomass per basin and legumes such as *Crotalaria* spp. grown in interspaces can generate 3-4 tonnes of green matter per hectare. The perennial leguminous green manure plant *Gliricidia* is very fast growing, hardy and resistant to regular harvesting of green matter. This plant can be very well grown along the borders of coconut plantation and can generate huge amounts of nitrogen rich green matter.

c) Basin management with legume cover crops

An agrotechnique has been developed to generate significant quantities of organic manure and nitrogen in coconut garden utilizing the leguminous cover crops. It involves cultivation of leguminous creepers

having symbiotic association with efficient *Rhizobium* strains in coconut basins and interspaces during the monsoon period and harvest and incorporation of biomass generated at the maximum vegetative growth of legumes. A field experiment on basin management with two legumes in adult coconut plantations revealed the effectiveness of this technique to substitute fertilizer nitrogen for coconut upto 50 per cent. Coconut palms under the treatment of *M. invisa* and *C. mucunoides* exhibited higher yield than the palms, which received the full dose of fertilizer nitrogen. The effectiveness of the legume treatment as a component in the management programme for root (wilt) disease of coconut has also been demonstrated. Among the ten species of legumes screened, *Pueraria phaseoloides*, *Mimosa invisa* and *Calopogonium mucunoides* were 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 140-150 days in monsoon season. Pelleting of inoculated seeds with neutral or inert materials enhances nodulation by introduced rhizobia in acidic soils. Basin management with legumes is an easily adaptable and less expensive agrotechnique for supplying organic manure and nitrogen at the site itself.

Alley cropping of Gliricidia in coastal sandy soil

d) Growing of Gliricidia as green leaf manure crop in coconut garden under littoral sandy soil

Coastal sandy soils, which are widespread along the coastal region of India, have poor physico-chemical properties, limiting the productivity. To mitigate this problem, investigations were conducted on the feasibility of growing Gliricidia as a green leaf manure crop in coconut garden under littoral sandy soil conditions. *Gliricidia sepium* was raised as an intercrop. Application of the Gliricidia prunings from interspace of the coconut garden could meet a major portion of nitrogen, part of phosphorous and potassium requirements.

e) Recycling of organic wastes from coconut palm

Organic wastes from coconut palm are rich in lignin and are resistant to easy decomposition. If recycled fully, this waste biomass can meet a major portion of nitrogen and a part of other nutrient requirement of palms. Meaningful utilization is possible by using the biomass directly as mulch or after proper composting.

f) Direct utilization of coconut wastes as mulch

Most of the organic wastes from coconut have high moisture holding capacity and can be very profitably used as moisture regulators and conservators rather than nutrient sources. This gains more practical

Vermicomposting in coconut basin

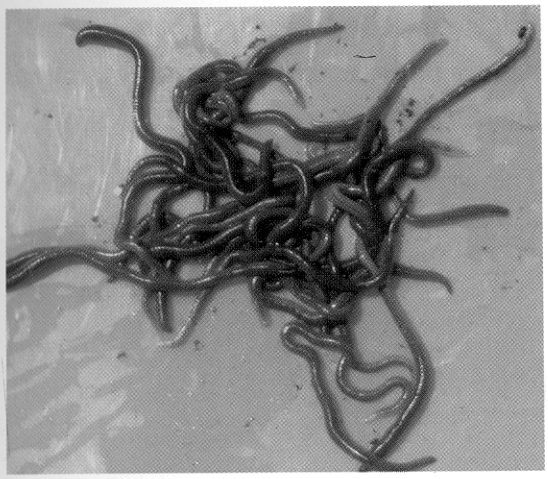
Pit method of vermicomposting in the interspace of coconut palms

Heap method of vermicomposting in coconut gardens

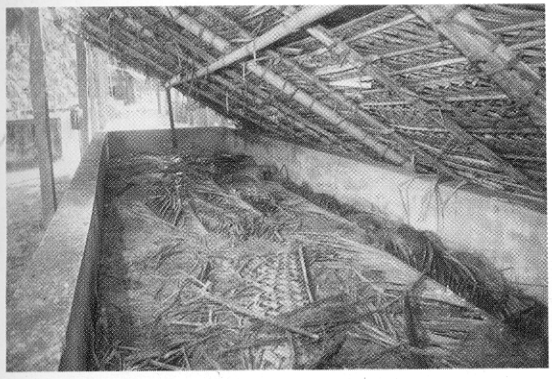
significance in the light of the fact that soils cannot be rejuvenated with organics in the absence of sufficient moisture. Similarly the full benefits from irrigation can be obtained only if there is sufficient quantity of soil organic matter. Keeping in mind the complementary roles of soil organic matter and moisture conservation, coconut leaves, husks and coir pith can be utilized directly for mulching. Spreading of these materials in basin areas will protect the soil from direct sunlight and heavy rains. It would also serve to control weed growth. Mulches can reduce the loss of soil moisture and create good microclimate in soil for the proper growth of plant roots and soil flora and fauna. Over a period of time, mulches will decompose and add to the soil organic matter reserves. Coconut husks and coir pith can also be buried in trenches taken in between the rows of palms. Coir pith has 400-600 per cent water holding capacity and this technique will be of immense value in long term moisture conservation. In addition, both these materials are rich in potash which would be available for plants over the years.

g) Vermicomposting

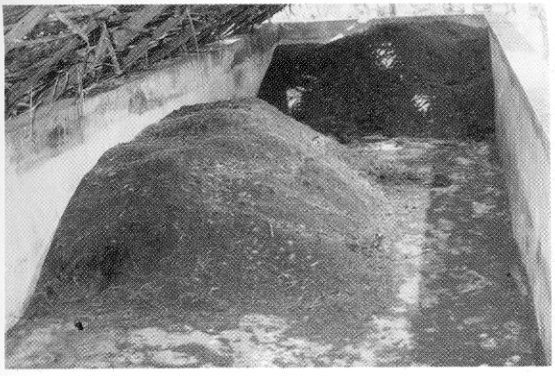
Studies have revealed that coconut plantation wastes could be effectively converted into rich vermicompost using the earth worm, *Eudrilus* sp. They can fully convert the wastes into vermicasts, leaving behind only mid ribs of the leaves. Nucleus cultures of the local strain of *Eudrilus* sp.



Eudrilus sp.



Vermicompost preparation in cement tank



Vermicompost ready for application

capable of composting coconut plantation wastes are being supplied from CPCRI at a nominal cost. These worms can be multiplied fast in a 1:1 mixture of cow dung and decayed leaves, mulched properly with grasses.

A low cost technology has been standardized for vermicomposting the biomass from coconut palms left exposed to the action of weather in the field for about three months. The weathered wastes obtained during the rainy season may be preferred. This waste can be used without chopping, thus saving a lot of labour. The coconut wastes used for oyster mushroom cultivation were also found suitable for vermicomposting. These organic wastes are to be treated with cow dung at the rate of 10 per cent by weight in the form of slurry. The quantity of cow dung should not be more, as the earthworms will prefer cow dung, keeping aside the coconut palm wastes. The heap should be watered regularly to maintain sufficient moisture and allowed to undergo a preliminary decomposition. After giving one or two turnings to reduce the heat generated, the earthworms may be introduced at the rate of 1 kg per tonne of material. The compost bed should be mulched properly using any locally available plant material or gunny bags and has to be protected from direct sun light. Watering is to be done to maintain enough moisture. As full leaves are used for composting, compact mass is not formed,

thus allowing free movement of air in the bed. In about 2-3 months, compost will be ready, leaving behind only mid ribs of the leaves. If the biomass used is old, composting will be faster. Even the thick petioles are converted into vermicompost, but will take more period based on the extent of weathering. On an average, 70 per cent recovery of vermicompost is obtained. The same technology for vermicomposting can be done in cement tanks, basins, heaps or large pits taken in the inter spaces of coconut palms. If composting is done in the field itself, labour required for transportation of the biomass and compost can be saved. This technology may be tried even in plantations with very limited irrigation facilities, as only a limited number of pits or trenches need to be watered. In coconut plantations with irrigation facilities, vermicomposting can be done in basins and palms can directly utilize the benefits.

The average nutrient composition of the vermicompost is N 1.8%, P 0.216%, K 0.16%, organic carbon 17.84% and C:N ratio 9.95. Total microbial counts and beneficial microbial population are also more in the compost compared to the base material. Two types of active nitrogen fixing bacteria not commonly isolated from soils are found regularly associated with vermicasts. Vermicompost contains nutrients in easily available forms in addition to a number of plant growth promoting substances and humic acids. Being granular and less bulky, they can be easily transported and incorporated into soils.

Pre and post vermicomposted coconut leaves

h) Coir pith composting

Coir pith composting

Coir pith compost

Coir pith contains very less nitrogen and has large amounts of lignin and phytotoxic polyphenols and has to be composted before using as a manure. Exposure to rains and sunlight for many years results in loss of problematic chemicals and the use of weathered coir pith may be advantageous. Fresh coir pith has a wide C:N ratio (about 100:1) and for initiating microbial action, nitrogenous organic or inorganic materials are to be added. Additionally, fortification with rock phosphate at the rate of 10 kg per tonne of coir pith can also favour microbial action. The well known technology for composting of coir pith using *Pleurotus sajor caju* may be utilized for large scale composting. For composting one tonne of coir pith, 5 kg urea and 5 bottles of *Pleurotus* spawn are required. Hundred kilograms of coir pith is spread on a level land in a shaded place and one bottle of spawn is sprinkled over it. The spawn layer is covered with 100 kg coir pith and 1kg urea is sprinkled over it. This process is repeated five times to get a heap, which is protected from direct sun light and rain. Proper moisture is to be maintained in the heap and is allowed to undergo degradation for one month. This composted coir pith can be used as manure in coconut plantations.

Water management

Research results show that irrigation during dry months could increase the yield of coconut palms. Irrigation enhances absorption of nutrients, enhances the rate of production of inflorescence, increases the number of female flowers per inflorescence, reduces button shedding and increases the number and size of nuts and weight of copra. Prolonged drought adversely affects the productivity of coconut palms.

Basin irrigation by irrigation channels

Drip irrigation in coconut garden

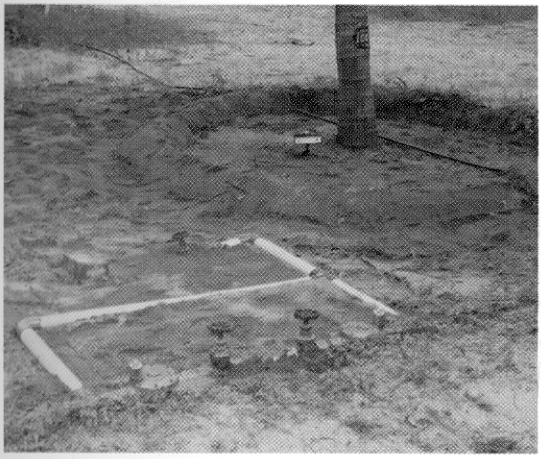
- In the west coast region, irrigation is required from November to May while in other coconut growing areas irrigation is provided throughout the year.
- The irrigation methods commonly adopted in coconut are flooding, basin irrigation, sprinkler or perfo sprays and drip irrigation. In certain parts of Tamil Nadu and East Godavari and West Godavari districts of Andhra Pradesh where adequate supply of water is available, coconut gardens are flood irrigated. There is considerable wastage of water in this method.
- In basin irrigation, water is applied in the basins of 1.8 m radius around the palm either through hose pipe or by irrigation channels. In basin irrigation method also, there is loss of water through deep percolation and surface evaporation.
- Sprinkler or perfo sprays are most suited in coconut gardens where inter or mixed

cropping is practised.

- In water scarce areas, drip irrigation is ideal as it saves water, energy and labour. The water use efficiency is high in this method of irrigation.
- At seedling stage, 45 litres of water once in four days is required.
- For adult palms, under west coast conditions, 20 mm irrigation through perfo sprays once in five days during December-February and once in four days during March-May is beneficial in sandy loam soils.
- In the west coast, 200 litres of water per palm once in four days is beneficial to coconut palms through basin irrigation.
- For drip irrigation, 32 litres of water per palm per day is recommended under West Coast conditions (at 66 per cent of open pan evaporation). For other regions, the quantity of water may have to be adjusted according to the evaporative demand.

Automatic irrigation system

CPCRI has developed an automatic irrigation system, which can automatically regulate the irrigation according to the crop water requirement. The system is suitable for coconut also. It consists of an electronic tensiometer, which senses the prevailing soil moisture tension and a control unit. Two negative pressures (tensions) can be pre-set in the instrument viz., upper limit at which irrigation is to be started and lower limit at



Auto irrigation system

which irrigation is to be stopped. After pre setting the tensions, the instrument is placed in the field. As the soil dries out, its tension increases. When the tension reaches the pre set upper limit, the irrigation starts. Once the irrigation is started, the soil moisture tension decreases and when it reaches the pre set lower limit, irrigation will be stopped automatically.

The automatic irrigation system is compatible with the high frequency irrigation systems such as drip, sprinkler, perfo irrigation etc. It reduces the labour required for irrigation and also enhances the irrigation efficiency.

Raising the level of ground in waterlogging prone areas

Drainage

Proper drainage in the coconut garden is equally important as irrigation for better performance of coconut palms. Waterlogged conditions result in poor growth of palms. In ill drained garden, drainage facilities are to be provided by digging deep and wide drains between the rows of palms and by raising the level of the ground around the individual palms.

Weed control through intercultivation

Weed control

Weeds compete with coconut palms for water and nutrients. Hence if the weeds are not removed, productivity of coconut will be adversely affected.

- Intercultivation by ploughing or digging the interspace twice in an year ie., once

A well maintained coconut garden

A neglected coconut garden

Mulching with coconut leaves

at the commencement of the monsoon season and the next at the fag end of the monsoon will be beneficial to control weeds. In slopy land, ploughing should be done across the slope.

- Intercultivation also helps in improving the soil rhizosphere micro-environment
- Weeds can be controlled using herbicides also. A mixture of 50 g Fernoxone (2, 4-D sodium salt) and 50 ml of Grammoxone (paraquat) in 10 litres of water or Glycel (glyphosate) spot application @ 30 ml per 10 litres can be used.

Soil moisture conservation in coconut garden

- Proper soil moisture conservation practices are vital for better performance of coconut palms; especially in slopy and undulating terrains.
- Regular ploughing or digging of the interspaces of coconut palms twice in a year, first at the beginning of south west monsoon and second at the fag end of the monsoon helps in moisture conservation.
- Mulching is an important practice for moisture conservation. The coconut basins can be mulched with coir dust, coconut husks, green leaves, dried leaves, organic wastes, and dried coconut leaves. Mulching should be done before the end of north east

monsoon and before the top soil dries up.

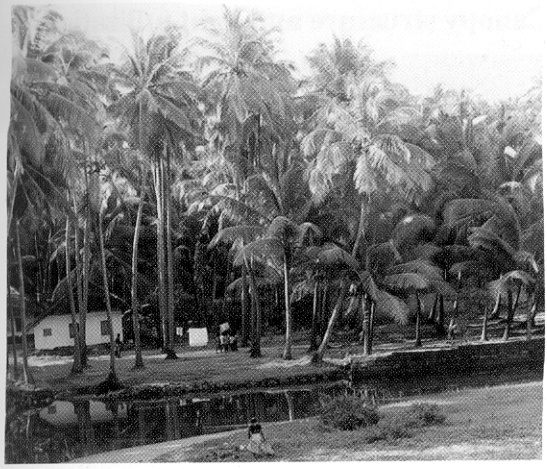
- Application of sufficient quantity of organic manure by way of cattle manure, farmyard manure, compost or green leaves improves the soil characteristics and provide nutrients to coconut palms. Organic matter addition enhances moisture retention capacity of sandy soil and clayey soils are made loose and porous thereby increasing aeration, drainage and water intake. Organic manure also helps in enhancing soil microbial activity and recycling of minerals.

Husk mulching for a newly planted seedling

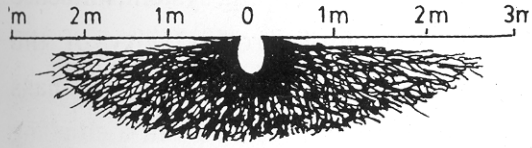
- Husk burial helps to absorb and retain large quantities of water for use by the coconut palms. Husk burial can be done in coconut basins or in the interspace. The beneficial effect of husk burial lasts for seven years. The husk can be buried either in linear trenches taken 3 m away from the trunk between rows of palms or in circular trenches taken around the palm at a distance of 2m from the trunk. The trenches may be dug with 50 cm width and 50 cm depth. The husks are to be arranged in layers with concave surface facing upwards and covered with soil. Coir pith can also be buried at the rate of 25 kg/palm/year.

Terracing in slopy land

- Measures such as contour bunding, terracing etc. can be taken up in slopy lands for soil and moisture conservation.



