Chapter 2

Organic Farming in Coconut

☆ *P. Subramanian, Murali Gopal, Alka Gupta, George V. Thomas, V. Krishnakumar and P. Chowdappa*

1. Introduction

There is an increasing demand among the consumers all over the world for organically grown agricultural commodities with increasing health consciousness. The production to meet this demand could be made possible only through preserving soil health, plant health and environmental health. Organic farming has gained importance globally as holistic production system so as to produce safe food for consumption aimed at minimizing all forms of pollution within the agro-ecosystem as well as protecting the environment. This system of managing agricultural holdings restricts the use of chemical inputs such fertilizers, pesticides, growth regulators and livestock feed additives *etc.* The focus on soil fertility management shall be on development and application of innovative agro technologies based on soil biodiversity to enhance the natural nutrient cycles and utilization of specific soil-plant-microbial associations in managing the soil nutrient status. The holistic approach in farming provides social and ecological advantages with the conservation of precious inputs such as soil and water and ensures long term fertility of soil for sustainability in cropping.

The coconut palm is one of the five legendary Devavrikshas and is eulogized as Kalpavriksha – the all giving tree – in Indian classics. Also called as *"Tree of Heaven"*, *"Tree of life"* or *"Nature's supermarket"*, coconut has considerable global significance as a versatile tree crop providing essential needs of human life *viz.* income, livelihood opportunity, food supplement, energy requirement, environmental stability and raw material for a number of enterprises. It stabilizes farming systems, especially in fragile environments such as small island states, and in coastal zones. No religious function is complete without coconut, which is an essential component of several rituals in Hindu tradition throughout India. It is considered a symbol of auspiciousness, blessing and prosperity. The coconut palm has significant influence on the rural economy particularly in the coastal regions of the world, where it provides livelihood security to over 12 million people. Coconut is an eco-friendly plant which helps to conserve soil, provides aesthetic beauty to the nature, perennial and less exhaustive and ideal tree for bio-hedging on the coastal ecosystem.

The demand for organic coconut products and spices (which are usually grown in coconut plantations as mixed crops) is increasing over the years and this trend is likely to continue. It provides opportunity for farmers who produce coconut (both mature and tender nuts) as well as various other value added products by following organic methods of farming to realize better returns through the premium price available for organic products. Though there is declining viability in some of the coconut producing countries, they continue to produce because of the importance given to coconut as a social crop. These countries have realized the potentials coconuts hold in economic development and poverty alleviation particularly, among the rural population. For most of these countries, coconut is still the backbone of their economy and it could be the base on which their rural economies are based.

The coconut is a 'no-waste tree' because even its waste products provide ample opportunity to augment farmers' income. Through R and D, the once considered wastes have been put into use and even turned up to be an income generating industry. Coir dust, the major by-product of coir production and considered a pollutant, is now being sought to conserve the environment. It is now used as substitute for peat as a potting medium for plants. Coir peat or dust, is now being exported and is becoming a significant foreign exchange earner in Sri Lanka. Coconut sap can be processed into a number of products, one of which is sugar. The midribs, twigs, spathe, leaves, shell *etc.*, are also now being utilized in the manufacture of handicrafts - another non-traditional export product from the Philippines.

2. Production Scenario

2.1. Global Scenario

Coconut is grown in more than 93 countries worldwide in 12.5 million hectares of land (2012-13), which constitutes about 0.7 per cent of the net crop of the world (Table 2.1). Close to ten million hectares is contributed by four countries, namely Indonesia, Philippines, India and Sri Lanka and they contribute 79.09 per cent of the total area under coconut and its production in the world. The Asian Pacific Coconut Community has 18 coconut producing member countries accounting for about 95 per cent of world area under coconut cultivation and production as well as exports of coconut products. The palm exerts a profound influence on the rural economy of many countries where it is grown extensively and provides livelihood security to several millions of farm families across the globe. The crop is grown in the coastal lands of continental south Asia and spread along the Indian and Pacific Ocean. The coconut oil ranks sixth among the eight major vegetable oils of the world.

Table 2.1. Area and Production of Ten Major Coconut Growing Countries in the World (2012-2013)

Country	*Area ('000ha) and Per cent Share*	*Production (million nuts) and Per cent Share*	*Productivity (nuts/ha)*
Indonesia	3,787.00 (30.35)	16,463.00 (22.84)	4,347
Philippines	3,550.00 (28.45)	15,353.00 (21.30)	4,325
India	2,137.00 (17.12)	22,680.03 (31.46)	10,615
Sri Lanka	395.00 (3.17)	2,513.32 (3.49)	6,363
Tanzania	310.00 (2.48)	427.51 (0.59)	1,379
Brazil	279.00 (2.24)	3,326.57 (4.61)	11,923
Papua New Guinea	221.00 (1.77)	1,482.59 (2.06)	6,709
Thailand	209.00 (1.67)	838.00 (1.16)	4,010
Mexico	176.00 (1.41)	1,463.74 (2.03)	8,317
Vietnam	158.00 (1.27)	1,235.45 (1.71)	7,819
Others	1,257.3 (10.07)	6,311.38 (8.75)	
Total	12,479.00	72,094.58	5,777

Source: APCC.

2.2. Indian Scenario

The coconut is not only significant in socio cultural needs of Indian society, but also has gained considerable importance in the national economy as a potential source of rural employment and income generation among the plantation crops. India, with an area of about 2.14 million ha under cultivation and production of 23 billion nuts (15.61 million tonnes) (2012-2013), stands third and first among the coconut growing countries in area and production, respectively. India shares 17.12 per cent of area under coconut cultivation and 31.46 per cent of coconut production in the world. Considering the area under cultivation and total production, India stands first in productivity of coconut among the major coconut producing countries of the world at 10615 nuts/ha during 2012-13. Unlike other world countries, India has the comparative advantage of having the crop grown under varied agro-climatic zones and hence, there is distinct difference in the pattern of distribution of coconut in the country. As a result of this unique distribution, a steady supply of coconut is ensured in the country throughout the year. Most of coconut production in India comes from the Western plains comprising of the states of Kerala, Karnataka, Maharashtra, Goa and Gujarat followed by the East Coast plains comprising of Tamil Nadu, Puducherry, Andhra Pradesh, Telengana and Odisha. Andaman and Nicobar and Lakshadweep are the two major coconut growing islands. Four southern states of India, *viz.*, Andhra Pradesh, Karnataka, Kerala and Tamil Nadu together account for 91.30 per cent of the total production in the country. In terms of area, they contribute to 89.11 per cent (Table 2.2).

In India most of the production comes from small and marginal farms and more than 90 per cent of the holdings are below one hectare with the average size being 0.22 ha. In the west coast of India, the palm is an essential component in the homestead system of farming where it is mostly grown as a rain fed crop.The countrywide demand for coconuts both for edible and non-edible purpose, and the adaptability of coconut palm to grow under varying soil and climatic conditions has generated keen interest among the farmers of even non-traditional zones in the country to plant a few seedlings in their homestead gardens. West Bengal, North Bihar, Chattisgarh, Assam, Tripura and Nagaland are the other non- traditional areas where coconut cultivation is being taken up.

Table 2.2: Area, Production and Productivity of Coconut in different States of India (Area with more than 2.0 per cent share) (2012-2013)

State	*Area ('000 ha) and Per cent Share*	*Production ('000 mt) and Per cent Share*	*Production (million nuts)*	*Productivity (nuts/ha)*
Kerala	796.16 (37.36)	3990.39 (25.60)	5798.04	7264
Karnataka	513.10 (24.01)	4169.90 (26.70)	6058.86	11808
Tamil Nadu	465.11 (21.71)	4760.67 (30.50)	6917.25	14872
Andhra Pradesh	128.90 (6.03)	1330.40 (8.50)	1933.07	14997
Odisha	54.29 (2.54)	262.17 (1.70)	380.93	7017
Other states	179.11 (8.35)	1095.57 (7.00)	1591.88	–
All India	2136.67	15609.10	22680.03	10615

Source: Coconut Development Board, 2013.

In most of the producing countries, about 50 per cent of the production is consumed domestically and balance is made available for global trade, whereas, the bulk of coconut produced in India goes for the domestic consumption. The decelerating growth in production of coconut in the major exporting countries in the world like; Philippines, Indonesia and Sri Lanka, on account of displacement of coconut area for more profitable enterprises like; oil palm cultivation, urbanization followed by real estate business *etc.*, have caused deficit in global supply of coconut and its products. Indian coconut and coconut products are, therefore, now gaining competitive advantage in occupying world market. However, in many of the EEC countries, Indian coconut products are yet to make the presence felt due to the fact that the products do not satisfy the quality standards prescribed in the European market as well as for want of organic certifications. In view of the emerging economic scenario and also due to the tremendous growth in the production and productivity of coconut in the country, it is necessary to explore new markets for these products abroad for the stability of domestic market. Promotion of organic cultivation in coconut gardens is, therefore, considered very much essential.