Coconut as a monocrop



Coconut root spread

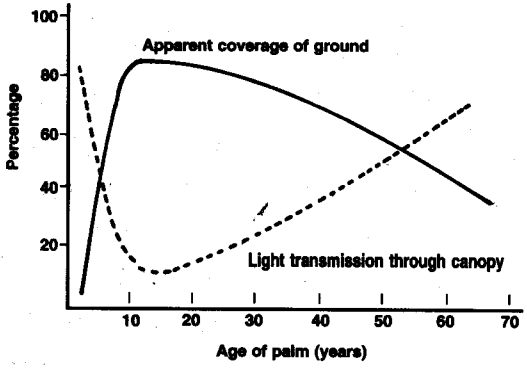
Coconut rooting pattern in coastal sandy soil

Coconut based cropping systems

In India coconut is predominantly cultivated in small and marginal holdings. These holdings neither provide gainful employment opportunities for the family labour throughout the year nor generate sufficient income to meet the family requirement. Coconut as a monocrop does not fully utilize the basic resources such as soil and sunlight available in the garden.

Rooting pattern

The rooting pattern in coconut is such that only 25 per cent of land area is effectively utilized. A spacing of 7.5m in the square system is recommended for coconut (175 palms/ha) for optimum production. Coconut palm, like other monocots, has a typical adventitious root system. Under favourable conditions, as many as 4,000 to 7,000 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 are confined to 30 to 120 cm depth of soil. Thus, 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.



Apparent coverage of ground by coconut canopy of various age groups

Canopy structure and light utilization

As coconut canopy's space utilization is very low (see figure), plenty of sunlight infiltrates and fall on the ground unutilized. The venetian structure of the coconut crown and the orientation of leaves allow part of the incident solar radiation to pass through the canopy and fall on the ground. In an intercropping system, light is the main limiting factor for the growth of the intercrop since light penetration of a plant stand is reduced through interception and absorption by the taller canopy plants. The light interception in a cropping system, influence the growth and productivity of the component crops and the biomass production of various crops in a cropping system will give a rough indication of their compatibility to the low light environment. Although the full yield potential cannot be realized in the crops under the system as much as that of monocropping system, the reduced yield itself is indicative of their adaptability to low light profiles. Age, spacing, soil fertility, varietal characteristics, leaf area and time of the day influence the light penetration through the canopy.

As much as 56 per cent of the sunlight is transmitted through the canopy during the peak hours (10.00-16.00 hrs) in palms aged around 25 years. The diffused sunlight facilitates growing a number of shade tolerant crops in the interspaces.

The nature and amount of sunlight transmitted through coconut canopy and

Intercopping in a young garden

Middle phase of growth -
A 15 year old coconut garden

Intercropping in a grown up garden

falling on the ground shows temporal as well as spatial variations. The angle of the sun rays (and thus the time of the day) influences the amount of light passing through the coconut canopy. The distribution of light at different positions in the canopy zone of coconut varies much because of the non-random distribution of leaves. This causes differences in the growth and yield of intercrops at different positions of the plantation floor.

Based on the growth habit of the palm and the amount of light transmitted through its canopy, the life span of coconut palm could be divided into three distinct phases from the point of view of intercropping.

1. Planting till full development of canopy (upto 8 years): Good light transmission initially; but decreasing with age; suitable for growing annuals/biennials; intercrops have minimal competition with coconut palm for ecological factors.
2. Young palms (9-25 years): Maximum ground coverage (80%) and low canopy due to shorter trunk; poor light availability; not suitable for growing of other crops in the interspace.
3. Grown up palms (>25 years): Gradual increase in the magnitude of light penetration to the ground; decrease in apparent ground coverage of canopy; taller trunk; ideal for raising annual and/ or perennial crops.

A number of crops can be accommodated

Light availability

in the unutilized area enabling better use of natural resources. Cultivation of other crops under coconut brings additional income and employment opportunities. It can also cushion the fluctuating income from coconut because of market fluctuations. The environment in irrigated coconut plantations favours luxuriant growth of grass and other vegetation throughout the year due to favourable microclimate of high humidity and favourable soil temperature. Hence it is worth to have intercrops in such conditions rather than to invest labour in clearing grass and other vegetation.

Criteria for selection of subsidiary crops

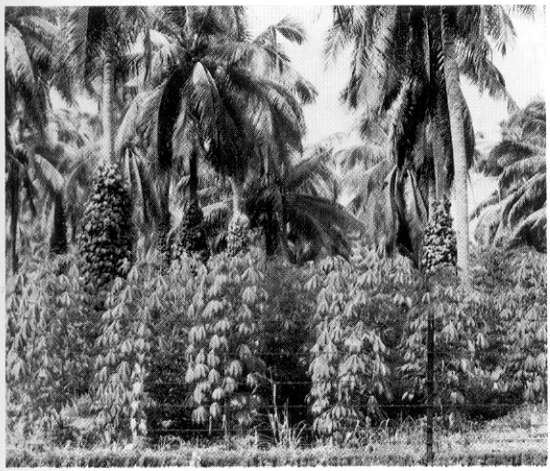
The desirable characters of crops to be grown under or between coconut palms are listed below:

1. Crops should be selected according to their shade tolerance and amount of solar radiation available.
2. Should not grow as tall as coconut.
3. Should not be more susceptible than the main crop to diseases they have in common.
4. Should not require harvesting or other operations that would damage the main

crop or induce soil erosion or damage soil structure.

5. Should not have an economic life longer than the main crop.
6. Its root system exploits different soil horizons/zones.
7. Crops should be selected according to the soil type, rainfall pattern, irrigation facilities and climatic conditions.

Availability of resources like finance, labour, rainfall, irrigation facilities, soil characteristics, farmers' needs and market demands are the other factors to be considered while selecting the crop combinations in a coconut based cropping system.



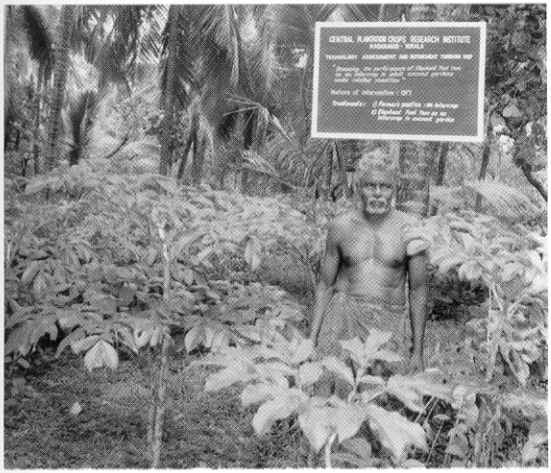
Intercropping with tapioca

Intercropping systems

Intercropping refers to the cultivation of annuals or biennials in the interspace of coconut. Details of the crops found suitable for raising as intercrops in a coconut garden are as follows:

Tuber crops

Tapioca, elephant foot yam, sweet potato, colocasia, greater yam and lesser yam are the tropical tuber crops cultivated as intercrops in coconut garden. The tuber crops partially meet the food requirements of a farm family and are always found in the homestead gardens.



Intercropping with elephant foot yam

Intercropping with ginger

Rhizome spice crops

Ginger and turmeric are the important rhizome spice crops commonly intercropped in coconut gardens. They are planted in raised beds of 1-1.2 m width, 30 cm height and convenient length. Farm yard manure is to be mixed with soil or the seed material is to be covered with farm yard manure in pits after planting. Ginger rhizome bits are planted at a spacing of 25 cm x 25 cm at a depth of 4.5 cm with bud facing upwards. Turmeric finger rhizomes are planted at a spacing of 15 cm x 30 cm covered with dry powdered cattle manure. Mulching with green leaves is to be done immediately after planting which is to be repeated after 50 days and 100 days of planting. Ginger is highly

Intercropping with turmeric

Maize as an intercrop

Intercropping with bottlegourd

Intercropping with cowpea

susceptible to soft rot disease against which *proper plant protection measures are to be* taken to ensure a good crop. The yield of ginger and turmeric as intercrop under average management conditions ranges from 7,000 to 8,000 kg/ha.

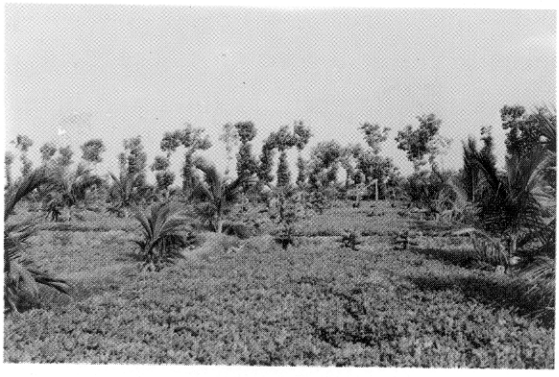
Cereals

Studies at Kasaragod revealed that upland rice varieties perform fairly well as intercrop. The rice variety 'Rohini' is the best performing variety. The upland rice can be sown immediately after the onset of monsoon.

Maize (*Zea mays*), varagu *(Paspalam scrobiculatum),* pearl millet *(Pennisetum typhoides)* and finger millet *(Eleusine coracana)* perform well as intercrops in coconut garden.

Vegetables

Raising of chillies, potato and French beans is found to be a profitable practice in maidan areas of Karnataka. The experiments conducted at Kasaragod have indicated that vegetables like snake gourd, bottle gourd, amaranthus, coccinia, brinjal and bitter gourd are compatible intercrops with coconut. Among different crop sequences tried, snake gourd – ridge gourd – amaranthus was found to be the most remunerative followed by amaranthus - bottle gourd - brinjal.



Ground nut intercropping

Banana as an intercrop in coconut garden

Pineapple as an intercrop in coconut garden

Pulses

Leguminous pulse crops help in enriching the soil with nitrogen when grown in association with coconut. Among the pulse crops, cowpea, blackgram, green gram, bengal gram, short duration red gram and soya bean give satisfactory yield in the maidan areas of Karnataka. Soya bean varieties PK 472, MACS 13 and MESCS 48 are highly promising as intercrop in coconut garden. Under Kerala conditions, horse gram, cow pea, green gram and black gram are the suitable intercrops giving yields to the tune of 250-500 kg per ha.

Oil seeds

Oil seed crops like ground nut are remunerative intercrops in coconut garden which also enrich the soil.

Fruit crops

Banana and pineapple are the most popular fruit crops grown as intercrops in coconut garden. In Kerala, Palayankodan, Robusta, Karpooravally and Poovan are identified as the suitable banana varieties for intercropping which give an yield of 8-12.8 kg/bunch. Suckers are planted in pits of 50 cm x 50 cm x 50cm size at a distance of 2.7 m. The recommended fertilizer dose is 160 g N, 160 g P_2O_5 and 320 g K_2O per plant per year which are applied in two split doses ie., half of the dose two months after planting and the remaining half at four months after planting.

Floriculture in coconut garden

Pineapple as an intercrop performs well in the partially shaded conditions of coconut gardens. A mean yield of 1.54 kg per fruit was obtained at Kasaragod. Healthy suckers weighing 500 to 1,000 g are to be planted in trenches of 1.0 m width, 0.3 m depth and of convenient length. Suckers are planted in two rows in the trench at a spacing of 70 cm x 30 cm. Recommended fertilizer dose is 8g N, 4g P_2O_5 and 8g K_2O per plant. The full dose of P_2O_5 is applied as basal dose. N and K_2O are applied as three equal split doses, ie., basal, 3 months and 6 months after planting. On an average, 8,000-12,000 kg of fruits per ha is obtained from pineapple intercrop.

Papaya also can be intercropped with coconut.

Floriculture

Orchids, anthuriums and other cut flowers and ornamentals can be successfully grown as intercrop in coconut garden.

Medicinal and aromatic plants

Presently there is high demand for natural herbs used in the preparation of ayurvedic medicines. Crops such as lemon grass, kacholam, dioscorea, arrowroot, sida, thippali (long pepper), neela amari and adapathiyan are suitable as intercrops in coconut.

Arrowroot as an intercrop

Betel vine in coconut garden

Mixed cropping with cocoa

Mixed cropping

Growing of perennial crops in association with coconut palm is referred to as coconut based mixed cropping. Cocoa, clove, nutmeg, cinnamon, pepper, betel vine, jack, breadfruit and mango are often raised as mixed crops in coconut gardens.

Cocoa

Cocoa is an ideal mixed crop for coconut garden. One year old cocoa grafts are planted at a spacing of 3m between plants in a single row system in between two rows of coconut palms. In a coconut garden with palms spaced at 7.5m x 7.5m, about 450 cocoa plants can be accommodated. Double hedge system can be followed for cocoa planting in coconut gardens with wider spacing ie., 8.5 m and above. Pits of 75 cm x 75 cm x 75 cm is dug and filled with 15 kg of farm yard manure or compost and top soil to a depth of 20 cm from the surface. Fertilizers @ 100g N, 40g P_2O_5 and 140g K_2O are to be supplied to an adult tree in two equal split doses ie., during May and September. 1/3rd of the above quantity can be given during first year of planting, 2/3rd during second year and full dose from third year onwards. The fertilizers may be broadcast in a circular area of 75cm radius and forked into the soil. Cocoa has to be pruned and shaped to get the canopy at a height of 1.8 to 2m allowing only a single storey of fan branches. It gives stabilized yield from seventh year onwards.

Cultural requirements of crops for mixed cropping in coconut garden

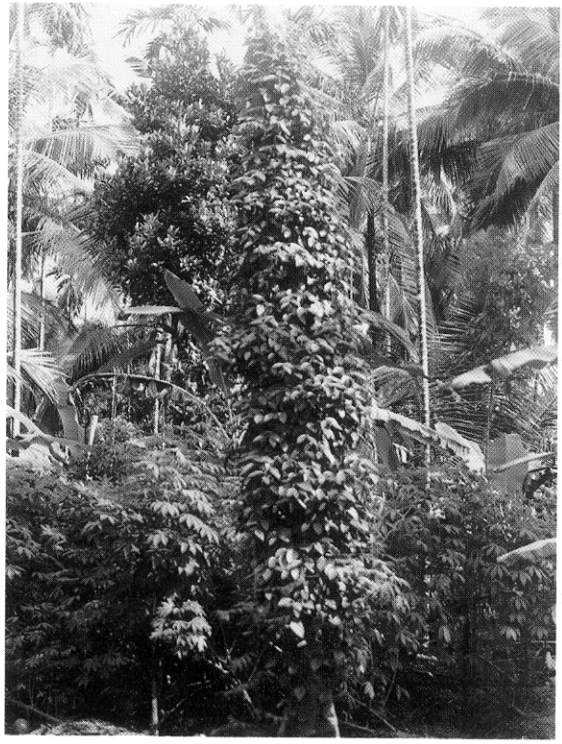
Crops	Propagation	Planting pits	Spacing	No. of plants per ha	Fertilizer dose (g/plant/year)		
					N	P_2O_5	K_2O
Cocoa	Grafts	75 x 75 x 75 cm	3m x 3m (single hedge)	450	100	40	140
Pepper	Rooted cuttings	50 x 50 x 50 cm	7.5m x 7.5m (at the base of the palm)	175	100	40	140
Clove	Seedlings	60 x 60 x 60 cm	7.5m x 7.5m (at the centre of four palms)	175	300	250	750
Nutmeg	Grafts	60 x 60 x 60 cm	7.5m x 7.5m (at the centre of four palms)	175	500	250	1000

On an average 10-15 kg of fresh pods per tree are obtained every year. 10-12 kg pods give 1.0 kg wet beans and 3.0 kg of wet beans give 1.0 kg of dry beans.

Pepper

Black pepper is commonly raised as a remunerative mixed crop with coconut in the west coast of India. Pepper varieties viz., Karimunda, Panniyur-2 and Panniyur-5 are found to be suitable for mixed cropping. It can be planted in the coconut basin using coconut trunk itself as the standard and also in the inter space. Rooted cuttings of pepper may be planted at a distance of 1 m from the bole of the palm on the northern side in pits of 50cm x 50cm x 50cm size. The pits are filled with a mixture of 10 kg farm yard manure or compost and top soil. The vines may be trained along the ground and then on the palms by tying to the trunk during the first two years.

Fertilizers at the rate of 100:40:140 g N, P_2O_5 and K_2O per vine per year respectively are to be applied for adult plants in two equal split doses during May and September. One third of the dose is to be given in the first year, two-third in the second year and full dose from the third year onwards. Fertilizers should be broadcast in a circular area of 45 cm radius and incorporated into the soil without disturbing the very fine root system of pepper. The height of the vines is to be restricted to 4m by pruning. Pepper begins to yield from third year onwards and comes to stabilized yield by 7-8 years. On an



Mixed cropping with pepper

average, one kg of dry pepper can be obtained from a vine.