3. Tall and Dwarf Varieties

Two main categories of coconut palms *viz.*, Talls and Dwarf are cultivated globally. The tall plants of the Typica group are generally cross-pollinated, whereas, in dwarf types of the Nana group, self-pollination is the norm. Tall varieties should always be chosen for agroforestry systems, because they only can reach up to the upper levels intended for them, and thus fully develop. Dwarf palms get easily overshadowed in the system, hindering their full development. In addition, the Nana varieties are more sensitive to drought as well as some pests and diseases than Typica varieties.

The tall cultivars are predominantly grown for fresh, oil yielding kernel, whereas, the dwarf cultivars for their attractive bright coloured tender fruits having sweet tender nut water. Tall varieties are the common type that occurs throughout the world. They are widely planted both for household and commercial production in all the coconut cultivating regions of the world. Generally, they are slow maturing, flower 6-10 years after planting and grow to a height of about 20-30 m. They are long-lived with an economic life of about 60-70 years, although much older palms are known to exist and yield well. They produce copra of good quantity and quality, and have fairly high oil content as compared to dwarf cultivars. Many *talls* are grown for the production of copra for oil extraction and coir for fiber. The different cultivars of the *tall* are generally named after the place where they are largely cultivated. The *tall* cultivars are most commonly grown in India are the West Coast Tall (WCT), Tiptur Tall (TPT) and East Coast Tall (ECT).

'Dwarfs' represent about 5 per cent of coconut palms and are also cultivated worldwide. They are more commonly found near human habitation and show traits closely associated with human selection. They are predominantly self-pollinated and with slow trunk growth in nature. These are believed to be mutants from tall types with short stature, 8-10 m when 20 years old. They begin bearing at an early age of around three to four years, however, with short productive life of 30-40 years. The nuts are smaller and the copra soft, leathery and low in oil content. The dwarf cultivars are generally grown for tender nuts and also used for hybrid production. The common dwarfs available in India are Chowghat Orange Dwarf (COD), Chowghat Green Dwarf (CGD), Kenthalli (KTOD) and Gangabondam (GBGD). Among the dwarfs, Chowghat Orange Dwarf has very good quality of tender nut water and has been released as a tender nut variety suitable for cultivation throughout India. Some of the common local varieties in India and their features, improved coconut varieties, coconut hybrids released in India are given in Tables 2.3–2.5.

4. Amenability of Coconut to Organic Farming

Being a perennial horticulture crop and the economic life span extending to more than 50-60 years after planting, the cultivation of the palm involves heavy investments during the juvenile phase and continuous recurring expenditure for its subsequent maintenance. The coconut palm, therefore, is characterized by high rate of investments in the initial years and for realizing the output in succeeding periods. Due to its unique nature of continuing growth and yielding phases, any change in the cultivation practices in the middle may upset the growth and physiology of the crop. A vast stretch of area under coconut in the country is rain fed, and hence, the success of coconut growing depends on the uniform distribution of an annual rainfall also.

Table 2.3: Local Coconut Varieties grown in India

Name of Variety	*Salient Features*	*Recommended States*
West Coast Tall (WCT)	The palms are tall, robust and bear large green nuts but have wide range of variation in size, shape and colour of nuts. Suitable for production of copra and tender nut. It comes to bearing in 5-7 years after planting. The average yield 15000 nuts/ha, copra yield 3.6 t/ha and oil 2.5 t/ha.	Kerala, Karnataka, Maharashtra, Goa, Tamil Nadu, Andhra Pradesh, Bihar, Andaman and Nicobar Islands, Gujarat, Lakshadweep and Puducherry
East Coast Tall (ECT)	The palms are tall, compact and bear medium sized oval shaped green nuts. Suitable for production of copra and tender nut. The average yield 14500 nuts/ha, copra yield 3.4 t/ha and oil 2.2 t/ha.	Odisha, Assam, West Bengal, Bihar, Andhra Pradesh, Meghalaya and Tripura
Tiptur Tall (TPT)	It comes to bearing in 5-7 years after planting. The palms are tall, robust. Suitable for production of copra and tender nut. The average yield 15050 nuts/ha, copra yield 3.7t/ha and oil 2.6 t/ha.	Karnataka
Andaman Ordinary (ADOT)	The palms are tall, robust and bear large green nuts but have wide range of variation in size, shape and colour of nuts. Suitable for production of copra and tender nut. It comes to bearing in 5-7 years after planting. The average yield 16450 nuts/ha, copra yield 3.6 t/ha and oil 2.4 t/ha.	Kerala and Andaman and Nicobar Islands
Gangabondam (GBGD)	The palms are semi tall, robust and bear large green nuts. It comes to bearing in 5-7 years after planting. Suitable for tender nut. The average yield 16000 nuts/ha.	Andhra Pradesh
Chowghat Green Dwarf (CGD)	It is an early bearing cultivar and takes about 3-4 years for initial flowering. The average yield 14000 nuts/ha.	Kerala, Karnataka, Andhra Pradesh, Tamil Nadu, Odisha, Andaman and Nicobar Islands, West Bengal, Goa, Gujarat, Assam, Bihar and Maharashtra
Malayan Orange Dwarf (MOD) and Malayan Green Dwarf (MGD)	These are two introductions from Malaysia and are suitable as tender nut varieties with 400 ml and 370 ml tender nut water/nut, respectively. Both these are early bearers and start flowering during 3rd or 4th year of planting.	Kerala, Tamil Nadu, Karnataka, Andhra Pradesh, Odisha and West Bengal.

Table 2.4: Improved Coconut Varieties

Variety	Important Traits	Nut Yield (ha/year)[@]	Copra Yield (t/ha/year)[@]	Recommended states/regions	Agency Responsible for Release
		Tall			
Chandra Kalpa	Drought tolerant, high copra oil content, suitable for neera tapping	17,700	3.12	Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra	Central Plantation Crops Research Institute (CPCRI)
Kera Chandra	High yield, dual purpose variety for copra and tender nut; suitable for soap industry	19,470	3.86	Kerala, Karnataka, Konkan region, Andhra Pradesh, West Bengal	CPCRI
Kalpa Pratibha	High nut, oil yield, dual purpose variety for copra and tender nut	16,107	4.12	Kerala, Andhra Pradesh, Tamil Nadu, Maharashtra	CPCRI
Kalpa Mitra	High nut, oil yield, drought tolerant	15,222	3.68	Kerala, West Bengal	CPCRI
Kalpa Dhenu	High nut, oil yield, drought tolerant	14,160	3.41	Kerala, Tamil Nadu, Andaman and Nicobar Islands	CPCRI
Kalpa Haritha	Dual purpose variety for copra and tender nut; less eriophyid mite damage	20,886	3.70	Kerala, Karnataka	CPCRI
Kalpatharu	Drought tolerant, ball copra, high yield, coir fibre amenable for dyeing	20,709	3.64	Kerala, Karnataka,Tamil Nadu	University of Hort. Sciences (UHS), Bagalkot, Karnataka
Pratap	High yield	26,727	4.01	Konkan region of Maharashtra	Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth (Dr. BSKKV), Maharashtra
Kamrupa	High yield	17,877	2.90	Assam	Assam Agricultural University (AAU), Assam
ALR (CN) 1	High yield	22,302	3.50	Tamil Nadu	Tamil Nadu Agricultural University (TNAU), Tamil Nadu
Kera Bastar	High yield	19,470	3.18	Bastar region of Chhattisgarh, Konkan region of Maharashtra, Coastal zone of Tamil Nadu, Andhra Pradesh	Indira Gandhi Agricultural University (IGAU), Chhattisgarh
Kalyani Coconut 1	High yield	14,160	3.84	West Bengal	Bidhan Chandra Krishi Viswavidyalaya (BCKV), West Bengal

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Variety	*Important Traits*	*Nut Yield (ha/year)* @	*Copra Yield (t/ha/year)* @	*Recommended states/regions*	*Agency Responsible for Release*
Kera Keralam	High yield, drought tolerant, suitable for neera tapping; soap industry	26,019	3.53	Tamil Nadu, West Bengal, Kerala	TNAU
ALR (CN) 2	High yield	21,240	2.89	Tamil Nadu	TNAU
VPM-3	High yield, drought tolerant	14,868	3.41	Tamil Nadu	TNAU
Kera Sagara	High yield	17,523	3.64	Kerala	Kerala Agricultural University (KAU), Kerala
		Dwarf/Semi Tall			
Chowghat Orange Dwarf	Tender nut purpose, orange colour fruit, coarse fibre	11,505	1.80	All coconut growing regions for tender nut	CPCRI
Kalparaksha	Semi-tall, high nut and oil yield in RWD prevalent areas; tender nut purpose	13,260 (17,748)#	2.85 (3.34)#	Kerala, Root (wilt) disease prevalent tracts	CPCRI
Gouthami Ganga	Tender nut purpose, green colour fruit	15,930	1.54	Coastal zone of Andhra Pradesh	Acharya N. G. Ranga Agril. University (ANGRAU), A.P.
Kalpasree	Early flowering, green colour fruit; superior oil - rich in linoleic acid, recommended for root (wilt) diseased areas	20,178	2.86	Root (wilt) disease prevalent tracts	CPCRI
Kalpa Jyothi	Tender nut purpose, yellow colour fruit	21,771	4.07	Kerala, Karnataka, Assam	CPCRI
Kalpa Surya	Tender nut purpose, orange colour fruit	9,133	2.20	Kerala, Karnataka, Tamil Nadu	CPCRI
Kera Madhura	Semi-tall, dual purpose variety for copra and tender nut	24,480	4.80	Kerala	KAU
CARI-C1 (Annapurna)	High copra content, tender nut purpose, green colour fruit	20,231	1.41	Andaman and Nicobar Islands	Central Agricultural Research Institute (CARI), Andamans
CARI-C2 (Surya)	Ornamental purpose, orange colour fruit	24,072	1.77	Andaman and Nicobar Islands	CARI
CARI-C3 (Omkar)	Ornamental purpose, yellow colour fruit	16,373	1.67	Andaman and Nicobar Islands	CARI
CARI-C4 (Chandan)	Ornamental purpose, orange colour fruit	11,505	1.80	Andaman and Nicobar Islands	CARI

@:Yield estimated at 7.5 m x 7.5 m spacing, population of 177 palms per ha under experimental conditions. It will vary according to organic farming practices being adopted. #: Figures in parenthesis indicate yield in root (wilt) disease free tracts.

Table 2.5: Coconut Hybrids Released in India

Hybrid Variety	*Source Population of Parents*	*Important Traits*	*Nut Yield[@] (ha/year)*	*Copra Yield[@] (t/ha/year)*	*Area Recommended*	*Agency Responsible for Release*
Chandra Sankara	COD x WCT	High yield	20,532	4.27	Kerala, Karnataka, Tamil Nadu	CPCRI
Kera Sankara	WCT x COD	High yield, drought tolerant	19,116	3.78	Kerala, Karnataka, Maharashtra, Andhra Pradesh	CPCRI
Chandra Laksha	LCT x COD	High yield, drought tolerant	19,293	3.76	Kerala, Karnataka	CPCRI
Kalpa Samrudhi	MYD x WCT	Dual purpose variety, Drought tolerant, higher nutrient use efficiency	20,744	4.35	Kerala, Assam	CPCRI
Kalpa Sankara	CGD x WCT	Tolerant to root (wilt) disease, high yield	14,868	3.20	Root (wilt) disease prevalent tracts	CPCRI
Kalpa Sreshta	MYD x TPT	Dual purpose variety, High yield	29,227	6.28	Kerala, Karnataka	CPCRI
Laksha Ganga	LCT x GBGD	High yield	19,116	3.73	Kerala	KAU
Ananda Ganga	ADOT x GBGD	High yield	16,815	3.63	Kerala	KAU
Kera Ganga	WCT x GBGD	High yield	17,700	3.56	Kerala	KAU
Kera Sree	WCT x MYD	High yield	23,364	5.05	Kerala	KAU
Kera Sowbhagya	WCT x SSAT	High yield	23,010	4.49	Kerala	KAU
VHC-1	ECT x MGD	High yield	21,240	2.87	Tamil Nadu	TNAU
VHC-2	ECT x MYD	High yield	25,134	3.74	Tamil Nadu	TNAU
VHC-3	ECT x MOD	High yield	27,612	4.47	Tamil Nadu	TNAU
Godavari Ganga	ECT x GBGD	High yield	18,585	2.79	Andhra Pradesh	ANGRAU, Andhra Pradesh
Konkan Bhatye coconut hybrid 1	GBGD x ECT	High yield	20,532	3.47	Maharashtra	Dr. BSKKV, Maharashtra

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Table 2.5–*Contd...*

Hybrid Variety	*Source Population of Parents*	*Important Traits*	*Nut Yield[@] (ha/year)*	*Copra Yield[@] (t/ha/year)*	*Area Recommended*	*Agency Responsible for Release*
Kalpa Ganga	GBGD x FJT	High yield, suitable for ball copra production	21,417	3.38	Karnataka	UHS, Bagalkot, Karnataka
Vasista Ganga	GBGD x PHOT	High yield	22,125	3.88	Andhra Pradesh, Karnataka	Dr YSR Horticultural University (Dr.YSRHU), Andhra Pradesh
Ananta Ganga	GBGD x LCT	High yield	22,656	3.84	Andhra Pradesh, Karnataka	YSRHU
VPM 5	LCT x CCNT	High yield			Tamil Nadu	TNAU

@:Yield estimated at 7.5 m x 7.5 m spacing, population of 177 palms per ha under experimental conditions. It will vary according to organic farming practices being adopted.

SSAT: Straits Settlement Apricot Tall; ADOT: Andaman Ordinary Tall; FJT: Fiji Tall; PHOT: Philippines Ordinary Tall; CCNT: Cochin China Tall; LCT: Laccadive Ordinary Tall; MYD: Malayan Yellow Dwarf; SSAT: Straits Settlement Apricot Tall.

The growth habit and planting methods of coconut make it highly suitable for managing through organic farming. About 74 per cent of the roots produced do not go beyond 2 m from the bole and most of the roots also confine to the 30 to 120 cm depth, thus, utilizing only limited extent of land area for growth of palms and leaving considerable area for inclusion of other crops to maintain crop diversity, an important requirement for organic farming. The orientation of leaves in the coconut crown helps penetration of sunlight into the soil and provides opportunities for exploitation of land and solar energy for inter/mixed cropping. Such a cropping system approach will also add large quantities of organic wastes to the system and their recycling within the system help to increase organic content of soil and improve microbial activity and make the entire production system more productive even in the absence of external inputs.

Coconut plantations are highly amenable to organic farming as they produce large quantities of waste biomass which, if recycled, can meet the nutrient demand of the crops to a great extent. The total availability of waste biomass from 2.14 million hectare of coconut plantation in the country has been estimated as 15.92 million tonnes annually. The natural decomposition of these wastes and the nutrient release are very slow due to the high lignin content and the nature of lignocellulose complex of the coconut waste materials. Substantial saving in terms of fertilizer input is possible through effective recycling of the waste biomass. Coconut is socially, culturally and religiously associated with millions of people around the world. Apart from healthy food and drink, it provides shelter, health, wealth and aesthetic values. Coconut not only provides livelihood to people who are directly or indirectly depending on the crop, but also ensures food security, nutritional security and alleviates poverty.

5. Climatic Requirements

Coconut palm is a unique plantation crop and stands apart from all other palms because of its high degree of consistency and continuity in flowering and fruit production, month after month (once it starts flowering), year after year, for decades. Depending on the site, coconut palms can be suited to cultivation on agroforestry systems. As a plant of the upper storey, with requisite light requirements, the coconut palms grow above such crops as citrus plants, cocoa, nutmeg, banana and many other crops.

5.1. Geographical Position

Coconut is essentially a tropical plant, growing mostly between 20°N and 20°S latitudes. The ideal elevation is up to 600 m above MSL and because of its temperature requirements, the palms cannot grow above 750 m, even near to the equator. Relative humidity plays a very important role in pollination and fertilization, thus directly influences yield. High humidity provides congenial conditions for the rapid spread of fatal diseases such as bud rot, leaf rot *etc.*

5.2. Temperature

The ideal mean annual temperature is 27°C with 5-7°C diurnal variation and humidity > 60 per cent. Very high humid conditions right through the growth of palms is not considered good from two aspects. One is that it reduces transpiration and thereby reduces the uptake of nutrients. High temperature might cause the young developing inflorescence to dry up, and limit production to those months in the year when the temperature remains at favourable level. In shallow and well-drained soils, effect of dry spell is more pronounced. Under such conditions and also where annual rainfall is less than 100 cm, economic production is possible only under irrigation. In places where the climate is characterized by long dry spells of hot day weather during summer and severe cold associated with cold wave and frost during winter; cyclone prone areas *etc.* are not suitable for coconut cultivation. Increase in temperature is also expected to have a detrimental effect on coconut oil quality, aroma and flavour. Increase in temperature is reported to reduce the oil content in coconut endosperm, resulting in increased content of starch, carbohydrates and reducing sugars in copra.

5.3. Rainfall

Rainfall is the one of the important factors that affects successful growth of coconut palm under natural conditions. Though the palms can tolerate wide range in intensity and distribution, a well distributed rainfall of about 200 cm per year is the best for proper growth and maximum yield. Since the tree does not store moisture and has no tap roots, it is not suited for regions with long and prolonged dry spells during which the water table goes considerably low. Very heavy rainfall may affect pollination due to washing of pollen grains. Since coconut is a perennial crop, delay in monsoon by two to three weeks would not adversely affect the yield and so no special cultural practices is followed. Flooding for shorter duration will not cause much damage to the palms. However, coconut palms do not tolerate high water table and stagnant water for longer periods. Prolonged water stagnation causes palms to suffer from physiological drought, where palms will not be able to uptake water and nutrients due to hampered root function because of lack of O_2 for respiration. Water logging in coconut basins is found to cause yellowing in leaves of palms. Microbial activity is also adversely affected under such situations.