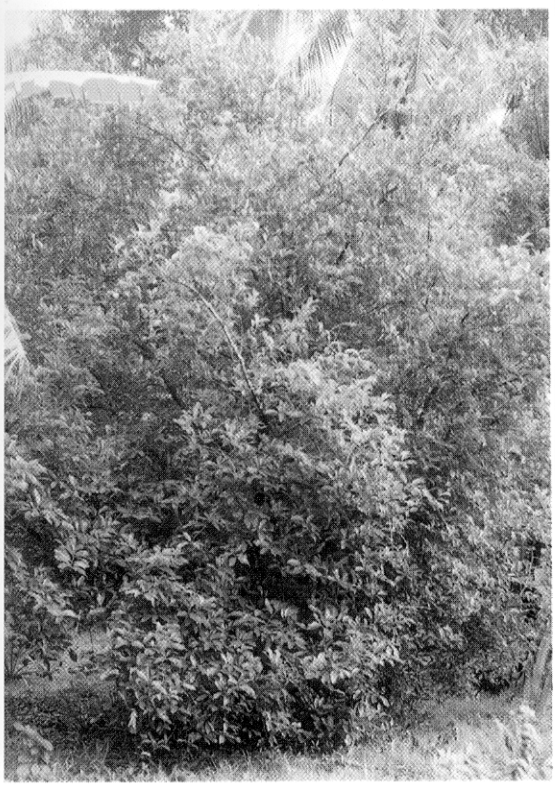
Clove

Clove can be grown as a remunerative mixed crop in coconut gardens in fertile, well drained soils with assured irrigation. It is planted at the centre of four coconut palms. Two year old clove seedlings may be planted in 60cm x 60cm x 60cm pit filled with a mixture of top soil and 15 kg farm yard manure or compost. In one hectare of coconut garden, about 150 clove seedlings can be planted. During the first year, fertilizers @ 20g N, 18g P_2O_5 and 50g of K_2O per tree is to be applied. The dose is gradually increased so that the adult dose of 300g N, 250 g P_2O_5 am 750 g K_2O is supplied in the fifth year. Fertilizers are supplied in two equal splits in May and September. Clove starts flowering at the age of six years and full bearing comes at 20 years. The flower buds are harvested when they turn light pink from green by hand picking with the help of platform ladders. Flower buds are dried in sun for 4-5 days till they turn brown in colour. An average yield of 3 kg is obtained from a tree per year.

Nutmeg

Two year old nutmeg grafts are planted in the centre of four coconut palms. It is preferable to use grafts prepared from high yielding female trees because of the dioeceous nature of the plant. While

Mixed cropping with clove



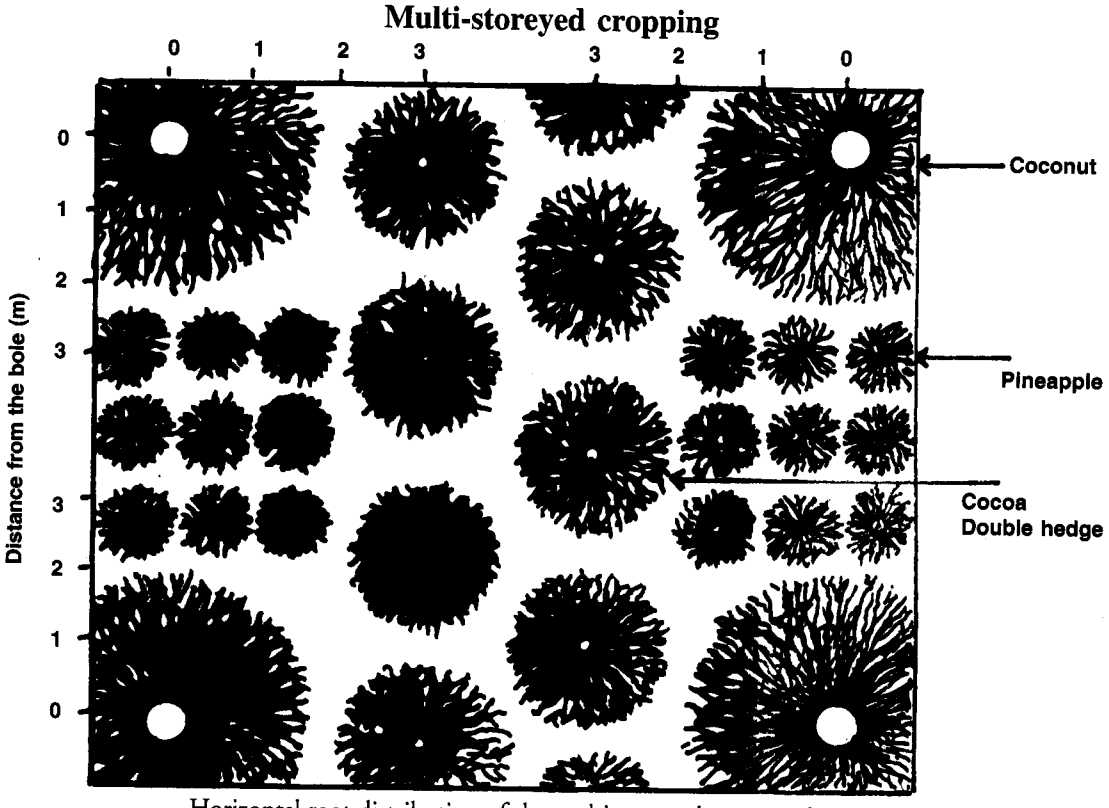
Nutmeg as a mixed crop

planting, the ratio between male and female grafts is to be kept a 10:1. Pits of 60x60x60 cm size may be taken and filled with a mixture of farm yard manure or compost and top soil. Fertilizers @ 20g N, 18g P_2O_5 and 50g K_2O has to be applied in the first year. The dose has to be gradually increased so as to reach 500g N, 250g P_2O_5 and 1000 g K_2O per tree per year by the fifth year.

Nutmeg flowers at 5-8 years of age and full bearing comes at 15-20 years. Fruits are to be harvested when they have split and the aril turn bright red in colour. The mace is dried in the sun for 10-15 days, till they become brittle and turn yellowish brown from the initial red colour. The nuts are dried till the kernel rattles within the shell. On an average, 1500-2000 fruits per tree will be obtained which comes to 8-12 kg nuts and 1.5-2.0 kg mace.

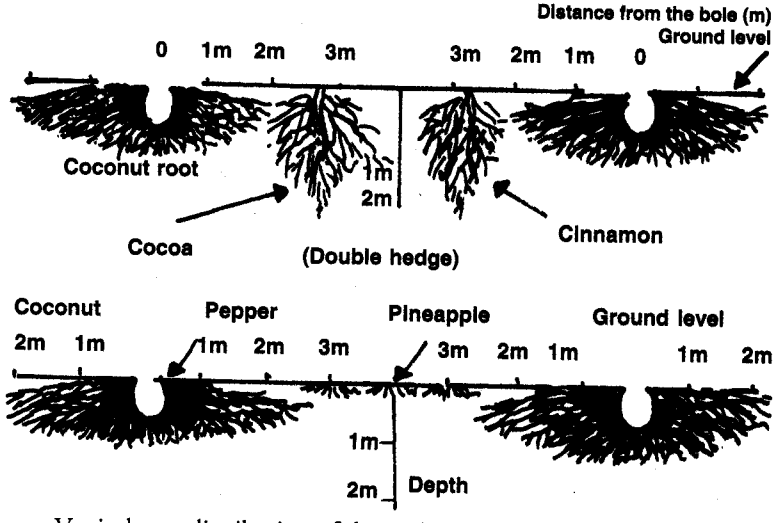
Cinnamon

Cinnamon is another tree spice which comes up well as a mixed crop. It can be planted in the double hedge system at a spacing of 3 m between plants. Harvesting can be started from the fourth year and continued in alternate years. Shoots of finger thickness and uniform brown colour are cut and the bark is extracted by peeling. Harvesting is a labour intensive operation and hence mixed cropping with cinnamon will be profitable only when family labour is used or labour is cheaply available.



Horizontal root distribution of the multi-storeyed crop combination

Multi-storeyed cropping is the cultivation of three or more crops having different morphological characteristics in the interspaces of coconut so as to intercept sunlight at different levels and feed at different soil depths. This system consists of an intensive four crop combination which includes coconut, black pepper (trained on coconut trunk), cocoa and pineapple.



Vertical root distribution of the multi-storeyed crop combination

Coconut palms above 20 years old are suitable for multistoried cropping. The pepper vine having its canopy at 2-8 m height on the coconut trunk, forms the second floor crop. The spread of the above ground parts of cocoa, which are pruned periodically are confined to a height of less than 3.5m from ground level. This constitutes the first floor. Pineapple forms the ground floor.

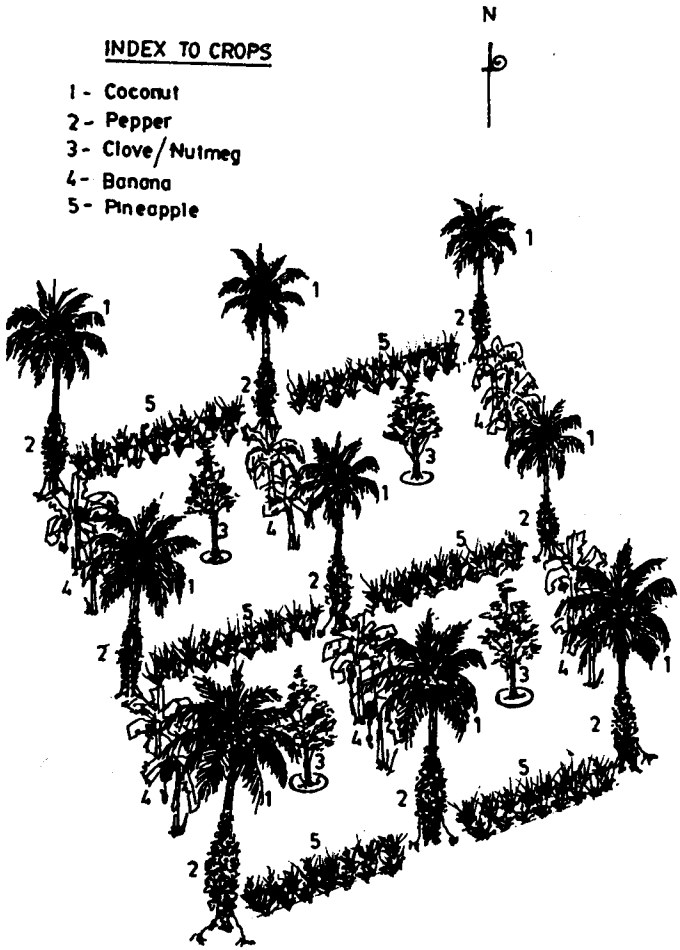
The distribution of roots of these crops showed that they did not overlap. Cocoa has tap root system. Most of its roots lay within a radius of 80-100 cm laterally. The fibrous roots of pineapple rarely extend beyond 50 cm laterally or vertically. This system requires irrigation during summer months. Recommended dose of fertilizers are to be given to each of the component crops.

High Density Multispecies Cropping System

Coconut based 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 holdings and aims at maximum production per unit area of land and time simultaneously ensuring sustainability.

This system includes annuals, biennials and perennials. The crops selected include cash



Coconut based HDMSCS

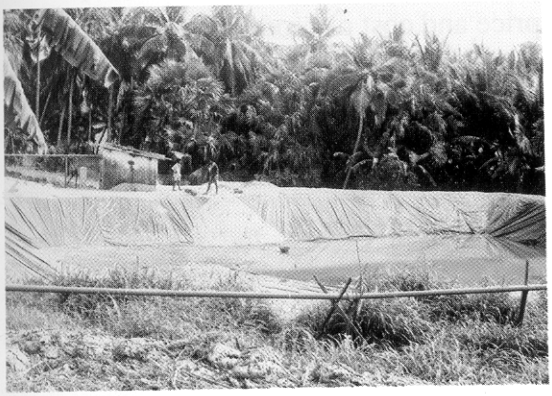
crops, food crops and fodder crops. The biomass other than the economic part is recycled within the system. The annual crops are removed as the canopy size of perennial crops increases.

A HDMSCS model was established at CPCRI, Kasaragod in 1.2 ha of 18 year old coconut plantation during 1983 by interplanting 17 additional crops. The crops selected were mango, breadfruit, jack, nutmeg, clove, sapota, acid lime, guava, pepper, subabul, banana, pineapple, papaya, coffee, elephant foot yam, colocasia and cassava. The annual crops (except banana) were withdrawn from the system in stages as the perennials grew. Some of the perennials like acid lime, sapota, mango, guava, pepper, subabul, papaya and coffee were also removed from the system as their performance was not satisfactory. Studies show that there is scope for reducing the fertilizer input for the crops in the HDMSCS.

Coconut based mixed farming system

Coconut based mixed farming system

Mixed farming in coconut garden involves cultivation of shade tolerant fodder crops in the interspaces of coconut and integrating animal enterprises like dairy, poultry, fisheries etc. and recycling the byproducts obtained. Fodder grasses like hybrid napier, guinea grass and Guatemala grass yield about 50 to 60 tonnes of green fodder per ha per year under coconut shade which is sufficient to maintain five crossbred milch cows. Leguminous crops like Brazilian Lucerne, cowpea and Pueraria also perform well. Summer irrigation is to be given using sprinklers to ensure a steady growth of fodder throughout the year. Grasses are to be replanted every four years after giving a thorough digging to prevent root matting.

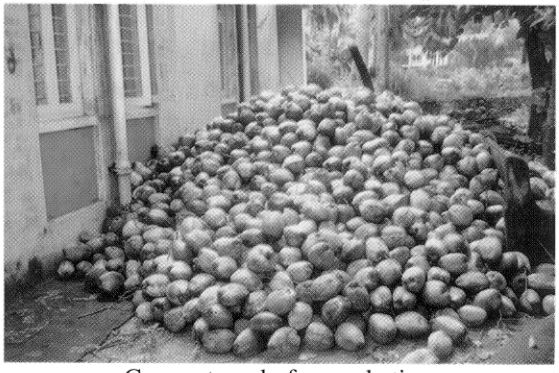


Fish farming in a coconut garden

Mulberry as a mixed crop

Coconut based sericulture system

In maidan areas of Karnataka state where coconut palms are planted at a wider spacing of 8 x 8 m or more, growing of mulberry as a mixed crop and silk worm rearing is popular. Through integrating sericulture with coconut cultivation, substantial increase in the net income and employment potential is achieved.



Coconut ready for marketing

Transporting of coconuts

Economic aspects of coconut cultivation

In view of economic liberalization and being a member of the World Trade Organization (WTO), certain macro and micro level changes are expected to take place in Indian agriculture. Since World Trade Agreement aims to boost agricultural trade through substantial reduction in protectionism, prices of agricultural commodities in member countries are expected to move closer to international prices. Hence to compete in international markets, product price and cost of production of agricultural commodities produced in the country should not be higher than those in other competing countries.

In the case of coconut and its products, India is in a disadvantageous position since the cost of production of coconut varies from Rs. 3.00 to Rs. 4.50 per nut (under different agro-climatic conditions and varied management practices), which is higher as compared to other coconut producing countries. Consequently based on the current market prices, the domestic prices of coconut oil in India is US $ 777 per tonne as compared to the international prices of US $ 543. Under this situation, the terms of trade for coconut products is not advantageous to India. Moreover in a free trade regime after 2005, Indian entrepreneurs related to coconut industry may import coconut products from other competing countries which would

drastically alter the domestic prices of coconut and its products. This in turn would reduce the profitability of coconut cultivation in the country.

Copra for market

Fresh kernel pieces for sales (at New Delhi)

In order to overcome these challenges, the policies regarding coconut should focus more on "competitiveness through higher productivity". One way to achieve this goal is to enhance the adoption of recommended cultivation practices at farmer's level so that the net return could increase from Rs. 16,700 per ha to Rs. 39,000 per ha, by just doubling the productivity from the present average yield of 40 nuts per palm to 80 nuts per palm under rainfed conditions. Research efforts have proved that there are possibilities for increasing the productivity and net return from coconut gardens through adoption of coconut based farming systems and the additional net returns realized ranges from Rs. 0.5 to 1.0 lakh per ha. Adoption of coconut based farming systems helps to reduce the variation in gross farm income, especially when the market prices for coconut and its products are low.

6. INTEGRATED PEST MANAGEMENT

Among the pest problems in coconut, the insects of concern mainly belong to the orders Coleoptera, Lepidoptera and Hemiptera. Apart from this, the eriophyid mite belonging to the Acarinae has recently emerged as a serious threat to coconut cultivation in India. Rodents also causes losses in certain areas.

Symptom of rhinoceros beetle attack

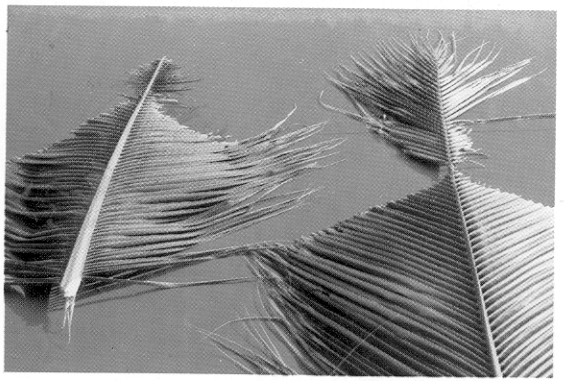
Rhinoceros beetle (*Oryctes rhinoceros*)

The adult beetle bores into the unopened fronds and spathes. The attacked frond when fully opened shows characteristic triangular cuts. Infestation on spathe often destroys the inflorescence and thus prevents production of nuts. The beetle breeds on decaying organic debris, farm yard manure, dead coconut stumps, logs and compost.

Control: An integrated approach having the following practices can effectively control rhinoceros beetle.

- Hook out the beetles from attacked palms by using beetle hook.
- Fill up innermost 2-3 leaf axils with sevidol 8 G, 25g + 200 g fine sand per palm. Filling leaf axils with 12 g naphthalene balls (approximately three balls) covered with fine sand at 45 days interval is also effective.
- Leaf axil filling is to be done thrice a year ie., during April, September and December.

- Maintenance of sanitation in coconut garden by prompt disposal of decaying organic debris.
- Manure pits and other possible breeding sites are to be treated with carbaryl 50 WP at 0.01 per cent concentration. Spraying is to be done thrice ie.,during April, September and December.
- Baculovirus of Oryctes and green muscardine fungus, *Metarhizium anisopliae* are the two promising pathogens of rhinoceros beetle which can be effectively used for the biological control of rhinoceros beetle.

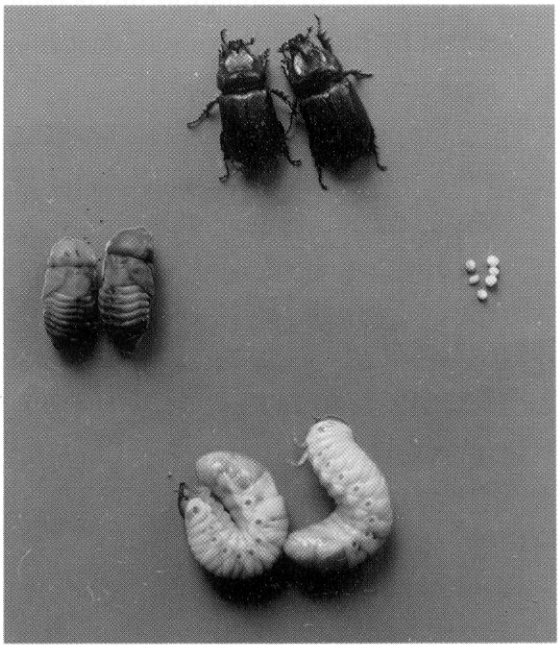


Characteristic triangular cut

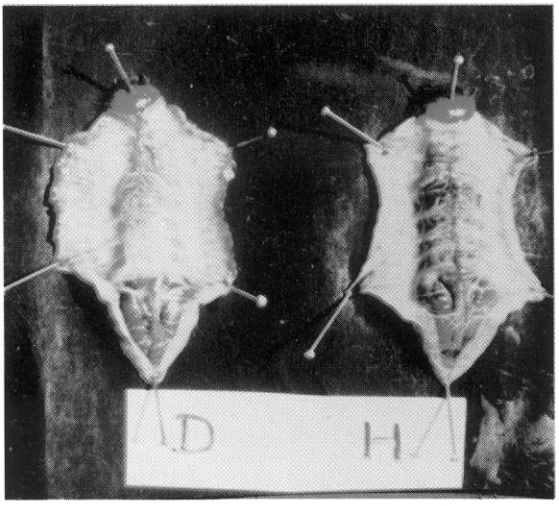
Mass culture and field release of Baculovirus

Virus(OBV) culture maintenance

1. Select OBV infested host, kill, dissect and cut the midgut and transfer it to a mortar.
2. Add 3-5 ml of sterile water and homogenize it using a mortar and pestle.
3. Draw the midgut suspension inside a syringe and carefully mouthfeed the healthy grubs with 1 ml of inoculum, (one midgut suspension can be used to inoculate 5-6 healthy grubs).
4. The inoculated grubs are then put in a plastic box (15 cm dia, 15 cm ht) containing 200 g of sterilized cowdung or coir dust moistened sufficiently with sterile water. Care should be taken to ventilate the box by making holes in the lid.



Life stages of *Oryctes rhinoceros*



Baculovirus infested grubs of rhinoceros beetle

5. Check regularly for the OBV infection and the procedure is repeated for maintenance of the viral culture.

Storage and inactivation

The cadavers or virus triturate could be stored at 4°C indefinitely. The infection half-life of the virus in cow dung is about five days and total inactivation on the eighth day. It could also be stored using skimmed milk (0.25 g/ml) kept at 0 to 7°C. Formaldehyde or dettol 1 per cent solution inactivates the virus and 54°C is the thermal inactivation point.

Field release of OBV

1. Allow 10-15 healthy adult rhinoceros beetles to crawl in a baculovirus infected midgut suspension kept in a shallow glass trough (1 g midgut/100 ml 0.001 buffer at pH 8.5) for half an hour.
2. Transfer the beetle into plastic boxes and starve them for 12 to 24 hours.
3. Release the beetle in the field preferably at dusk and observe the field for rhinoceros beetle control once in six months.

Mass culture and field release of Metarhizium fungus

Inoculation of breeding ground with an entomopathogenic fungus *Metarhizium anisopliae* also gives effective control.

M. anisopliae var. *anisopliae* (spore size 5.8um) and *M. anisopliae* var. *major* (spore

Insecticide application

enemies three weeks after spraying chemicals.

Mass multiplication of parasitoids

Techniques standardized for the mass multiplication of larval parasitoids and pre-pupal parasitoids of leaf eating caterpillar are summarized as follows:

Mass multiplication of larval parasitoids *Apanteles taragamae* and *Goniozus nephantidis*

Particulars	Parasitoid	
	A. taragamae (Braconidae)	*G. nephantidis* (Bethylidae)
Rearing cages	Cylindrical specimen tube glass jar (10 x 5 cm) mouth covered with cloth.	7.5 x 2.5 cm with cotton plug
Host/stage	Opisina or Corcyra larva (second instar) 15-20 Nos. on leafbit with gallery *in situ*	Opisina or Corcyra larva (4^{th} to 7^{th} instar) 1-2 Nos.
Number of parasitoids to be used	Male and female one each (newly emerged)	One or two mated females (2-3 days old)
Days of adult emergence	10-25	10-14
Progeny	Female biased	Female biased
Remarks	Parasitised larvae to be removed after 12 hrs to fresh leaflet (for Opisina) and to 'semolina' (for Corcyra) for feeding and development	Parasitoid stings and paralyses third instar host larvae, but egg laying occurs from fourth to further instar.

Mass multiplication of pre-pupal parasitoids of *Opisina arenosella*

Particulars	Parasitoid		
	E. nephantidis (Elasmidae)	*B. nosatoi* (Chalicididae)	*X. punctata* *X. nana nana* (Ichneumonidae)
Rearing cages	Specimen tube (7.5 x 2.5 cm) with cotton plug	Cylindrical glass jar with mouth covered with muslin cloth	Glass chimney (22 x 4.5 cm) with muslin cloth covering of the openings
Host/stage	Opisina prepupae	Opisina pupae with cocoons and silken galleries – 20-30 Nos. placed on cardboard pieces.	Opisina/ Anadevidia pupae with cocoons by sandwich method -5 or 6 Nos.
Number of parasitoids	2 or 3 mated females (1-2 days old)	30 to 50 Nos. of both sexes	1 or 2 mated females (4-5 days old)
Days of adult emergence	11	12-20	10-12
Progeny	Female biased	Female biased	Female biased
Remarks	Highly host specific and stage specific	Host specific Exposure period 4-5 h	Exposure period 1-3 h

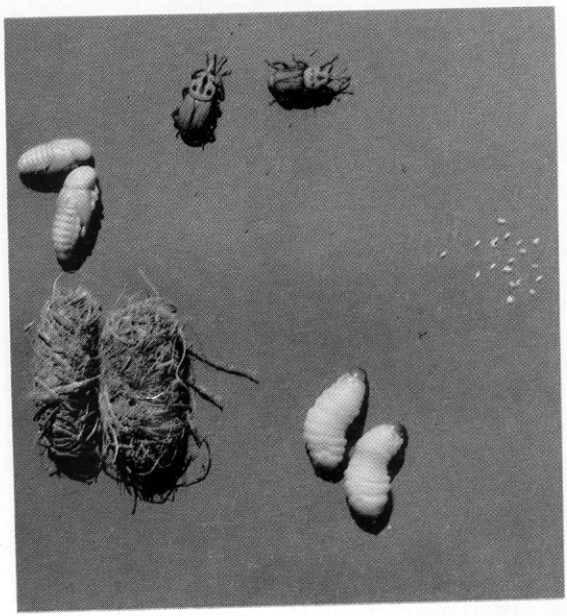
Release of parasitoids against leaf eating caterpillar

Red palm weevil (*Rhynchophorus ferrugineus*)

Red palm weevil is a dreaded pest of young coconut palms. It generally attacks palms of age group 5-20 years. Sometimes seedlings of below five years are also infested. The major symptoms of attack are presence of holes on the stem, oozing out of viscous brown fluid and extrusion of chewed up fibres through the holes, longitudinal splitting of leaf bases and wilting of inner leaves. Sometimes the gnawing sound produced by the feeding grubs inside will also be audible. Symptoms of pest

Severely damaged palm

Symptom of red palm weevil attack



Life stages of red palm weevil

infestation usually become clear at an advanced stage when the crown topples.

Control

- When green leaves are cut from the palms, petiole of not less than 120 cm may be left on the trees in order to prevent the entry of the pest through the cut end.
- Avoid making steps or any other injury on the tree trunk to avoid entry of the pest through the injured tissues.
- Cut and burn the dead coconut palms.
- Palms affected by bud rot disease are more prone to red palm weevil attack.

Stem injection against red palm weevil

Pheromone trap for red palm weevil

Hence they are to be treated with insecticides also, after the fungicidal treatment.

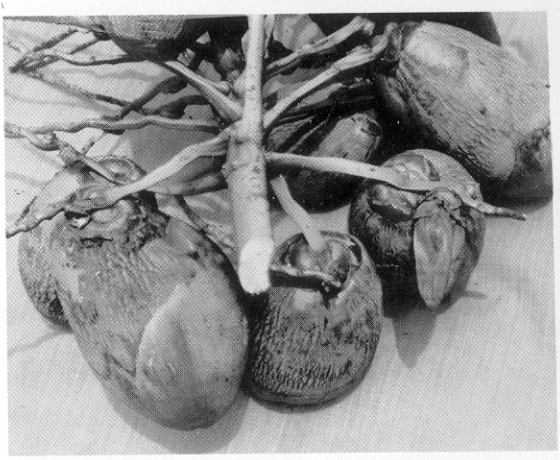
- Curative treatment of infested palm can be done by injection of carbaryl 1% or 0.1% endosulfan. All the holes on the affected stem should be plugged after injecting the insecticide suspension to the palm.
- Inject the insecticide solution into the trunk through a hole above the infested portion using an augor and funnel. If the pest infestation is through the crown, the insecticide suspension should be slowly poured after cleaning the crown of all affected materials.
- Coconut logs of 50 cm long, split longitudinally and cut surfaces smeared with fresh toddy fermented with yeast and acetic acid are effective traps. Weevils just trapped can be collected and destroyed.
- Peeled coconut petioles arranged in trays and treated with macerated sugarcane + yeast are suitable substitutes for coconut log traps.

Eriophyid mite (*Aceria guerreronis*)

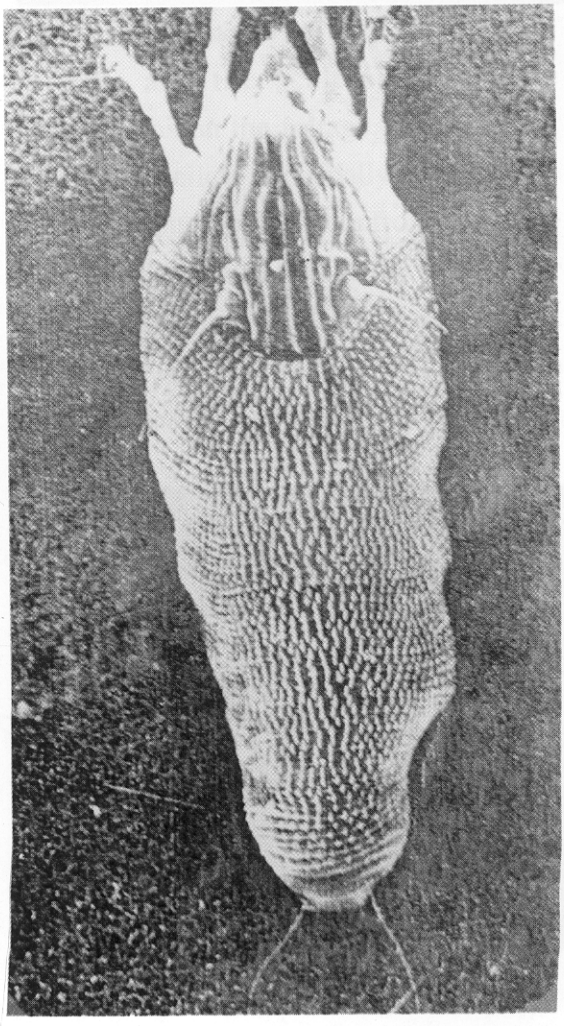
Recently coconut gardens in some parts of Kerala, Tamil Nadu and Karnataka are seriously affected by a non insect pest called eriophyid mite. These mites infest coconut

Initial symptom of eriophyid mite attack on the button

by sucking sap from the soft tissues of buttons. In the initial stages, symptoms are seen as triangular patches close to perianth. Later because of the continuous desapping by 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

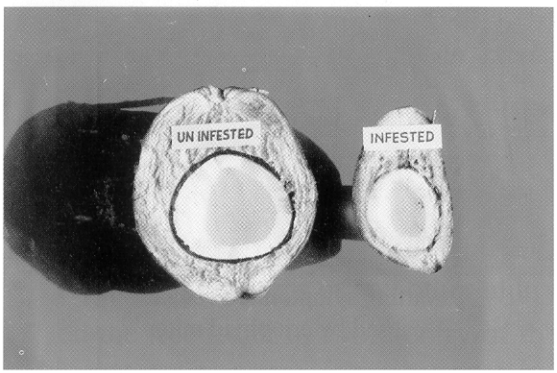


Warting symptom on coconut caused by eriophyid mite



Adult of eriophyid mite (microscopic view)

surface of nuts. The liquid oozing from these patches dries and as a result dried decayed matter is noticed. The damage thus caused affects the quality of husk and dehusking becomes difficult.



Loss due to mite

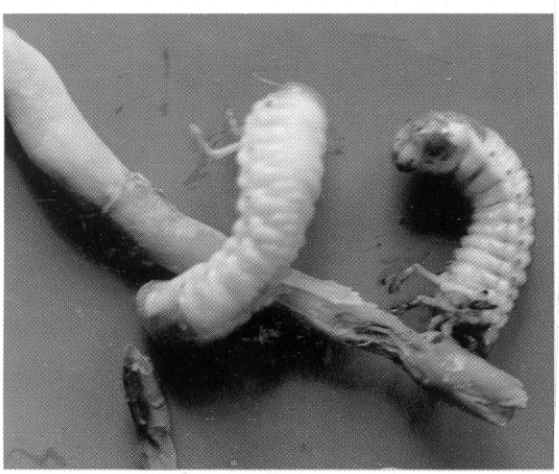
Control

The following pesticides are found to be effective against the eriophyid mite:

Pesticide	Concentration(%)	Quantity per litre of water
Micronised wettable sulphur	0.4	5g
Carbosulfan	0.05	2ml
Neem oil-garlic-soap mixture	2.0	20ml 20g 5g
Azadirachtin	0.004	4 ml

White grub (*Leucopholis coneophora*)

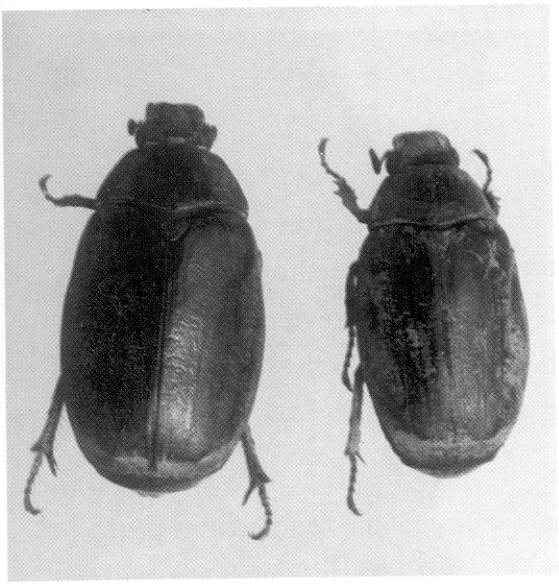
The soil inhabiting white grubs cause damage to the roots of coconut. Besides coconut, it infests tuber crops like tapioca, colocasia, sweet potato etc, grown as intercrops in coconut garden. The leaves of affected palms become sickly pale yellow. Severely infested palms exhibit button shedding and tapering of crown region.



White grub - feeding on coconut root

Control

- Regular ploughing or digging of infested soil at the onset of premonsoon showers.
- Apply 100 g of phorate 10 G per palm in May-June and September-October and incorporate with the top 15 cm soil.



White grub adults

Mealy bug colony on open leaf

The inscticide is to be applied in the active root zone of the palm evenly leaving a distance of 50 cm from the base of the trunk. The granule should be raked and mixed with the soil. Provide copious irrigation to the garden after the insecticide application.