5.4. Impact of Drought

In coconut, spikelets on the inflorescence are formed about 15 months before the opening of spathe and the pistillate flowers before 12 months. Even after the spathe is opened, female flowers remain for about 11 to 12 months to develop into full mature nuts. Drought affects coconut palms and the impact can be seen from the year of drought till four years. Severe drought during early formative phase of the inflorescence may kill the growing points due to desiccation resulting in the abortion of spadix. Any coincidence of drought or dry spell with critical sensitive stages such as inflorescence primordial initiation, ovary development, button size nut stage adversely affects the nut yield. In severe drought situations, drooping of leaves due to low leaf water potentials, shedding of buttons and immature nut fall, bending and breaking of leaves *etc.* may happen.

6. Soil Requirement

Coconut is grown in different soil types such as lateritic, coastal sandy, alluvial and also in reclaimed soils of the marshy lowlands and it does best in relatively coarser textured soils likes sandy loams, sandy coastal alluviums and sandy river valleys. It is found to grow well on littoral (coastal) sand which is generally unsuitable for many other crops provided it is managed carefully in the early stages with organic manuring and watering. It tolerates salinity and a wide range of pH (from 5.0-8.0). Soil with a minimum depth of 1.2 m and fairly good water holding capacity is preferred for coconut cultivation. Shallow soils with underlying hard rock, low lying areas subject to water stagnation and clayey soils are to be avoided as it will be difficult to raise successful coconut plantations under such conditions. Proper supply of moisture either through well distributed rainfall or irrigation and sufficient drainage in waterlogged soil are essential for coconut.

7. Environmental Services of Coconut

Coconut is a perennial plantation crop and committed to the land for decades. At a time when there is considerable impact of climate change on growth and production of various crops, the above and below ground portion of coconut provides an opportunity to C-sequestration of 20 to 35 t ha^{-1} $year^{-1}$, which is the highest among many of the plantation crops. Coconut, cultivated along with compatible companion crops, provides around 20 t of biomass for recycling and effective utilization of such biomass can improve the soil fertility status as well as the soil microbial community.

8. Production of Planting Materials

Seedlings will be required when planting is to be taken up for new plantation or replanting the existing old and senile plantations. In such cases, selection of seed nuts, raising seedlings and selection of good quality seedlings are very important in coconut, because evaluation of the performance of the new progeny is possible only several years after planting. Location specific varieties which are adapted to local soil and climatic conditions are to be considered, since they are time tested. Many varieties and hybrids have been released for cultivation in different states.

8.1. Mother Palm Selection

For raising nursery, seed nuts are to be collected from selected mother palms. Such mother palms should be of 20 years old or more. Wherever possible, it is advisable to select middle-aged trees as they will be in their prime of life and it is easier to distinguish good yielder from low/poor yielder.

The important characteristics to be considered are:

1. Straight stout trunk with even growth and closely spaced leaf scars
2. Spherical or semispherical crown with short fronds
3. Short and stout bunch stalks without tendency to drooping
4. More than 30 leaves and 12 inflorescences carried evenly on the crown
5. Inflorescence with 25 or more female flowers

6. Consistent yield of about 80 nuts under rainfed conditions and 120 nuts under irrigated conditions
7. 150 g copra per nut
8. Free from any disease and pest incidence

8.2. Collection of Seed Nuts and Sowing

Only fully matured nuts, which are about 12 months old, should be harvested. The nuts should not be allowed to fall, but should be cut down, and carefully lowered, using a rope to avoid possible damage to the nuts. The ideal time for collecting seed nuts and their sowing is April-May and June in west coast region of India, while in the east coast region, sow nuts during October-November to coincide with the monsoon. However, when irrigation facilities are available, seed nuts can be collected and sown at any period of time depending of the requirement. Nuts which are too big or too small in the bunch and also the nuts of irregular shape and size are to be discarded. Following the harvest, the nuts should be stored in a covered, well-ventilated place. In case of tall varieties, sowing is to be done one or two months of storage after collection, whereas, seed nuts should be sown for dwarf varieties either immediately or within 10-15 days after harvest. Before sowing, the nuts are to be sorted again and only those nuts containing water are to be used.

8.3. Raising Nursery

The site selected for raising nursery should be well-drained with coarse-textured soil and close to irrigation water source. The seed nuts can be sown in flat beds if there is no drainage problem. Take raised beds for sowing wherever water stagnation is a problem. Seedlings can be raised in nurseries either in the open area provided with artificial shade or in coconut gardens where the palms are tall and the ground is not completely shaded. The seed nuts should be planted in long and narrow beds at a spacing of 40 cm x 30 cm during May-June or September-October, either vertically or horizontally in 20-25 cm deep trenches. The advantage of vertical planting is that it causes less damage only during transit. However, if sowing is delayed due to some reason, the nut water goes down considerably, and in such cases, adopt horizontal sowing for better germination.

8.4. Selection of Seedlings

Seed nuts, which do not germinate within 6 months after sowing as well as those germinated but have dead sprouts, are to be removed to ensure only good quality seedlings are produced. Seedlings, which are 10 to 12 months old, are to be selected for planting through rigorous selection based on the following characteristics:

1. Early germination, rapid growth and seedling vigour
2. Six to eight leaves for 10-12 month old seedlings
3. Collar girth of 10 cm and above
4. Early splitting of leaves

Figure 2.1: Coconut Nursery Seedlings.

8.5. Poly Bag Nursery

Good quality seedlings can be raised using poly bags (500 gauge thickness, 45 cm x 60 cm with 8-10 holes at the bottom) by transplanting germinated seeds in to the bags. The common potting media are top fertile soil mixed with sand (3:1), and top fertile soil, sand or coir dust and well rotten and powdered cattle manure (3:1:1). Potting mixture using sand + vermicompost (3:1) is also ideal for raising poly bag seedlings. As the entire ball of earth with the root system, after removal of poly bag, can be placed in the pits, no transplanting shock will be experienced by the seedlings. The poly bags should be removed from the coconut plantation

Figure 2.2: Coconut Poly Bag Seedlings.

after the planting is completed.Application of 25 g each of biofertilizers such as *Azospirillum* spp. and Phosphobacterium *Bacillus* sp. results in production of more vigorous and robust seedlings.

8.6. Bio-Priming of Seedlings

Bio-priming of seedlings with bio-inoculants such as *Pseudomonas fluorescens* imparts tolerance to diseases as well as promote their better growth. Initial establishment of such seedlings will be superior in the main field with enhanced growth and field tolerance to diseases. Application of talc based preparation of *P. fluorescens* @ 50 g (10^8cfu) per seedling during four, seven and ten months after sowing in the nursery will be beneficial. At the time of planting seedlings in the main field, coconut seedlings are to be dipped in 100 g (10^8cfu) of talc based preparation of *P. fluorescens* in slurry mode. Use of Plant Growth Promoting Rhizobacteria (PGPR) based bioinoculants, '*Kera Probio*', (talc formulation of *Bacillus megaterium*) @25 g/seedling and '*Ker*AM' (Arbuscular Mycorrhizal bioinoculant) @50 g/seedling also helps in producing robust coconut seedlings. The seedlings in the nursery, in general, do not require any additional nutrition, as the endosperm provides them with sufficient nutrients.

9. Planting and After Care

9.1. Preparation of Land and Planting

In loamy soils with low water table, planting in pits (1.0 m x 1.0 m x 1.0 m) filled up to 50 cm depth is generally recommended. However, in places where the water table is high, planting at the surface or even on mounds becomes necessary. Even while planting at the surface or mounds, digging pits and filling has to be done. If planting is taken up in the littoral sandy soil, application of 0.15 m^3 of red earth is recommended to improve the physical characteristics of soil. The type of soil decides the depth of pits to be taken for planting. In areas with laterite soil and rocky substratum, deeper and wider pits (1.2 m x 1.2 m x 1.2 m) are to be dug and filled up with top soil, powdered cow dung and ash up to a depth of 60 cm before planting. Addition of 2 kg of common salt will help in loosening the soil in such areas. In order to conserve soil moisture in the pits, arrange two layers of coconut husk with concave surface facing up at the bottom of the pit before filling up the soil. Plant the seedling at the center of the pit by removing the soil mixture and press the soil well around the seedling and shade using coconut leaves or palmyrah leaves or any other suitable shading materials.

9.2. Spacing

For tall varieties of coconut, a spacing of 7.5 m x 7.5 m is generally recommended. If triangular system is adopted, an additional 20 to 25 palms can be planted. If wider spacing is adopted, it provides ample opportunity for intercropping a number of annual and perennial crops in the interspaces, which ensures crop diversity in the plantation. In case dwarf varieties are used for cultivation, there is possibility of reducing the spacing to be adopted.

9.3. Time of Planting

Planting the seedlings during May/October, with the onset of pre-monsoon rains is ideal. In places where assured irrigation is available, planting can be done at least a month before the monsoon sets in to allow seedlings to establish well before the onset of heavy rains. In low-lying areas, planting is to be done in September once the heavy rains ceases.