Other pests

Mealy bugs and scale insects

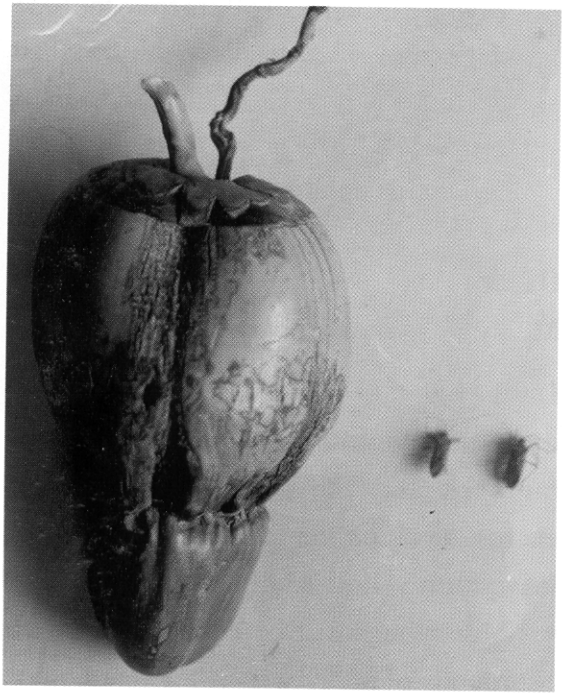
During summer months, mealy bugs cause damage to spindle leaves, spathes and bunches and the scale insects make encrustations on the foliage. The infested leaves turn yellow and finally dry up.

- Mealy bugs can be controlled by two rounds of spray with 0.1% fenthion or 0.05 % monocrotophos
- Spray 0.1% fenthion or malathion against scale insects.

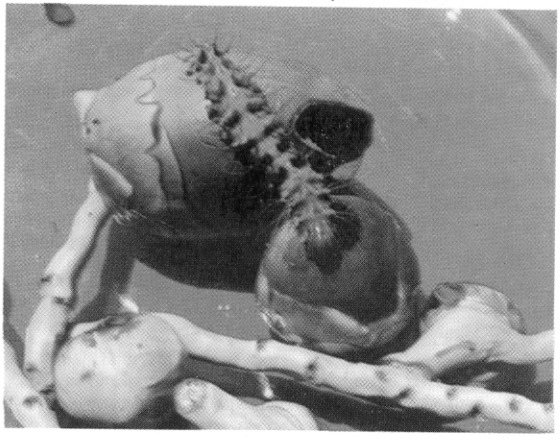
Termites

In coconut nurseries, termites, *Odontotermes obesus* cause damage to seedlings.

- Field sanitation by promptly removing/ disposing organic matter and covering the germinating nuts with a layer of river sand reduce termite infestation.
- Drench the nursery with 0.05% chlorpyriphos twice at 20-25 days interval.
- If adult trees are infested, swab the tree trunk with chlorpyriphos 0.05%.



Coconut damaged by coreid bug

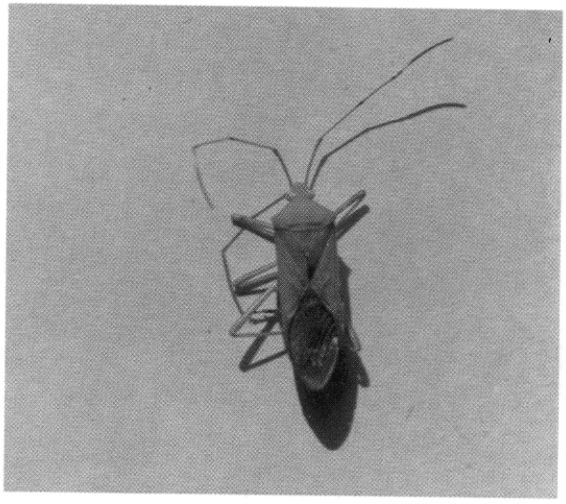


Coconut buttons infested by nut borer caterpillar

Coreid bug (*Paradasynus rostratus*)

This pest has become a serious problem in the recent years. The attacked buttons do not develop and the tender nuts become barren. Even the nuts which are retained in the bunches become deformed with the characteristic crevices on the husk just below the perianth. There will also be gummy exudation from such crevices.

Spraying carbaryl or endosulfan 0.1% on the unopened spathes and bunches (except on the newly opened inflorescence) will control the pest.

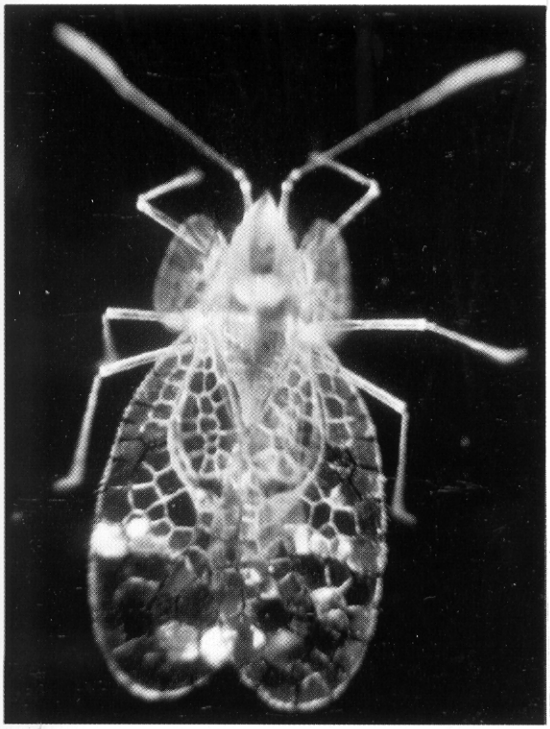


Coreid bug – adult

Slug caterpillar (*Contheyla rotunda, Latoia lepida*) and Nut borer (*Cyclodes omma*)

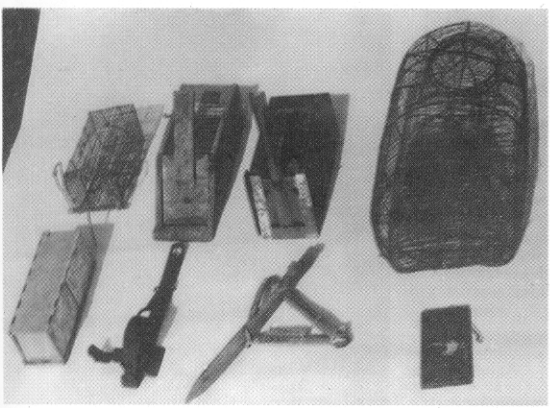
At times, the slug caterpillars as well as nut borers assume serious status by sporadically appearing in coconut garden.

- Spray coconut palm with carbaryl (0.1 per cent) to control these pests.



Lace bug *Stephanitis typicus*

Rodent damage



Different types of traps used for trapping rodents

Lace bug (*Stephanitis typicus)*

Lace bug sucks sap from coconut leaves and also acts as a vector in the transmission of phytoplasma which is the causal organism of coconut root (wilt) disease.

- Spray 0.1 % endosulfan to control the lace bug.

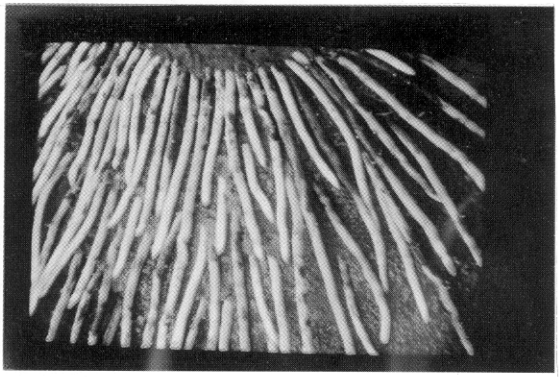
Mammalian pests

Rodents damage tender nuts and cause severe crop loss. Shed tender nuts with characteristic holes can be seen at the base of the infested palms.

- Provide mechanical barriers by fixing GI sheet bands, 40 cm wide around the trunk of palms at the height of 2m from the ground
- Placement of 10 g bromodiolone wax block two times at an interval of 10-12 days on the crown of one tree out of every five trees.
- Rat burrows in the field(in rice ecosystem etc.) can be fumigated with aluminium phosphide tablets.

Nematode management in coconut garden

Plant parasitic nematodes like the burrowing nematode (*Radopholus similis*) also infest the coconut palm. The nematode infested coconut palms exhibit general decline, yellowing, button shedding and reduction in leaf size. The symptoms on roots are more specific. Elongated orange coloured lesions



Root lesions due to nematode attack

are seen on tender and semi hard roots. Tender roots on heavy infestation become spongy in texture. The integrated management of nematodes in coconut includes the following:

- Use of nematode free coconut seedlings and planting materials of other intercrops.
- Application of phorate 10G @ 100 g per palm twice a year ie, during May-June and September-October.
- Use of less susceptible/tolerant cultivars or hybrids of coconut and intercrops in infested areas.
- Avoid use of banana as a shade crop in coconut nurseries.
- Incorporate leaves and tender stem of *Crotalaria juncea, Pueraria javanica* and/*or Gliricidia maculata* into the soil in September-October.

CPCRI Regional Station, Kayangulam - an advanced centre for plant protection studies

7. INTEGRATED DISEASE MANAGEMENT

Bud rot disease affected palm

Diseases that occur on coconut palms account for substantial loss in their productivity. Among the maladies, bud rot, root (wilt), leaf rot, Thanjavur wilt, stem bleeding and Tatipaka are important as they cause significant decline in yield and in certain cases the death of the palm.

Bud rot

Causal organism :

Phytophthora palmivora

Symptom

The earliest symptom is the yellowing of one or two younger leaves surrounding the spindle. The spindle withers and droops down. The tender leaf base and soft tissues of the crown rot into a slimy mass of decayed material emitting a foul smell. The disease kills the palm if not controlled at the early stages. Palms of all age are liable to be affected but normally young palms are more susceptible. The disease is more prevalent during the monsoon months when the temperature is low and humidity is high.

Control

- In early stages of the disease, when the spindle leaf starts withering, cut and remove all affected tissues of the crown and apply Bordeaux paste and protect it from rain by providing a polythene covering till normal shoot emerges.
- Burn all disease affected tissues

removed from the palm.

- As a prophylactic measure, spray 1% Bordeaux mixture on spindle leaves and crown of affected palms as well as neighbouring palms before the onset of monsoon.
- Leaf axil filling with sevidol 8G, 25g mixed with 200g sand is recommended to prevent red palm weevil infestation of affected palms.

Dwarf varieties of coconut are sensitive to copper injury. Hence Bordeaux mixture spraying should not be done; instead, place small perforated sachets containing 2-3 g of Indofil M-45 in the top two or three leaf axils to control bud rot disease.

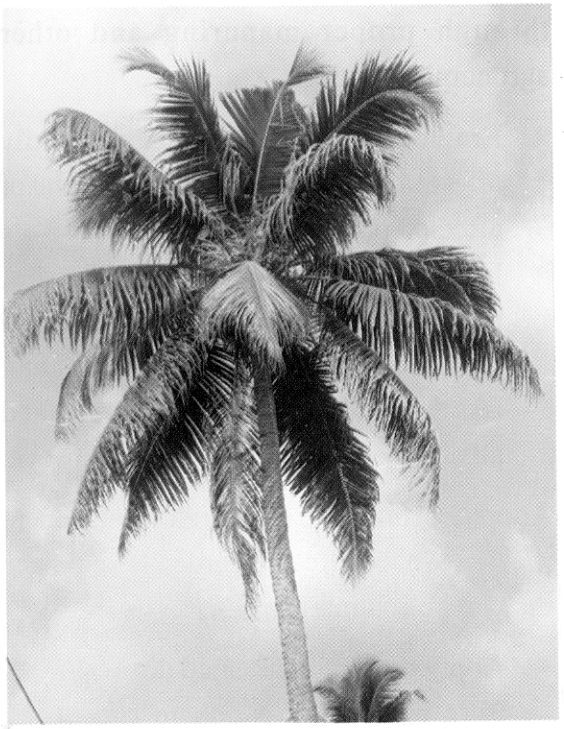
Removal of the affected tissues in the crown

Preparation of 1% Bordeaux mixture

Dissolve 1 kg of powdered copper sulphate crystals in 50 litres of water. In another 50 litres of water, prepare milk of lime with 1 kg of quick lime. Pour the copper sulphate solution into the milk of lime slowly, stirring the mixture all the while. Test the mixture before use for the presence of free copper, which is harmful to the palms, by dipping a polished knife in it. If the blade shows a reddish colour, add more lime till the blade is not stained on dipping. Always use plastic, cement, earthen or copper vessels for the preparation of Bordeaux mixture.

Bordeaux paste

Dissolve 100 g of copper sulphate and 100 g of quick lime each in 500 ml water



Palm showing root(wilt) advanced stage symptoms

separately. Mix together to make one litre of Bordeaux paste 10%.

Root (wilt) disease

The root (wilt) disease of coconut made its first appearance in Kerala after the great floods in 1882. Since then the disease has spread to many places. Presently the disease occurs in a continuous manner in eight southern districts of Kerala. Root (wilt) disease is also observed in a sparse manner in isolated pockets in the remaining six northern districts of Kerala and also in a few locations in the neighbouring state of Tamil Nadu.

Causal organism: Phytoplasma. The disease is transmitted by lace bug *Stephanitis typicus* and plant hopper *Proutista moesta.*

Symptoms

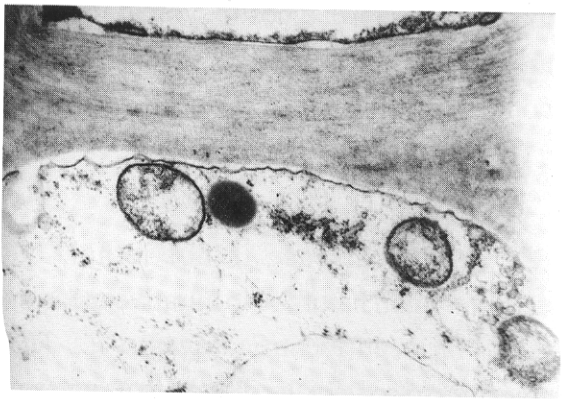
Flaccidity, the characteristic bending or ribbing of the leaves, general yellowing and marginal necrosis of the leaflets are the important visual diagnostic symptoms. Nuts are smaller and kernel becomes thin. Oil content of copra is also reduced.

Plant hopper *Proutista moesta*

Management

Root (wilt) disease is not lethal, but debilitating in nature. No curative measure has so far been identified against it. The strategy is to contain the disease to its present geographical limits and managing the disease by improving the condition of affected palms and increasing the yield

Root(wilt) disease superimposed by leaf rot



Phytoplasma in sieve tube of root (wilt) diseased palm

through proper manuring and other agronomic practices.

- Eradication of the disease in mildly affected areas by cutting and removal of affected palms.
- In the heavily disease affected tracts, remove all the severely affected uneconomic adult palms (those yielding less than 10 nuts per palm per year) and all diseased palms in the prebearing age.

Adopt the following improved management practices in the affected gardens to enhance the yield of palms.

- Apply the recommended dose of NPK, 3 kg magnesium sulphate and 50 kg organic manure per palm per year.
- Organic recycling by following mixed farming system -Raising fodder crops in the interspace and maintaining milch cows and application of farm yard manure to palms.
- Growing suitable inter and mixed crops
- Basin management with green manure crops
- Irrigation during summer months
- Control of leaf rot disease which is usually noticed in root (wilt) affected palms.
- Replanting with progenies of disease free palms located in hot spot areas.

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.

Leaf rot affected coconut palm

Causal organisms

Colletotrichum gloeosporioides, Exserohilum rostratum and *Fusarium solani* are the fungal organisms causing leaf rot.

Symptom

The first visible symptom of the disease is blackening and shrivelling up of the distal ends of the leaflets in the central spindle and in some of the younger leaves. Later the affected portion breaks off in bits giving the infected leaves a fan like appearance. If no protective measures are undertaken, 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.

Removal of rotten portion in the crown

Control

- Cut and remove the rotten portion of the spindle and two successive leaves.
- Pour 300 ml of fungicidal solution containing 2 ml of hexaconasol (Contaf 5EC) or 3g mancozeb (Indofil M-45) in the cavity around the base of the spindle.
- Apply 20 g phorate 10 G mixed with 200 g fine sand around the base of the spindle

to ward off insect pests.

- Treat the palms twice in a year ie., during April-May and October-November.

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 – symptom on trunk

Stem bleeding disease

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

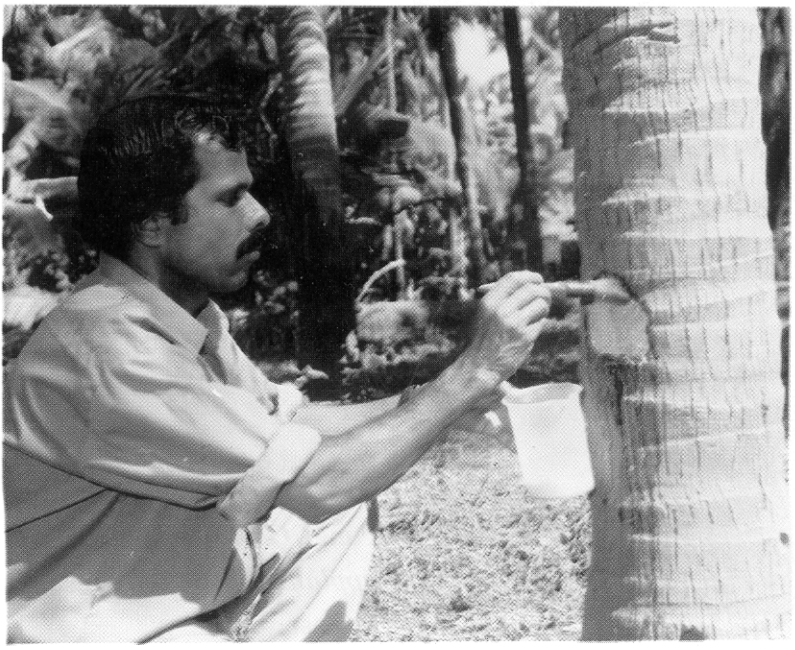
Causal organism

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.

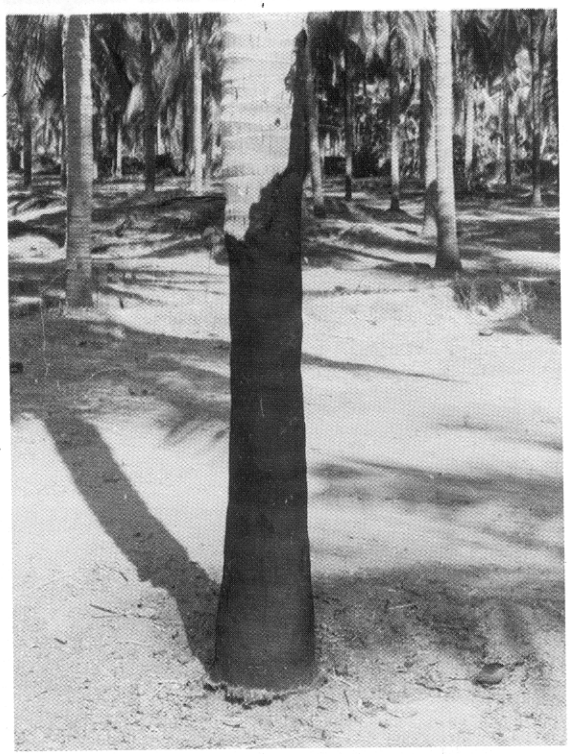
Symptom

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 bleeding patches spread throughout as the disease advances. The liquid oozing out dries up and turns black. The tissues below the lesions become rotten and turn yellow first and later black. Leaves in the outer whorl

Removal of stem bleeding disease affected tissues



Treatment with calixin in the chiselled area



Treated palm

turns 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.

Control

- Remove completely the affected tissues using a chisel and dress the wound with calixin 5% and apply coal tar after 1-2 days.
- Root feeding of 100 ml calixin 5% thrice a year during June, October and January prevents further spread of lesions.
- Apply recommended dose of fertilizers and provide irrigation during summer.
- Apply 5 kg neem cake per palm during September-October.

Thanjavur wilt

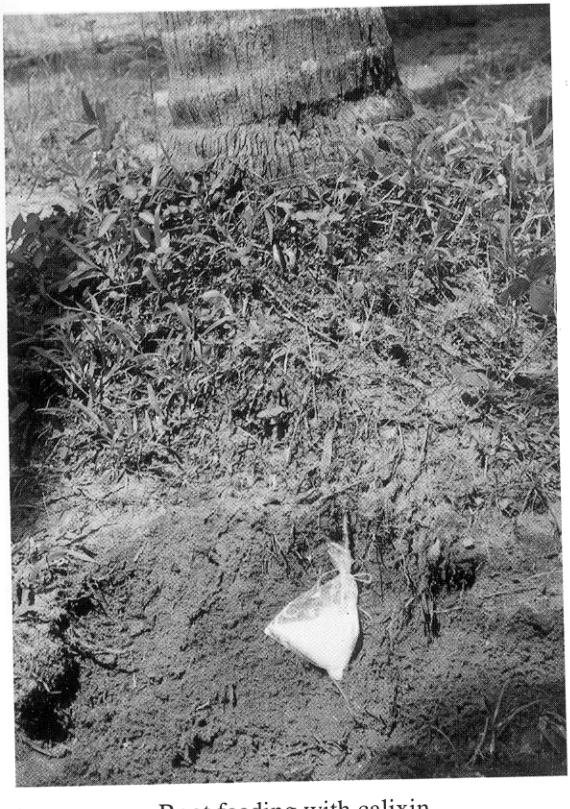
Thanjavur wilt/Ganoderma disease

Thanjavur wilt first appeared in the coastal areas of Thanjavur district of Tamil Nadu after cyclones of 1952 and 1955 and hence the name Thanjavur wilt. Now it is present in all the coconut growing areas in Tamil Nadu and in some parts of Kerala.

Causal organism

Fungi, *Ganoderma lucidum* and *Ganoderma applanatum* are the causative agents of the disease.

Fruiting bodies in the trunk



Root feeding with calixin

Symptom

Decay of root system, flaccidity of spindle leaves, browning of outer leaves, arrested fruit set and appearance of bleeding patches on the basal region on the stem are the symptoms observed. Ultimately the palm dies off. In advanced stages, the bracket of fungus causing the disease is seen on the stump.

Management

- Apply organic manures (50 kg) and 5 kg neem cake per palm and provide irrigation.
- Provide drainage channels between rows of palms.
- Isolate the affected palm from the healthy ones by digging a trench around the affected palm.
- Adopt phytosanitary measures – removal of dead palms, burial of the affected roots and bole in a pit.
- Apply 100ml calixin 5% through root feeding at quarterly intervals for one year.
- Drench soil with 0.1 per cent calixin @ 25 litres per palm.

Mahali (Fruit rot and nut fall)

Causal organism

The fungus, *Phytophthora palmivora* causes the disease.

Symptom

Shedding of female flowers and immature nuts are the symptoms of the disease. Lesions appear on the young fruits or buttons near the stalk which later develop into decay of the underlying tissues.

Control

- Spray 1% Bordeaux mixture or 0.5% copper oxychloride preparations on the crown of palms once before the monsoon and once or twice after the monsoon at 40 days interval.
- Collect and burn the fallen (disease affected) nuts.

Leaf blight

Leaf blight or Grey Leaf spot

Causal organism: Fungus, *Pestalotia palmarum.*

Symptom

In the mature leaves of the outer whorl, yellow specks encircled by a greying band appear which later turn to greyish white. The spots coalesce into irregular necrotic patches causing extensive leaf blight. When the infection is severe, the leaf blade completely dries and shrivels off.

Control

Cut and remove older affected leaves and spray the foliage with 1% Bordeaux mixture.

Tatipaka disease

This is named after its place of occurrence ie., the Tatipaka village of East Godavari district in Andhra Pradesh. It is a slow spreading disease and affects mostly heavy bearing palms of middle age group. At present, the incidence level of this disease is reported to be negligible.

Causal organism: Electron microscopic evidence supports a phytoplasmal etiology.

Symptom

Development of an abnormally large crown with dark green inner leaves and higher yield is the precursor of disease incidence. Subsequently, the crown becomes smaller in size producing progressively shorter leaves. The stem begins to taper. The leaves give a fasciated appearance due to improper unfolding of leaflets. The affected tree produces smaller bunches with atrophied barren nuts.

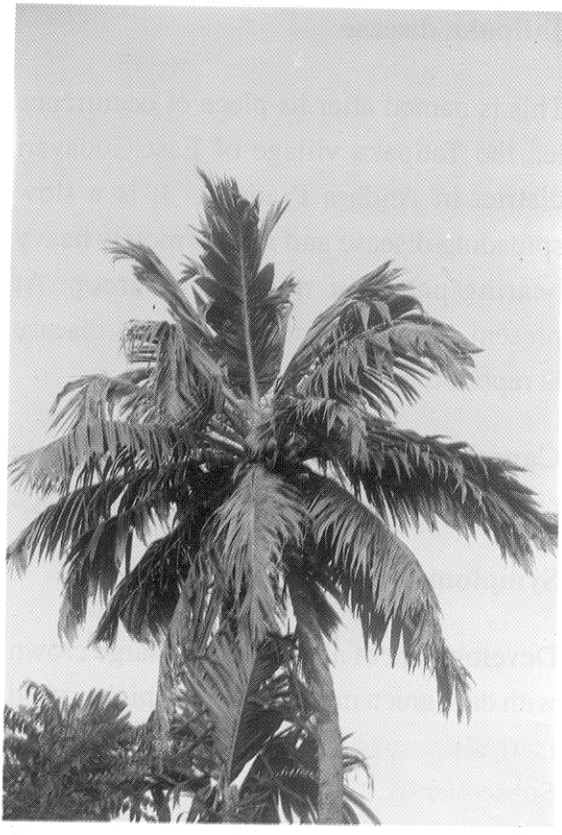
Crown choke disease – boron deficiency symptom

Management

Infected trees cannot be cured. Spread of the disease can be prevented by strictly prohibiting the use of planting materials from the affected areas.

Crown choke disease

Crown choke symptom is caused by acute shortage of boron. The disease is commonly observed in Assam and West Bengal.



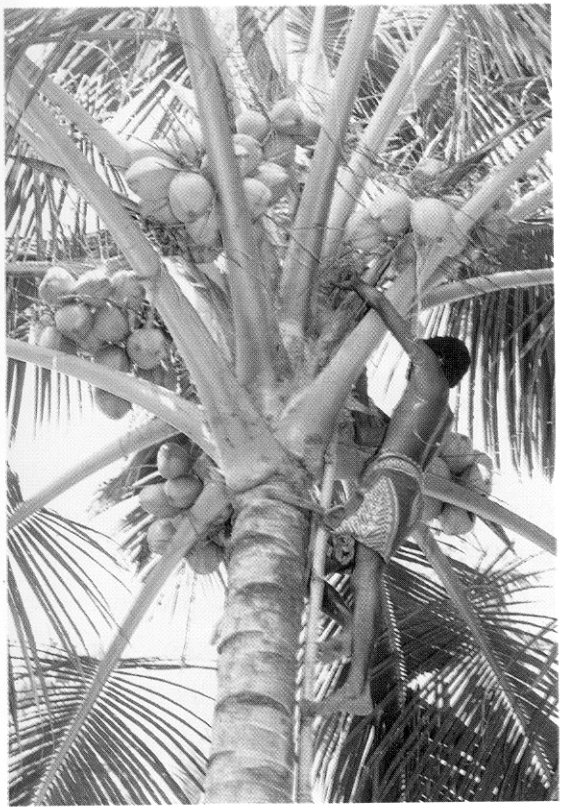
Palm showing fasciation due to boron deficiency

Symptom

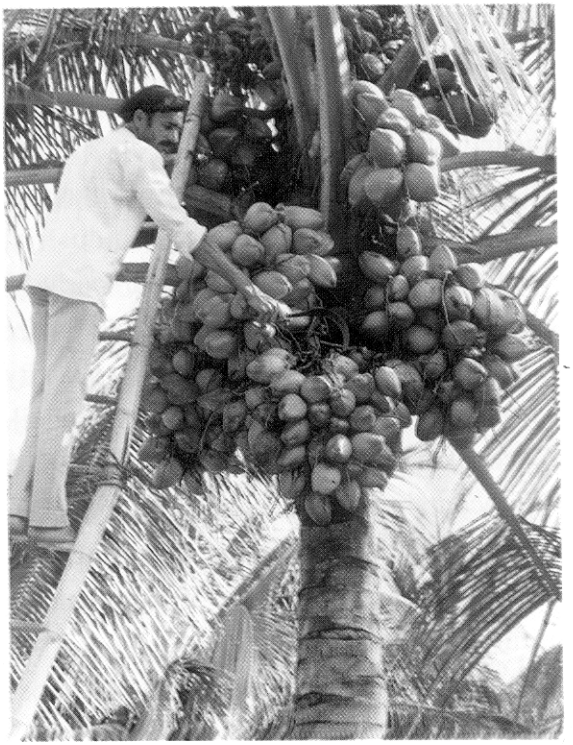
Emergence of shorter leaves with deformed and crinkled leaflets is the first symptom. Often the leaflets show severe tip necrosis and fail to unfurl. In many cases, it shows a choked appearance to the frond. As the disease progresses, stick like leaf stalks emerge.

Control

- Soil application of borax @ 50 g per palm at half yearly interval ie.,during February-March and August-September improves the condition of the palm.
- Making slits in the tight extension of the petiole and opening out the crown would help in the normal emergence of fronds.



Traditional method of harvesting



8. HARVEST AND POST HARVEST TECHNOLOGY

Harvesting

Usually 11-12 months 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. Ladders are also used for climbing coconut palms in certain areas. Now a days, 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. Unskilled persons with a few hours of training can climb palms using this climbing device. CDB is organizing training programmes for unemployed youth on coconut climbing with the climbing device.

Storage and seasoning

Harvested nuts are stored or seasoned before further processing. This practice has the following advantages:

Traditional method of climbing coconut palm

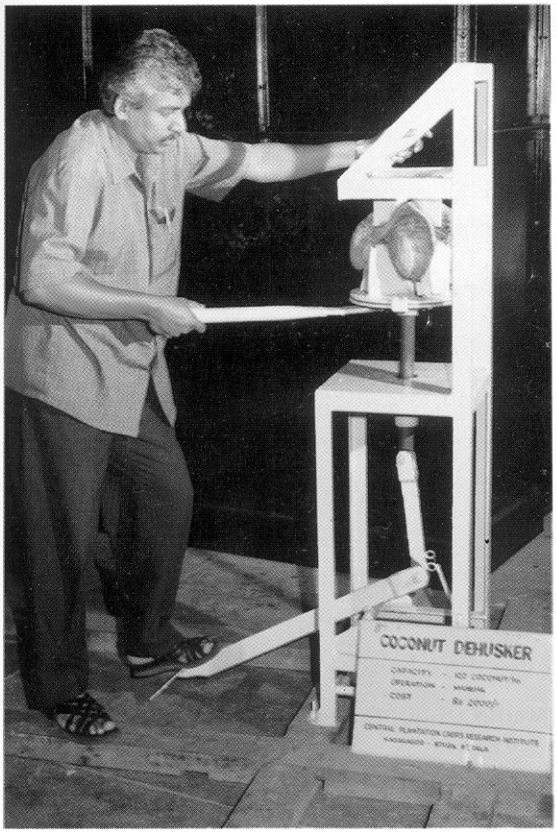
Coconut palm climbing device

- Decrease in moisture content
- Increase in thickness of copra
- Increase in oil content
- Greater meat resistance to bacterial sliming while sun drying
- Easier husking
- Cleaner and easier shelling
- Uniform quality of copra

Post harvest processing

In the traditional coconut producing States of India, the post harvest processing is presently confined to the production of edible and milling quality copra, coconut oil and coir and coir based products. Technological research in the country has been successful in evolving appropriate processing technologies for the profitable utilization of some of the products and by-products of the coconut palm. As a result, it has become possible to encourage product diversification and by-product utilization in the industry.

Coconut is an important source of vegetable oil used for both edible and industrial applications. It is estimated that nearly 50 per cent of coconut produced in India are consumed raw; while the remaining quantity is converted to copra to obtain coconut oil. Coconut meat (kernel), the endosperm of the fruit, contains 20 per cent carbohydrate, 36 per cent fat and 4 per cent protein at a moisture content of about 50 per cent. A number of products are derived from coconut of which copra is the most



Coconut dehusker

Keramithra

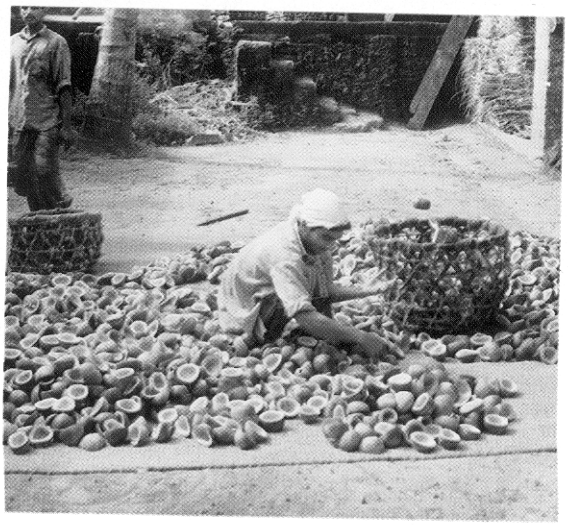
important one. Coconut oil can be extracted either from fresh kernel or from copra. Milled copra yields the coconut oil that is extensively used for edible and cosmetic purposes and copra cake is a valuable animal feed. Other products from coconut are the desiccated coconut, coconut cream, coconut milk powder, shell powder, activated carbon etc. Copra production, oil extraction, coir manufacture, desiccated coconut manufacture and toddy tapping are the major activities of coconut processing sector in India. To cope with the market fluctuations, there is a need for product diversification and byproduct utilization.