9.4. Care of Young Palms

The seedlings are to be protected from heavy sunlight by proper shading and irrigated during summer months. In sandy soils, irrigate once in four days with 45 l of water. In areas subject to water logging, proper drainage is to be provided by making drainage channels. Care should be taken to avoid soils covering the collar region of coconut seedlings due to heavy rain. The soil washed down by the rains and covering the collar of the seedlings is to be removed. Widen the pits every year before the application of organic manures and gradually fill up the pits as the young plants grow. Inspect the plants at regular intervals for any insect or fungus attack and necessary remedial measures should be taken up as and when required.

9.5. Irrigation

The coconut palm responds well to summer irrigation. Methods such as drip irrigation or basin irrigation (hose irrigation) can be adopted depending on the situation. Drip irrigation is a micro irrigation system in which the water is applied to the root zone at the rate at which the palm can take up. It is ideal considering the advantage of water saving. Another advantage is that vermiwash and other organic solution also can be applied through drip irrigation *i.e.* fertigation. Make small pits of 30 cm^3 one metre away from the bole of the palm at equidistance and fill the pits with coir pith or locally available mulch. Place a conduit tube of 40 cm length diagonally in the pit and allow water to drip through the tube. Apply water at 66 per cent of open pan evaporation through drip irrigation based on the evaporation. In order to supply 32 l/day, four drippers at a discharge rate of 4 l/hour will be required so that daily two hours of irrigation is sufficient. Where basin irrigation is practiced, 200 l/palm once in 4 days will be beneficial. Irrigation is to be commenced during November when the soil moisture depletes to 50 per cent ASM. In other parts of India especially Tamil Nadu and Andhra Pradesh, irrigation is to be practiced throughout the year except rainy period. Care should be taken to use only uncontaminated water for irrigation. Under west coast conditions of India, irrigation through perfo-sprays 2 cm once in 5 days during December-February and once in 4 days during March-May has been found to be beneficial in sandy loam soil in improving growth of palms.

9.6. Weeding

Generally, weeding is to be done when the monsoon recedes preferably during September- October. Application of any kind of chemical herbicide is not allowed under organic system of cultivation. Therefore, depending on the intensity of weed growth, they are to be removed by hand around the palm base and the weeds in the inter space need only be slashed with sickle. Clean weeding is to be avoided. While weeding, dried shoots and other thrashed materials can be used as mulch around the base of palms, which will help to conserve moisture in the ensuing dry months and help in vermicomposting process in the basin as well as in the interspaces.

9.7. Nutrient Management for Palms in the early Growth Phase

Seeds of any one of the green manure crops such as *Pueraria phaseoloides*, *Vigna unguiculata* (cowpea), *Crotalaria juncea* (sunhemp), *Calopogonium mucunoides* or *Sesbania aculeata* (daincha) may be sown in the palm basin with the receipt of first monsoon rains (May-June and September-October for the areas benefited by South-West monsoon and North-East monsoon, respectively) according to the soil and climatic conditions. The plants are to be uprooted and incorporated *in situ* at the time of flowering one or two plants. If no intercrops are grown in the interspaces, green manures crops can be grown in the interspaces which helps to check the weed growth also.

9.8. Soil and Water Conservation under Rainfed Situations

Conservation of natural resources like soil and water for sustainable crop production under organic farming is very much essential. This is very important when coconut is grown under rainfed condition with undulating terrain and sloppy conditions. Coconut cultivation provides various kinds of organic materials in the plantation. Coconut leaves, husk and coir pith could be utilized as mulches to reduce the loss of soil moisture. Decomposition of such mulch materials after a period of time will result in enrichment of soil organic matter pool and create conditions for proper root growth and proliferation of soil flora and fauna. Coconut husk is an important organic material and a good source of plant nutrients. On dry weight basis, the average composition of material is 0.23 per cent N, 0.04 per cent P_2O_5, 0.78 per cent K_2O, 0.08 per cent Ca and 0.05 per cent MgO. On an average, husk constitutes 45 per cent of the weight of nut and, on this basis, a nut weighing 1,000 g will have 450 g of husk with 20 per cent moisture.

9.8.1. Mulching

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 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. 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. The best time for mulching is before the end of the monsoon rains and before the top soil dries up. For mulching, coconut leaves cut into two or three pieces can be used. In order to cover 2 m radius of coconut

Figure 2.3: Coconut Leaves as Mulch.

basin, 15 to 25 fallen coconut leaves are required to spread in 2- 3 layers. Mulching with composted coir pith to 10 cm thickness (approximately 50 kg/palm) around coconut basin is also ideal method to conserve moisture as it can hold moisture five times of its weight. Because of its fibrous and loose texture, incorporation of coir pith considerably improves the physical properties and water holding capacity of soil and thereby increases the coconut productivity. The applied material may last

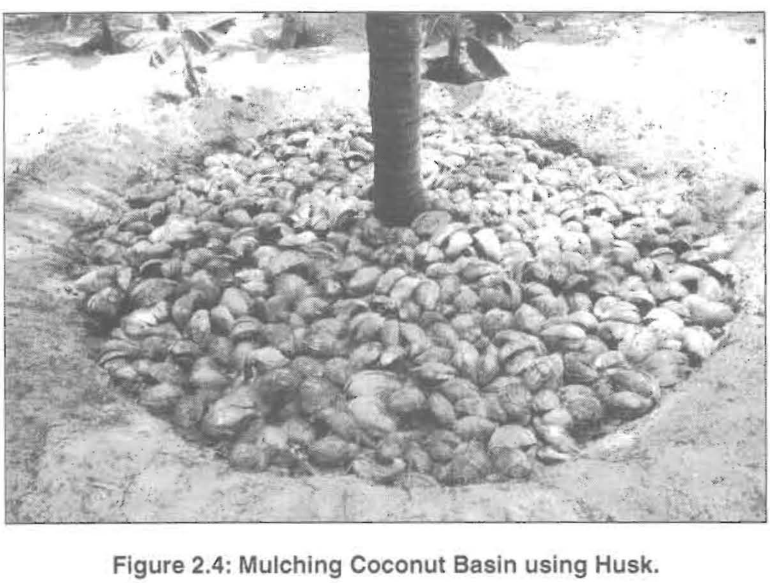

Figure 2.4: Mulching Coconut Basin using Husk.

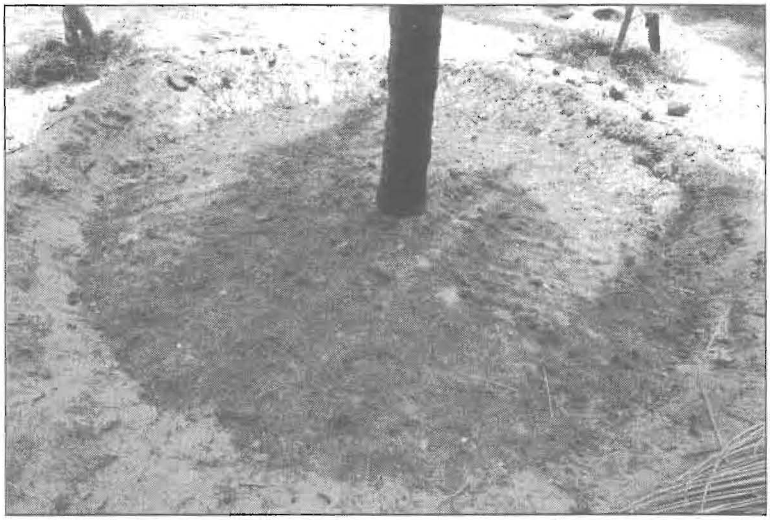

Figure 2.5: Mulching Coconut Basin using Coir Pith.

for about 4 to 5 years. The weeded materials also can be used for mulching and should be properly dried before applying in the basins.

9.8.2. Burying Coconut Husk

Burying coconut husk in trenches in between the rows of palms is also effective for moisture conservation in coconut gardens. This cultural operation is to be done at the beginning of the monsoon in linear trenches of 1.5 m to 2 m wide and about 0.3 m to 0.5 m deep between rows of palms with concave side of husk facing upwards. Each layer is to be covered with soil. Husks can also be used as surface mulch around the base of the palms by placing them in a single layer and keeping the convex side upwards up to a radius of 2 m from the base. Coconut husks are also important sources of potash, which becomes available to the palms over a period of time.

9.8.3. Catch Pit filled with Coconut Husk

Construction of catch pits of 1.5 m length x 0.5 m width x 0.5 m depth in sloppy gardens helps in conserving soil and water. A bund is to be made at the downside using the excavated soil and pineapple suckers planted on it. This pit also is to be filled with coconut husk while taking up planting of pineapple.