Husking

Manual dehusking of nuts with the aid of an iron rod driven to the ground which is traditionally done, requires skill and is strenuous. Presently mechanical devices are available for dehusking nuts. These devices are able to reduce the drudgery involved in dehusking. CPCRI has developed a manually operated coconut dehusker that can husk 110 nuts per hour. A power operated dehusker with a capacity of 600 nuts per hour also has been developed at CPCRI. The dehusker developed by the scientists of Kerala Agricultural University is a very handy tool and marketed under the name 'Keramithra'.

Copra processing

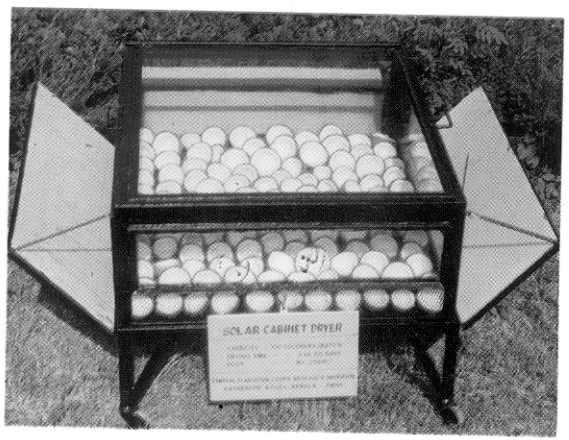
Optimum moisture content in copra is 5 to 6 per cent. Sun drying, smoke drying, kiln drying and indirect hot air drying are the commonly used methods for drying coconut.



Sun drying of copra

Sun drying

Traditional system of copra drying is by spreading the cups (split open coconut) on any open surface for sun drying. It takes about eight days for sun drying of copra. Deposition of dirt and dust on wet meat during sun drying results in deterioration of copra quality. Further, cloudy weather and low atmospheric temperature also reduce the quality of copra.



Solar dryer

Solar dryer

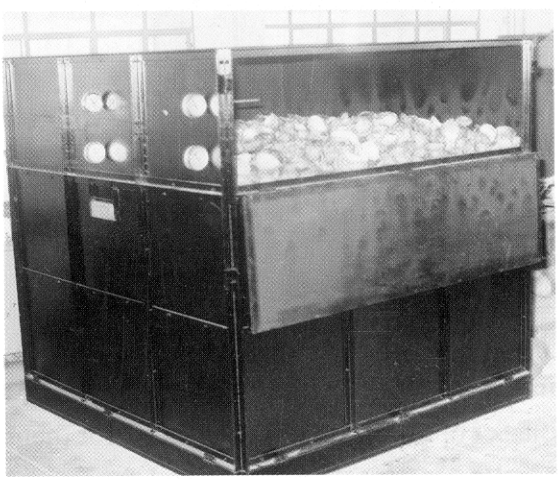
Use of a closed type solar dryer avoids the quality deterioration of copra due to deposition of dirt. Drying time also is reduced to 3-4 days. A batch type of solar cabinet dryer with a capacity of 100 nuts developed at CPCRI, takes only three days for drying.

Small holder's copra dryer

Indirect drying

Small holder's copra dryer

An indirect type copra dryer of 400 nuts per batch capacity (using agricultural waste as fuel), developed at CPCRI, is gaining popularity among coconut growers. The dryer requires only three sq. m. for housing and could be carried by 2-3 persons. The drying time required per batch is 36 hours spread over four days. Kerala Agro Industries Corporation is manufacturing this type of dryer in a large scale for sales to farmers.



Smoke free copra dryer

Smoke free copra dryer for medium holdings

CPCRI has also developed a smoke free copra dryer for medium holdings with a capacity of 1000 nuts per batch which can dry coconuts in 24 hrs. It has got a unique furnace where in the fuel used is only shell.

Large holder's copra dryer

Large size copra dryer with a capacity of 3500-4000 nuts was also developed at CPCRI. The unit is suitable for large holdings and copra processing societies.

Electrical copra dryer

Electrical copra dryer

CPCRI has developed an electrically operated dryer with forced hot air circulation. Its capacity is 1000 nuts per batch with a drying time of 28 hours.

Ball copra

Ball copra is of superfine quality and commands a premium price in the market. It is prepared by storing fully matured nuts for 10-12 months, when kernel will get detached from the shell. CPCRI has developed a process to prepare ball copra in shorter time by giving different heat treatments.

Ball copra

Better grade copra gives good quality oil

Copra grading

The copra is graded in the order of its market value. The grading is mainly based on moisture content, the foreign matter and black copra. The maximum limits for them are 10 per cent, 2 per cent and 5 per cent respectively. However, the good quality

Milling copra

Coconut oil ready for market

copra should have the following requirements:

Moisture	:	6 per cent
Oil content	:	71 per cent
Acid value	:	2.5 per cent
Foreign matter	:	0.5 per cent
Mouldy cups	:	5 per cent
Wrinkled cup	:	5 per cent (free)
Black copra	:	1 per cent (free)

The grade specifications and definitions of quality of milling copra and edible ball copra for procurement under price support scheme are as follows:

	Milling copra	
1.	Foreign matter (per cent by weight –maximum)	1.0
2.	Mouldy and black kernels (per cent by count -maximum)	10.0
3.	Wrinkled kernels (per cent by count - maximum)	10.0
4.	Chips (per cent by weight - maximum)	10.0
5.	Moisture content (per cent by weight - maximum)	6.0
	Edible ball copra	
1.	Size(diameter) minimum in mm	75
2.	Foreign matter (per cent by weight – maximum)	0.2
3.	Mouldy and black kernels((per cent by count - maximum)	2.0
4.	Wrinkled kernel (per cent by count -maximum)	10.0
5.	Chips (per cent by weight - maximum)	1.0
6.	Moisture content (per cent by weight -maximum)	1.0

Copra moisture meter

Copra moisture meter

The traditional method of estimating the moisture content of copra is quite subjective by feeling the texture of copra or its inflammability. The copra moisture meter, developed at CPCRI, is useful to estimate the moisture content of copra in a scientific and accurate way. It is a simple device working on the principle of electrical conductivity. It is calibrated to read the moisture content from 5 to 40 per cent so that the moisture content at different stages of drying can be found out.

Coconut Development Board implements programmes to assist entrepreneurs involved in copra processing for modernization by introduction of improved copra dryers/other processing machineries/ equipments in order to improve the production of quality copra.

Coconut products and byproducts

Desiccated coconut (DC)

Dehydrated coconut meat in the grated or shredded form is desiccated coconut. It is used in confectionery and other food industries. The process involves shelling, paring, disintegrating, drying, sieving and packing. Desiccated coconut powder is obtained by drying the ground or shredded coconut kernel after the removal of brown testa. It is used extensively in confectioneries, puddings etc as a substitute to raw grated coconut. The composition of desiccated coconut is

Moisture	:	2-3 per cent
Fat	:	65-68 per cent
Solids nonfat	:	30-32 per cent

Process demonstration and consultancy services for setting up of DC unit are provided by the CFTRI, Mysore.

Regional Research Laboratory(RRL), Thiruvananthapuram has perfected a method for the partial extraction of oil from desiccated coconut in order to produce a low cost desiccated coconut and superior quality coconut oil.

In India, desiccated coconut is manufactured by a number of small-scale units in Karnataka, Tamil Nadu, Kerala and Andhra Pradesh. To improve the quality of DC, the Coconut Development Board is providing financial assistance for the introduction of Agmark/ISO standards in coconut processing units.

Desiccated coconut

Tender coconut water – a refreshing drink

Tender coconut water

Tender coconuts are valued both for the refreshing drink and gelatinous kernel, which is a delicious food. The tender nut water is rich in potassium and minerals. Glucose content is maximum in seven months old nuts and hence the best stage for drinking. The dwarf coconut variety, Chowghat Orange Dwarf (COD) is an ideal tender nut variety. The composition of tender nut water from this variety is as follows:

Quantity of tender nut water : 350 ml/nut

Calorific value : 17.5/1000g of tender nut water

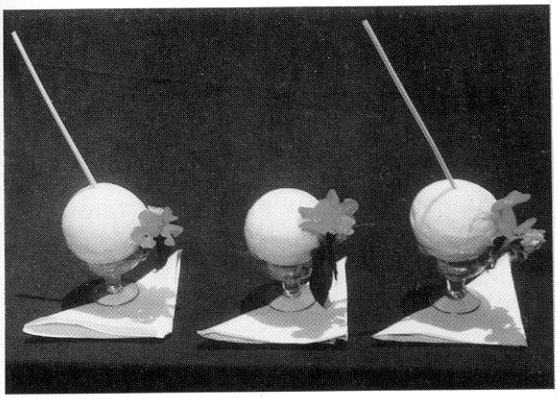
Sugar : 7.1 mg/100 ml of tender nut water

Potassium : 2000 ppm

Sodium : 20 ppm

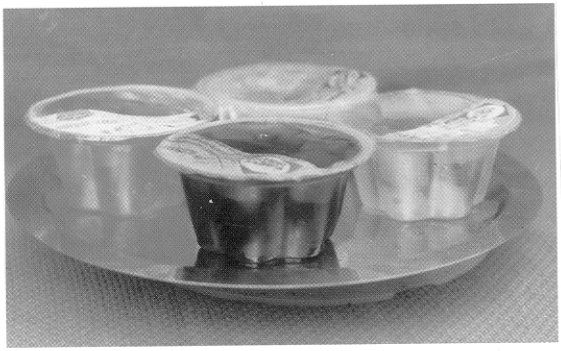
To encourage this highly nutritive and healthy soft drink, a new technology was developed for tender nut water packing by Defence Food Research Laboratory (DFRL), Mysore, through a sponsored project of CDB. The technology is made available to the entrepreneurs for large scale production of tender nut water packets.

Tender coconut water in packets for sale



Snow Ball Tender Nut

Vinegar



Nata-de-coco

Coconut jam

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 eight months age is more suitable for making SBTN in which there is no decrease in quantity of tender nut water and the kernel is sufficiently soft. The technology for preparing snow ball lender nut has been developed at CPCRI.

Matured coconut water

Technologies have been developed for upgrading and bottling of matured coconut water as a soft drink using certain preservatives. Matured coconut water is being successfully utilized for the production of vinegar using the technology developed at CFTRI, Mysore, under a CDB sponsored project.

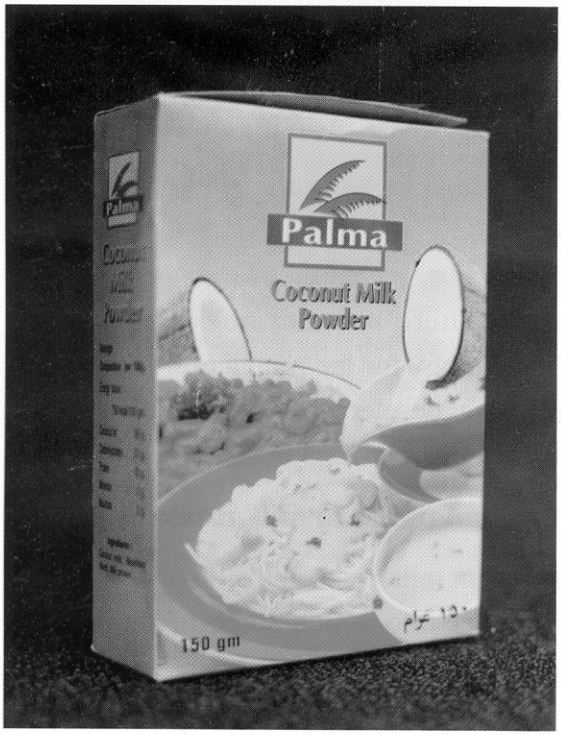
Nata-de-coco

Nata-de-coco is prepared from matured coconut water. It is a gelatinous delicacy formed by the action of a micro-organism in a culture medium of coconut water. Technology for the production of Nata-de-coco was developed by CDB and is available for commercial exploitation.

Coconut milk and milk products

Coconut milk is an emulsion of coconut oil in water into which some of the soluble components of the milk have already been passed. Apart from the household culinary

Coconut milk



Coconut milk powder

uses, coconut milk is also utilized as a substitute for dairy cream as evaporated and sweet condensed milk, in the preparation of white soft cheese and similar food recipes. As compared to cow's milk, coconut milk is richer in fat, but poorer in protein and sugars.

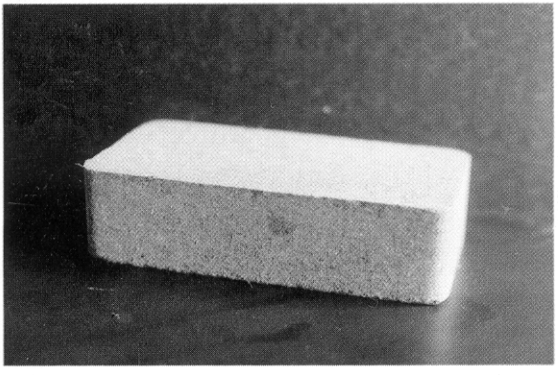
Coconut cream

Coconut cream is the concentrated form of milk extracted from fresh matured coconut. This is an instant product that can either be used directly or diluted with water to make various preparations such as curries, sweets, desserts, puddings etc. It can also be used in the manufacture of bakery products and for flavouring food stuffs. Technology for the production of coconut cream and milk was developed by RRL Trivandrum through a CDB sponsored project.

Coconut cream

Sweet coconut chips

Coconut biscuit



Coir pith briquette

Coconut spray dried milk powder

CFTRI, Mysore has developed a technology for the production of coconut spray dried milk powder under the CDB sponsored project.

Coconut syrup, coconut honey, coconut jaggery and **sweet coconut chips** are some of the other products.

Toddy

Coconut toddy is obtained from the inflorescence before the flowers fully develop. Sweet toddy is the unfermented fresh juice obtained by tapping. Toddy on fermentation becomes an alcoholic drink.

Coconut byproducts

The major coconut byproducts like husk and shell can be converted to various value added products.

Byproducts from husk

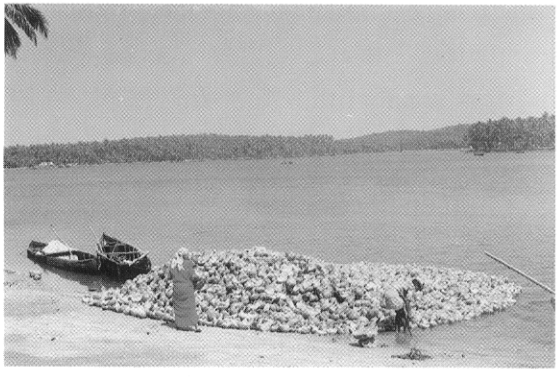
About 30 per cent of husk is fibre and 70 per cent is coir dust. Coir and coir products form the major output from coconut husk. Coir pith is useful as a manure (after composting), mulch material and for making briquettes. The coir pith briquettes can be used as a substitute fuel in the place of firewood for tile and brick industries.

Coconut shell charcoal

Shell charcoal is obtained by burning the shell of fully matured nuts with a limited supply of air so that they do not burn away

Shell charcoal

Shell products



Husk ready for retting

to ash but are only carbonized. It is used extensively for the manufacture of activated carbon. The charcoal has a high absorption capacity for gases and colouring matter and can be used as a refining agent, both as deodorizer and a decolouriser. It is also used in laundries and smitheries.

Activated carbon

Shell charcoal on activation is transformed into activated carbon which is having the ability to absorb effectively even trace quantities of either unwanted or valuable liquids and gases. Activated carbon is used in solvent recovery processes, water and effluent treatment and the treatment of flue gas before discharge into the atmosphere.

Shell flour

Shell flour is prepared by grinding clean coconut shells to a fine powder. It is used as a filler in the manufacture of phenolic moulding powders. It is also used as a filler in phenolic glues for plywood and laminated sheet manufacture, filler for mosquito incens coils and filler in specialized surface finishes, resin castings etc.

Coir and coir products

India is the leading coir producing country in the world. Annually, about 61031 tonnes of various coir products valued at 303 crores of rupees in the international market are produced in India. Mechanical defibring process producing the brown fibre and the microbiological retting process producing white fibre are the two major coir

manufacturing methods. White fibre production is concentrated in Kerala and it is entirely spun into coir yarn, which is then woven into mats, mattings and floor covering. It is also used for the manufacture of ropes and cordages. Bristle fibre is used for making brushes while mattress fibre is used primarily in the manufacture of mattress, upholstery and insulation materials. Bristle and mattress fibres combined together are used extensively for the production of rubberised coir for upholstery works, mattresses, filter, insulation materials etc. A small portion of the brown fibre is converted into coir yarn.

Coir products

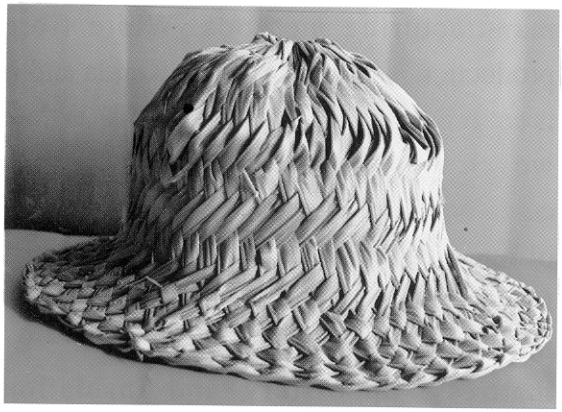
Handicrafts from coconut

A variety of handicraft items, from utility articles to show pieces are manufactured from coconut materials such as wood, shell, fibre and leaflet midrib.

Coconut shell is hard, takes a high polish, can be carved, coated with lacquer, inlaid with silver or other metals and generally used with ornamental effect. It is also used in the manufacture of hookah. Coconut shell cups are used for serving ice cream and salads.

Coconut wood is ideal for the manufacture of various products such as furniture, doors, windows, curios, handrails of staircases, wall panels etc. Coconut timber is suitable for making carved decorations.

Coconut fibre is used to manufacture a variety of coir products such as bags, table mats, wall hangings, chains, bangles etc.



Handicraft using coconut leaflets

Other coconut palm materials such as midribs of leaflets, spathes and stipules are used in the manufacture of a variety of products.

Financial assistance is given by the CDB to artisans engaged in the manufacture of handicraft items using coconut palm parts/ products.

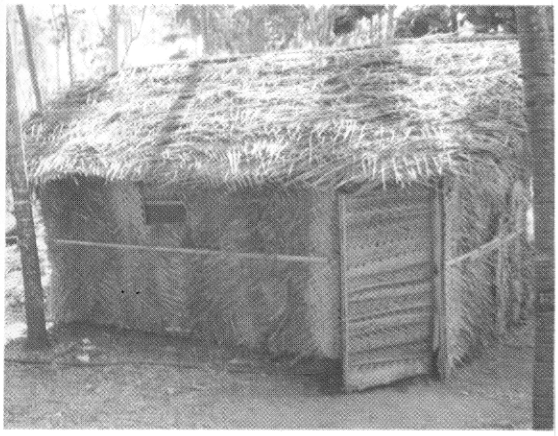
Coconut wood processing

Freshly cut coconut trunks from senile coconut trees can be used as timber after treatment with preservatives for increased shelf life. Treated coconut timber can be used as electric poles, telecom poles and for interior uses for making furniture, window and door frames.

Coconut wood processing

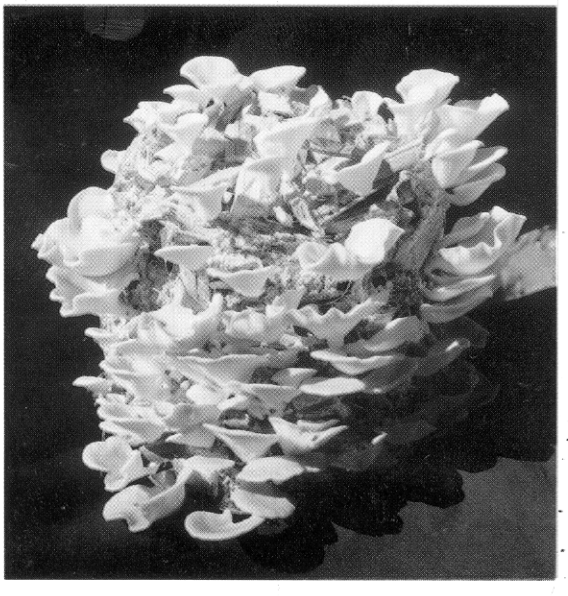
Handicraft using coconut

Handicraft using coconut wood and shell



Mushroom house for the production of mushroom from coconut byproducts

Mushroom cultivation using coconut byproducts



Oyster mushroom

Mushroom cultivation using coconut byproducts

Methods to cultivate mushroom using byproducts 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 byproducts 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% 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% urea and 1% super phosphate helps to reduce the interval between flushes. *Pleurotus eous, Pleurotus flabellatus, Pleurotus florida* and *Pleurotus sajor caju* are the mushroom species suitable for cultivation using coconut byproducts.

9. RESEARCH AND DEVELOPMENT

Production potential of a released cultivar

Coconut trial plot

India could make significant achievements in enhancing coconut production and productivity through concerted efforts of the farmers, extension personnel and scientists engaged in the coconut research and development activities. Through the systematic research conducted during the last few decades, a substantial number of viable technologies related to crop improvement, production and protection have been evolved for enhancing coconut production. However, our farmers are not able to exploit the production potential from these technologies to the extent desirable. Extent of adoption of the recommended practices plays a crucial role in improving coconut productivity. Various organizations involved in the research and development of coconut are streamlining their programmes to enable the farmers to make use of the technologies for enhancing the production and productivity.

Research programmes

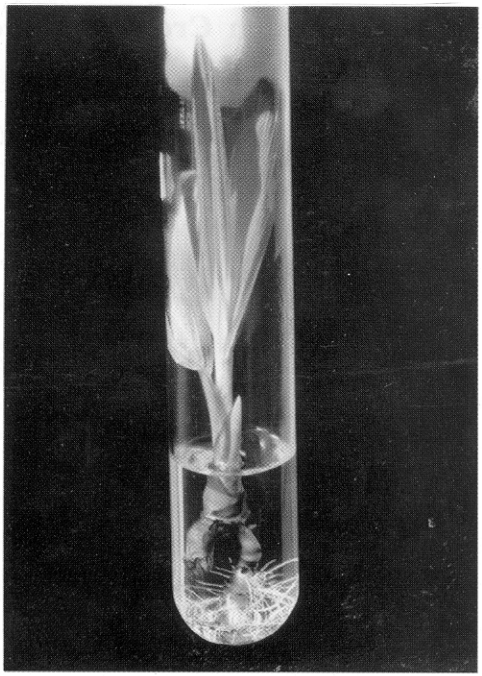
The important organizations conducting research on coconut in India include Central Plantation Crops Research Institute (CPCRI) under the Indian Council of Agricultural Research(ICAR) and State Agricultural Universities.

Central Plantation Crops Research Institute (CPCRI)

CPCRI – a pioneering coconut research organization

Production of quality planting materials - a priority programme

Central Plantation Crops Research Institute is the pioneering research organization in India conducting research on different aspects of the coconut cultivation. The headquarters of CPCRI is at Kasaragod in Kerala state. It has three Regional Stations- at Kayangulam in Kerala where research is conducted on coconut plant protection, at Vittal in Karnataka for research on arecanut and cocoa and at Minicoy in Lakshadweep Islands for research on coconut. Besides, CPCRI has Research Centres at Mohitnagar in West Bengal, Kannara in Kerala, Hirehalli in Karnataka and Kahikuchi in Assam. A Seed Farm also is maintained at Kidu in Karnataka State for the production of planting materials of the mandate crops. CPCRI maintains the International Gene Bank of Coconut for South Asia at the Seed Farm, Kidu. The World Coconut Germplasm Centre, at Sipighat in Andamans is also functioning under CPCRI. The research programmes of CPCRI are carried out under five Divisions viz; Crop Improvement, Crop Production, Physiology, Biochemistry and Post harvest technology, Crop Protection and Social Sciences. The primary mandate of CPCRI is to develop varieties and appropriate production, protection and processing technologies for coconut, arecanut and cocoa through basic and applied research and to transfer



Biotechnology - a thrust area of research at CPCRI

Micro-irrigation studies

technologies developed to the farmers through the Development Departments. CPCRI also co-ordinates research on the mandate crops within the country through the All India Coordinated Research Project (AICRP) on Palms.

CPCRI has achieved commendable success in evolving a large number of appropriate technologies. CPCRI holds the world's largest coconut germplasm repository. Performance of the high yielding coconut cultivars and hybrids released from CPCRI is widely appreciated. Scientists in Crop Production Division were able to standardize various crop management technologies for coconut. Integrated management practices for the various coconut pests and diseases have also been evolved. The research achievements of CPCRI on biological control of major coconut pests have been receiving worldwide appreciation.

Efforts are also made by CPCRI to disseminate the research results among the cultivators through the Development Departments. CPCRI has been organizing institutional training programmes on different aspects of management technology of coconut for the benefit of extension personnel involved in coconut development activities. For effective dissemination and popularization of the available coconut cultivation technologies among the extension personnel and farmers, extension

Demonstration on intercropping in coconut gardern

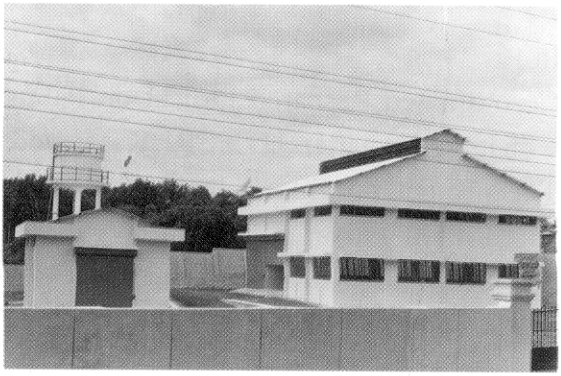
pamphlets, CD ROMs, Video Cassettes etc. are also prepared by the CPCRI. On farm demonstrations on different coconut cultivation technologies in farmers' fields also are taken up by CPCRI. The Agricultural Technology Information Centre(ATIC), recently established at the Institute, provides various information and technology services on the 'single window system concept'.

All India Co-ordinated Research Project on Palms

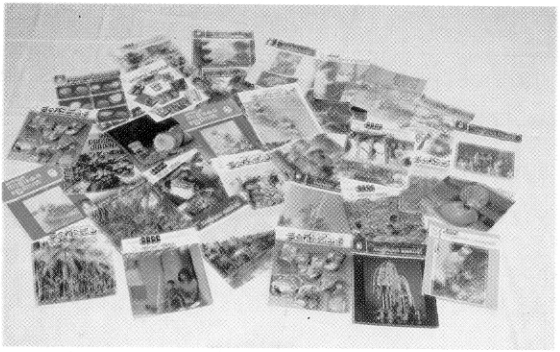
In 1970, the ICAR sanctioned the All India Co-ordinated Research Project on Palms with its head quarters at CPCRI, Kasaragod. The project provides adaptive research support for coconut through collection, conservation, cataloguing and evaluation of germplasm, evaluation of new hybrids and high yielding varieties of coconut, standardization of agro-techniques for various agro-climatic regions including development of appropriate farming systems and development of efficient pest and disease management strategies especially for pests like leaf eating caterpillar and rhinoceros beetle and diseases like Tatipaka and Ganoderma/Tanjavur wilt. At present in addition to Kasaragod Centre, nine Centres viz., Ambajipet (Acharya N.G. Ranga Agricultural University), Kahikuchi (Assam Agricultural University), Arsikere (University of Agricultural Sciences, Bangalore), Ratnagiri (Konkan Krishi

Mixed cropping trials at an AICRP Centre

DSP farm (CDB)



Technology Development Centre of the CDB



Periodicals of CDB

Vidyapeeth), Jagadalpur (Indira Gandhi Krishi Viswa Vidyalaya), Konark (Orissa University of Agriculture and Technology), Aliyarnagar and Veppankulam (Tamil Nadu Agricultural University) and Mondouri (Bidhan Chandra Krishi Viswa Vidyalaya) are carrying out coconut research under the All India Co-ordinated Research Project on Palms.

Sponsored research programmes of Coconut Development Board

In order to promote product diversification and by-product utilization of coconut and to create a vibrant coconut based economy, a Technology Development Centre has been established at the head quarters of the Board. Under the sponsored research programmes of the Board, new technologies have been developed for the manufacture of coconut cream, spray dried coconut powder, coconut water based vinegar and process for the preservation and packaging of tender coconut water. Technology has also been developed for the manufacture of *Nata-de coco*, a gelatinous dessert delicacy.

Development and transfer of technology

Taking into cognizance the problems faced by farmers and the need to improve the coconut production scenario in the country, various development programmes are being implemented by different agencies for assisting coconut cultivators. At the National

Level, the Coconut Development Board and at the state level different Agriculture/ Horticulture Departments play a critical role in the implementation of various coconut development programmes.

Coconut Development Board

The Coconut Development Board is a statutory body established by the Government of India for the integrated development of coconut cultivation and industry in the country. The Board which came into existence on 12th January, 1981, functions under the administrative control of the Ministry of Agriculture, Government of India, with its head-quarters at Kochi in Kerala State and three Regional Offices at Bangalore, Chennai and Patna. There are six State Centres situated in the states of Orissa, West Bengal, Assam, Tripura and Andhra Pradesh and in the Union Territory of Andaman & Nicobar Islands.

Coconut Development Board Headquarters

The functions of Coconut Development Board include the following:

- Adopting measures for the development of coconut industry.
- Recommending measures for improving marketing of coconut and its products.
- Imparting technical advice to those engaged in coconut cultivation and industry.
- Providing financial and other assistance for expansion of area under coconut.
- Encouraging adoption of modern

Organising Symposium
to promote coconut products

Seminar to discuss development strategies

Publishing books as reference guide for development personnel and farmers

technologies for processing of coconut and its products.

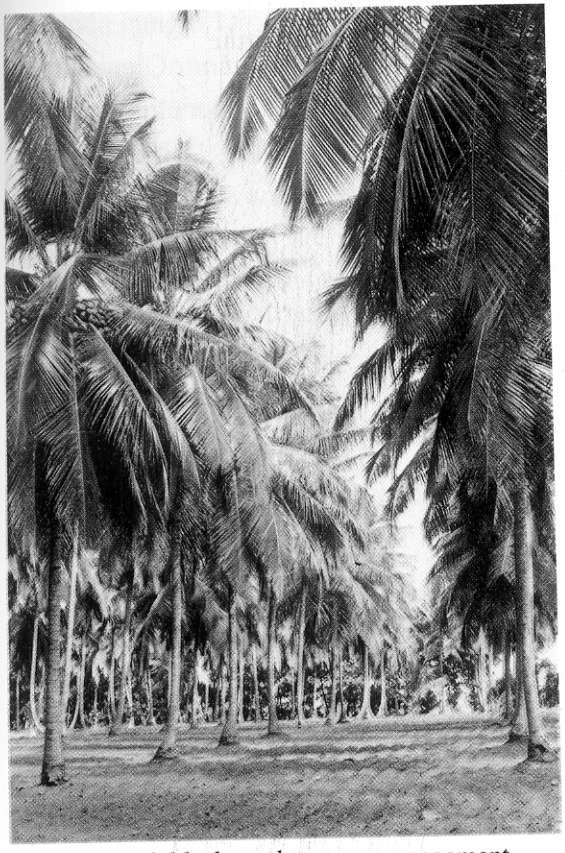
- Adopting measures to get incentive prices for coconut and its products.
- Recommending measures for regulating imports and exports of coconut and its products.
- Fixing grades, specifications and standards for coconut and its products.
- Financing suitable schemes to increase the production of coconut and to improve the quality and yield of coconut.
- Assisting, encouraging, promoting and financing agricultural, technological, industrial or economic research on coconut and its products.
- Collecting statistics on production, processing and marketing of coconut and its products and publishing them.
- Undertaking publicity activities and publishing books and periodicals on coconut and its products.

To achieve the above objectives, the Coconut Development Board is implementing various programmes.

State Agriculture / Horticulture Departments

The Agriculture/Horticulture Departments in the major coconut growing states in the country are implementing various development schemes and extension programmes for the benefit of coconut farmers.

Many of the states have been implementing special programmes for the production and distribution of planting materials, distribution of plant protection chemicals and fertilizers and establishing bio-control laboratories for the production and distribution of bio-control agents against coconut pests. Financial incentives are also provided in the form of subsidies for the installation of pump sets, digging well and other irrigation structures. Schemes for combating sudden incidence of pests and diseases are also taken up by the departments. Organizing coconut farmers at grass root level for group management of coconut production activities and conducting farmers training programmes and other extension programmes are the major educational programmes implemented by Agriculture/Horticulture Departments. These development schemes and extension programmes are implemented through the staff of the Department functioning at the grass root level. Besides the above, local bodies like grama panchayats also implement location-specific development schemes under the technical guidance of the Agriculture/Horticulture Department.



Better yields through proper management

It would be ideal, if the farming community avails the facilities offered by various research and development organisations for improving the returns from coconut cultivation as well as the coconut productivity in the country.

ACRONYMS

AICRP	All India Co-ordinated Research Project
AO	Andaman Ordinary
ATIC	Agricultural Technology Information Centre
CDB	Coconut Development Board
CFTRI	Central Food Technological Research Institute
CGD	Chowghat Green Dwarf
COD	Chowghat Orange Dwarf
CPCRI	Central Plantation Crops Research Institute
DC	Desiccated Coconut
DFRL	Defence Food Research Laboratory
DSP Farm	Demonstration cum Seed Production Farm
DxT	Dwarf x Tall
ECT	East Coast Tall
GB	Gangabondam
HDMSCS	High Density Multispecies Cropping System
ICAR	Indian Council of Agricultural Research
LO	Lakshadweep Ordinary
MYD	Malayan Yellow Dwarf
OBV	Oryctes Baculo Virus
ppm	parts per million
RH	Relative Humidity
RRL	Regional Research Laboratory
SBTN	Snow Ball Tender Nut
SSAT	Strait Settlement Apricot Tall
TxD	Tall x Dwarf
VHC	Veppankulam Hybrid Coconut
WCT	West Coast Tall
WTO	World Trade Organization

SUBJECT INDEX

PHOTO INDEX