9.8.4. Contour Trench filled with Coconut Husk

In plantations, where the land slope is high, this approach is to be adopted. Trenches of 50 cm width x 50 cm depth and convenient length are to be made in between two rows of coconut palms. These trenches are to be filled with coconut husk in layers by keeping the bottom layer facing up and top layer facing down. A bund of 20 cm height and suitable width (>50 cm) is to be prepared at the downstream using the excavated soil and two rows of pineapple plants are to be planted on the bund with a spacing of 20 cm x 20 cm. The pineapple plants are found to stabilize the bund and provide additional income to the farmer. The runoff water from the

Figure 2.6: Catch Pit with Pineapple on Bund.

upper side along with soil particles will be collected in the trenches. Coconut husk kept in the trenches will retain the moisture and makes it available for plants during summer months.

10. Nutritional Management

In an organic production system, the fertility program should be based on materials of microbial, plant or animal origin, such as green manure, compost or mulch, which are organically produced on the farm; or of organic quality, obtained from the surrounding farms or natural environment; or other inputs which are allowed. One of the basic principles of soil fertility management in organic systems is that plant nutrition depends on 'biologically-derived nutrients' instead of using readily soluble forms of nutrients supplied through fertilizers and the idea should be to feed the soil to make it living rather than feeding the plants. Hence, sufficient quantities of biodegradable material of microbial, plant or animal origin should be returned to soil to increase or at least maintain its fertility and the biological activity within it.

Once start flowering, coconut palms produce a spadix in the axil of each leaf, and the yield depends on the number of leaves produced per year. Vegetative as well as reproductive growth goes on simultaneously and hence, nutrition is important all the time. Coconut palms export nutrients to the above ground parts continuously from a limited volume of soil throughout its existence. It is, therefore, essential that a nutritionally rich environment is provided in the root zone of coconut all round the year to realise adequate yields. The organic farm is to be maintained as a closed ecosystem to the extent possible. Soil and nutrient loss through soil wash, run off and percolation water should be minimized through proper agronomic practices. All the crop residues and farm wastes should be recycled through suitable composting techniques and applied to fields so that soil fertility is maintained and nutrient requirement of coconut palms and other crops met.

Regular nutrition from the first year of planting is essential for good vegetative growth, early flowering and bearing and high yields of coconut palms. The inflorescence primordium can be detected about 4 months after the first leaf primordium is differentiated; the male and female flowers, 22 months thereafter. The opening of the fully grown spathe occurs one year later. Any hindrance to successful growth of the tree during these productive phase results in reduction in yield and the cumulative effect of these adverse growths appears only after two-three years. Therefore, the crop production practices require the need for uninterrupted application of inputs over longer periods to ensure continuous flow of returns. A deficiency in potash will result in a large reduction of yield for coconut palms. The vast majority of the potassium is thereby contained in the husk and fruit water of the coconuts. In cultivation systems which include cocoa, returning the cocoa shells to the site will supply sufficient potassium to balance out the extraction. The continual pruning of crops on diversified agroforestry systems also will provide an important source of nutrients (*e.g.* of potassium).

10.1. Cultivation of Legumes (Green manures or deep-rooted plants)

The coconut palm is cultivated in humid tropical soils characterised by low organic matter content due to the higher pace of degradation of organic materials caused by heavy rain fall, optimum temperature and porous soil texture. The major portion of inorganic N, wherever applied, is lost through leaching. Organic manures are important in sustaining soil fertility and productivity especially with a perennial crop like coconut. Application of organic materials like coconut coir pith, miscellaneous tree leaves, cattle manure *etc.* are recommended for coconut. However, due to the non-availability of land for exclusive cultivation of green manure crops and also the short supply of cattle manure for use as organic manure, organic manuring is practiced only in limited scale in coconut cultivation.

The Soil Science Society of America in 1971 described green manure as "plant material incorporated with the soil while green or soon after maturity for improving the soil". In practice, it includes *in situ* growing and incorporation of biomass or collection and ploughing of the biomass grown outside the main field. The best known and popular green manure crops are those, which fix nitrogen in association with *Rhizobium*. Biomass production of green manure crops and their nitrogen and phosphorus contents vary widely according to the species, their growth stage, environmental conditions, soil fertility and crop management practices. The basin area of 1.8 to 2.0 m radius around the bole of coconut palm generally is left unutilized by most of the farmers for any other purpose. Wherever the inter space between the palms is cultivated with intercrops such as tuber crops, cocoa, pepper and banana, green manure crops can be raised in the coconut basins. If vermicomposting is practiced in trenches taken in between coconut rows, green manure crops can be grown in the basins. Cultivation and incorporation of green manure result in significant increase in the population of specific groups of microorganisms as well

Figure 2.7: Green Manure Crop in Coconut Basin.

as the enzymatic activities, which suggest a modification in the soil environment to the benefit of plant growth.

Nitrogen fixed symbiotically by legume-rhizobium association can form an important source of nutrients and organic manure for coconut palms. Leguminous green manure crops such as *Pueraria phaseoloides, Mimosa invisa, Calopogonium mucunoides, Crotalaria juncea* (sunhemp) and *Vigna unguiculata* (cowpea) can be successfully raised in coconut basins. The biomass production and nitrogen contribution by green manure legumes and their influence on soil fertility parameters vary with soil type, climatic factors and type of green manure raised. Sow 100 to 150 g seed of any of the green manure cover crop mentioned above in coconut basins with the onset of the pre-monsoon in May. Sowing during heavy rainfall should be avoided. Among these leguminous crops, the former two species are preferable because of shade tolerance, self seeding nature and higher biomass productivity. Stir the soil around the basin in 1.8 to 2.0 m radius area lightly and broadcast the seeds uniformly and later on cover them by slight raking. Allow the plants to grow in the basin and harvest the biomass as and when one or two plants start flowering and put back into the basin and cover with soil. While doing so, the soil should be disturbed to the bare minimum.

On an average about 15-20 kg green biomass could be generated in the basin of coconut palm and their incorporation can contribute around 100-150g nitrogen/ basin and other major nutrients as well as enhance the population of specific groups of beneficial micro organisms (bacteria and nitrogen-fixers) in the basin thereby improving the soil fertility. The significant increase in the population of micro organisms and the enzymatic activity modifies the soil environment for the benefit of palm growth. When irrigation is practiced, sowing of green manures may be undertaken twice in a year. The method of cultivation of green manure in coconut basin is simple, inexpensive and can be adopted even by small farmers. With continuous cultivation of legumes, it is possible to improve soil organic matter resources for sustaining soil fertility and enhance coconut yield. Besides legumes, several other plants may be used as green manure. For example, water hyacinth (*Eichhornia crassipes*) which grows wildly in stagnant and backwaters in Kerala contains 2.0 per cent N on dry weight basis and some sea-weeds containing 1-2 per cent N, may be used for manuring crop in coastal areas like Kerala.

10.2. *Glyricidia sepium* as Green Manure

Generation of large quantities of nitrogen rich biomass is also possible through the cultivation of the fast growing perennial leguminous green leaf manure tree crops. A fast growing multipurpose tropical leguminous tree, *Glyricidia sepium* with high nitrogen fixing potential is well adapted in coconut growing soils. This can be very well grown along the borders of coconut plantation also and can generate adequate amount of nitrogen rich green leaves. The boundary of one hectare coconut garden can accommodate 450 to 500 cuttings. It can also be raised in littoral sandy soils where no other green manure can establish. *Glyricidia sepium* is propagated either through vegetative cuttings or seeds. One metre long stem cuttings or 3 to 4 months old seedlings raised in poly bags or raised beds can be used for planting. It is preferable that the planting season coincides with the monsoon (South West/ North East monsoon). For better establishment, a basal dose of 50 g of rock phosphate per pit (30 cm^3) may be applied. Height of the plants should always be maintained at 1 m by pruning.

Figure 2.8: Growing Glyricidia as Green Manure Crop.

The best growth and biomass of Glyricidia leaves could be obtained with planting of three rows of Glyricidia (at 1 m x 1 m spacing between two rows of coconut) and three pruning of leaves (February, June and October). Pruning can commence one year after planting. This could produce around 8 t of biomass in one hectare of coconut garden and about 10 kg green manure/palm/year can be made available to the palm. The loppings can be chopped and incorporated into the soil as green manure. Application of Glyricidia prunings from the interspaces of one hectare of coconut garden to palms could supply around 90 per cent, 25 per cent and 15 per cent of the requirement of N, P and K, respectively.

10.3. Biofertilizers in Organic Cultivation

The traditional additives for improving soil health and fertility in organic farming comprises of farm yard manure, composts and vermicomposts, sewage and sludge, night soil, green manure, oil cakes, meat, blood and fish meal as well as crop residues. With increasing awareness of contribution of soil microorganisms towards the soil health and fertility, use of microorganisms as biofertilizers has gained importance for improving the soil health and fertility. Bio-fertilizers are microbial inoculates containing active strain of selective microorganisms like bacteria, fungi, and algae or in combination. Biofertilizers are important components of organic farming, which help to nourish the crops through required nutrients. These microbes help to fix atmospheric nitrogen, solubilize and mobilize phosphorus, translocate minor elements like zinc, copper, *etc.*, to the plants, produce plant growth promoting hormones, vitamins and amino acids and control plant pathogenic fungi, thus helping to improve the soil health and increase crop production.

The group of micro-organisms responsible for biological nitrogen fixation, phosphorus mobilization and production of plant growth promoting substances have been found to be closely associated with the coconut palms and the palms can benefit from the use of beneficial micro-organisms as biofertilizers. The diazotrophic bacteria isolated from coconut roots include different species of *Azospirillum, Herbaspirillum* sp. *Azoarcus* sp., *Burkholderia* sp., *Arthrobacter* sp.,*Pseudomonas* sp. and *Bacillus* sp. Phosphate solubilizing microbes of coconut soil include *Pseudomonas* sp., *Bacillus* sp. and *Micrococcus* sp. Efficient strains of nitrogen fixing bacteria and phosphate solubilisers can be used for preparation of biofertilizers employing locally available materials such as vermicompost and coir pith as carrier materials. Enhancing the soil fertility by using *Rhizobium* sp. in conjunction with green manure crops like *Pueraria phaseoloides, Mimosa invisa* and *Calopogonium mucunoides* supplements 187 to 196 g N per coconut basin in laterite soils and 102 to 153 g N per coconut basin in sandy soils. Stem nodulating legumes such as *Sesbania rostrata, Aeschynomene* sp. and *Neptunia oleracea* have also become popular in improving the soil fertility. The N-fixing bacteria associated with such stem nodulating legumes belong to *Azorhizobium* and fast growing species of *Rhizobium.*

Bacteria such as *Pseudomonas* and *Bacillus* excrete acids into growth medium and hence solubilize bound phosphates. These organisms are quite useful in utilization of rock phosphates with low content of P_2O_5.

The population of phosphate solubilizing bacteria and fungi will be higher in coconut based high density multiple species cropping, multi-storied cropping with cocoa and mixed farming with napier grass as compared to that of coconut monocrop. Rhizosphere bacteria that exerts beneficial effect on plant growth, referred to as plant growth promoting rhizobacteria (PGPR),belonging to several genera *e.g. Actinoplanes, Agrobacterium, Alcaligenes, Amorphosporangium, Arthrobacter, Azospirillum, Azotobacter, Bacillus, Bradyrhizobium, Cellulomonas, Enterobacter, Erwinia, Flavobacterium, Pseudomonas, Rhizobium, Streptomyces* and *Xanthomonas*. *Bacillus* spp. are suitable due of their endospore producing ability. More recently *Pseudomonas* spp. are also receiving much attention as PGPR because of their multiple effects on plant growth promotion. Species of *Pseudomonas* and *Bacillus* can produce phytohormones or growth regulators that cause crops to have greater amounts of fine roots, which have the effect of increasing the absorptive surface for uptake of water and nutrients. These PGPR are referred to as biostimulants and the phytohormones they produce include IAA, cytokinins, GA and inhibitors of ethylene production. Bacteria in the genera *Bacillus, Streptomyces, Pseudomonas, Burkholderia* and *Agrobacterium* are the biological control agents. They suppress plant disease through induction of systemic resistance, and production of siderophores or antibiotics.

Utilization of vermicompost produced from coconut leaves results in the production of high quality biofertilizers with more than 10^8 cfu bacteria per gram of the carrier material. The recommended dose of biofertilizer for coconut is 100 g of carrier based inoculants per palm. The biofertilizer is to be applied in the coconut basin, twice in a year (pre monsoon and post monsoon), by mixing with top soil followed by application of organic amendments. Organic amendments such as vermicompost, coir pith compost, farm yard manure, neem cake, green manures *etc.* can be combined with biofertilizers. While applying biofertilizers, organic amendments such as vermicompost are added @ 20 kg/palm. Use only certified biofertilizer inoculants. The biofertilizer should be mixed with one kg vermicompost and applied to soil and incorporated. Care should be taken to use only biofertilizer containing adequate number of living micro organism and before the expiry period mentioned in the packet.

Optimum soil moisture is essential after biofertilizer application to ensure the survival of the introduced microbial inoculum in the soil. Hence, biofertilizer application should coincide with the onset of monsoon especially when the palms are maintained under rainfed condition. However, under irrigated conditions, it can be applied at any time, since maintaining optimum moisture is not a problem. Use of biofertilizers in coconut gardens can reduce dependency on chemical fertilizers and thus bring both economic and ecological benefits. Among the microorganisms that are promising enough to fit well into the coconut based cropping systems are the mycorrhizal fungi and certain other free-living microorganisms with specific functions. The group of microorganisms responsible for nitrogen fixation, phosphorus mobilization and production of plant growth promoting substances are used as biofertilizers in coconut based cropping systems.

The inoculation of associative diazotrophs such as *Azospirillum, Arthrobacter, Azoarcus, Herbaspirillum, Bacillus, Burkholderia* and *Pseudomonas* enhances growth and vigour of polybag raised coconut seedlings. These bioinoculants are highly effective in enhancing root biomass and branching of the secondary roots of the coconut seedlings. Organic amendment along with microbial inoculation brings

Figure 2.9: Kera Probio and Cocoa Probio.

about a greater level of plant response.The beneficial nature of biofertilizers becomes even more important in coconut based mixed cropping/farming systems as the component crops continually add plant residues to the soil which undergo organic recycling. This leads to alterations in the composition of the rhizosphere, which promotes the growth and population of beneficial microorganisms. Inclusion of livestock enterprises also creates a favourable environment for proliferation of beneficial microflora. In mixed cropping, dominated nitrogen-fixing microbial group is the bacterium *Beijerinckia* and phosphate-solubilizers such as *Pseudomonas* sp., *Bacillus* sp., *Aspergillus* sp. and *Penicillium* sp. are present in higher numbers. Not only this, higher inhibition potential of resident soil bacteria to phytopathogens is seen in coconut based cropping systems when compared to coconut monocropping systems. When coconut is grown with cocoa, rhizosphere activity increases and a better mobilization of phosphates take place coupled with fixation of nitrogen and production of growth substances such as auxins and gibberellins in rhizosphere, which is observed to enhance yield. Inoculation of *Azospirillum brasilense* in polybags helps in enhancing the vigour of coconut seedlings by inducing profuse growth of root biomass of coconut seedlings.

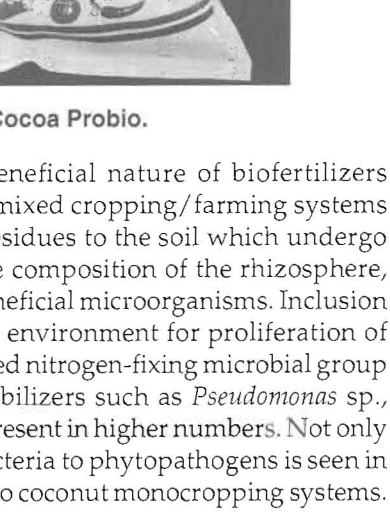

Figure 2.10: CPCRI 'Ker AM'.

Soil amendments as well as farming practices also bring about a protracted change in rhizosphere microflora, which favour the growth of specific microorganisms, thus leading to better plant growth and crop yield. For example, organic amendments like cow dung increase VAmycorrhizal colonization as well as the population of phosphate solubilizing bacteria in the root zone of coconut palms. Other organic amendments such as farm yard manure, coir pith, neem cake and green manures, *etc.* can be combined with microbial inoculants like *Beijerinckia indica* for improving the nitrogen fixation by indigenous diazotrophs in coconut soils.Arbuscular mycorrhizal symbiosis can improve host responses to other environmental limitations, like drought, salinity, pollutants, erosion, and infection by pathogenic fungi. In India, a number of fungi belonging to four genera *viz., Glomus, Gigaspora, Sclerocystis,* and *Acaulospora* have been found to form mycorrhizal associations with coconut. The occurrence of a mixed population of AM has been commonly recorded from the coconut rhizosphere soils. The colonization rate is higher in tall varieties compared to dwarf ones. Two PGPR based bioinoculants, *'Kera Probio'*, a talc formulation of *Bacillus megaterium*, effective for raising robust coconut seedlings, and *'Cocoa Probio'*, containing *Pseudomonas putida*, effective for raising healthy cocoa seedlings, have been developed at ICAR-CPCRI. Both these bioinoculants were also found to be effective for vegetable crops such as tomato, brinjal and chilli.

Similarly an Arbuscular Mycorrhizal bioinoculant, *'Ker*AM*'*, has been developed at ICAR-CPCRI, which is a soil based AMF bioinoculant for coconut seedlings. The bioinoculant contains *Claroideoglomus etunicatum*, one of the dominant AM species isolated from coconut agro-ecosystem with high potential to increase the growth parameters of coconut seedlings.

10.4. On Farm Biomass Recycling

Organic materials influence the physical, chemical and biological characteristics of soil, which in turn affect growth, development and yield of crops grown in a particular soil. The level of nutrient extraction in a coconut palm/mixed cropping system can be balanced by encouraging the decomposition of organic materials made available through mulching material, green manure crops and application of composts.The availability of waste biomass in the form of coconut leaves, stipules, spathe, bunch waste and husk from a well-managed coconut plantation with 175 palms/ha has been estimated as 14 to 16 tonnes per hectare per year. Coconut based cropping/farming system with inter/mixed crops generate still higher quantities of biomass. The natural decomposition of these wastes and the nutrient release are very slow due to the high lignin content and the nature of lignocellulose complex of the coconut waste materials. By effective recycling of this waste-biomass, the requirement of a major portion of nitrogen and a part of other nutrients of crops could be met. It also helps to replenish the nutrients exhausted by the palms internally without depending on the external sources. The estimates indicate that the biomass production by coconut-pineapple cropping system will be 4.3 times that of pure coconut stands. Studies at Kasaragod have revealed that cocoa as a mixed crop in coconut garden added to the soil 818 and 1985 kg (oven dry wt.) per hectare per year of biomass through shed leaves and pruning under single and double hedge systems, respectively. As much as 50 kg N, 4.85 kg P and 29.1 kg K per hectare could be returned to the soil every year under the double hedge cocoa system (Varghese *et al.*, 1978). The addition of large amount of organic refuses by the cocoa was found to improve the soil physico-chemical characteristics and thereby positively influence the yield of coconut. The availability of biomass for recycling in the high density multispecies cropping system was around 12.7 t to 18.2 t per hectare in terms of fronds, bunch waste and other organic materials in case of coconut, fallen leaves in clove, above ground biomass for banana, crown and leaves in case of pineapple *etc.* This biomass, if recycled, and applied into the land can enhance the productivity and sustenance of the system in terms of nutrient need besides economic benefits.

Integration of crops and livestock in mixed farming is also widely practiced in majority of the coconut growing areas and they generate additional income, provide relief against the fluctuating prices of nuts, generate more employment as well as provide large quantity of biomass for recycling. Mixed farming involves integrating animal enterprises such as dairy, poultry, duck rearing and aquaculture and cultivation of shade tolerant fodder crops in the interspaces of coconut as well as effectively recycling all the organic residues. The animals not only enhance the nutritional status of the household members but also help to augment the farm income by the sale of milk, eggs and other products. While the crop residues and fodder provide animal feed, the manure and litter of the livestock provide renewable sources of organic matter and plant nutrients. They help reduce dependence on fertilizers and maintain soil health, resulting in a high degree of organic recycling. Here the system is kept productive by maximizing the complementary and synergistic effects of the components involved. Such recycling of waste will improve the soil health and, thus, provide ecological sustenance to the system. Microbial biomass and activities of soil enzymes (phosphatase and dehydrogenase) will also be more in the farming system when compared to the mono culturing of coconut. Fodder grasses such as hybrid Napier and Guinea grass can yield about 50 to 60 tonnes of fodder per hectare in a year under coconut shade. This will be sufficient to maintain five crossbred milch cows and provide enough farm yard manure that can be used as a component for meeting the on farm organic manure requirement of the system. This will also increase the labour opportunities in the farm. Biogas plant of suitable capacity can also be installed in the farm for production of biogas for use in the farm house and slurry for manuring coconut and other component crops.

10.5. Vermicomposting for on farm Waste Recycling

Vermicomposting involves conversion of biomass into useful compost using very efficient strain of epigeic earthworm belonging to *Eudrilus euginae,* or other earthworms which can be easily done *in situ* in coconut plantations using coconut leaves and other biomass including wastes from intercrops especially from banana. When the organic wastes available from a plantation are recycled through vermicomposting, it can supply the major portion of nitrogen and a part of other nutrients required by the palms. The leaf dry matter production by tall coconut palms is around 32 kg/palm/year and hence the availability of leaf from one hectare of coconut plantation can be estimated as 5.6 t per hectare per year. In this manner all the leaves produced from one coconut palm can be converted into very good organic manure. Apart from coconut leaves, other agro-wastes like pineapple waste, banana pseudo stem and leaves and glyricidia green manure can also be effectively used along with coconut leaves for vermicomposting. Hence, the agro-wastes generated from coconut based cropping system can also be recycled efficiently in the production system. Various methods such as cement tanks, trenches as well as composting in the coconut basin itself can be adopted for vermicomposting wherein composting in the basins itself reduces the cost of transportation of leaves and application of vermicompost. Vermicomposting can also ideally be done in permanent cement or brick tanks constructed under shaded conditions to maintain appropriate quantity of substrate, optimum moisture, temperature which are necessary for efficient vermicomposting.

The weathered wastes obtained during rainy seasons are preferred. These organic wastes are to be treated with cow dung @ 10 per cent by weight in the form of slurry and must be allowed to undergo a preliminary decomposition for about 2 –3 weeks. The earthworms @ 1000 worms per tonne of coconut leaves are to be introduced. 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. Regular watering is to be done to maintain enough moisture.The low cost vermicomposting technology enables production of high quality organic manure from coconut leaves in a period of 60-75 days, leaving behind only a portion of un-decomposed material.The indigenous earthworm *Eudrilus* sp. also has affinity for wastes other than coconut leaf wastes. A coconut garden, where other intercrops/ mixed crops are grown, generates leaf wastes from these intercrops also. All these mixture of wastes can be successfully composted using *Eudrilus* sp. earthworm. It has been found that coconut leaves can be mixed with pineapple waste, banana pseudo stem or glyricidia leaves in 3:1 ratio for effective utilization of other wastes commonly produced in coconut based cropping system.

The average nutrient composition of the vermicompost recovered will be around 1.2-1.8 per cent (N), 0.1-0.2 per cent (P) and 0.2-0.4 per cent (K), organic carbon (17.84 per cent), and C/N (9.95:1). The composted palm wastes also contain higher levels of micro nutrients such as Fe, Zn, Cu and Mn when compared to that of the untreated substrate.

The C/N ratio of the organic matter ingested by the earthworm decreases and bound nutrients are converted into easily available forms. The passage of organic matter through the gut of earthworms results in enhanced availability of nutrients, increased counts of microbes and enrichment with a number of bio-active compounds. Thus, vermicompost increases soil fertility through addition of plant nutrients, growth hormones, increased level of soil enzymes and important micro-organisms as they are rich in microbial diversity, population and activity. Total microbial counts and beneficial microbial population will also be more in the coconut leaf compost compared to the base material. This enables disposal of coconut wastes in a less expensive way and eco-friendly manner with the benefit of producing high quality organic manure in the coconut plantation itself.

10.6. Vermicomposting in the Coconut Basin

The same technology for vermicomposting could be taken up in large pits taken in the inter spaces of four coconut palms in sandy loam and coastal sandy soils. If vermicomposting is done in the field itself, lot of labour required for transportation of the biomass and compost can be saved. This technology is also suitable for plantations having limited irrigation facilities, as only a few pits or trenches are to be watered. With minimum soil disturbance, open a basin with a radius of 2 m from the trunk. Cut the fallen dried coconut leaves from individual palm into two or three pieces and spread them in the basin in such way that the leaflets can hold water to hasten pre composting process. As a first step, begin the initial vermicomposting with the addition of five to six coconut leaves. Later, add more leaves in respective basins as and when available. In areas, where palms are grown under rainfed condition, vermicomposting is feasible only in the rainy period and hence, it may be started with the beginning of monsoon season. In fields where irrigation is adopted, maintenance of optimum moisture is easy and hence, year round vermicomposting is possible. After completion of the process of pre curing for three weeks, apply cow-dung @ 10 per cent of leaf weight and release around fifty earthworms of *Eudrilus* sp. to each basin. Wherever possible, the cow dung should be obtained from the organically maintained dairy unit. Cover the basin with suitable mulch material such as dried weed material *etc*. In case of continuous rainfall, care should be taken to drain excess water in the basin to avoid water stagnation.

The vermicomposting system should be kept adequately moist at 40 to 50 per cent as deficit in soil moisture will result in death of worms and it necessitates further application of earthworms. Vermicomposting directly in coconut basins not only provides major, secondary and micro nutrients, but also acts as mulch, improves soil physico chemical properties, suppresses weed growth and ensures higher microbial population build up thereby enhancing soil health. Continuous supply of biomass materials in the basins is to be ensured for effective functioning of earthworms. Advantage of this system is that all the coconut leaves and weeds added into the basin are completely composted. By this method, around 25 to 30 kg of vermicompost is added per palm per year.

10.7. Vermicomposting in Trenches

Vermicomposting in trenches can also be done by opening trenches of 1.5 m width and 1.0 m depth in interspaces of coconut garden. Apply fallen dried leaves in such trenches, apply cow dung @ 1:10 (cow dung: coconut leaves) and release earth worms @ 1:1 (1 earthworm per kg of dried leaves).Other organic materials *i.e.*, dry weeded materials can be also applied in the trenches. Proper turning of the added materials should be done for adequate aeration and to hasten vermicomposting process. Newly fallen dried leaves can also be placed in the trenches as and when available. Once the vermicomposting is completed, remove the vermicompost and apply to coconut palms. This method can be practiced even under limited irrigation or when palms are maintained under rainfed conditions. By this method, it could be possible to produce vermicompost for application @25 to 30 kg per palm per year. *In situ* recycling of coconut wastes by vermicomposting in trenches dug in interspaces of four coconut palms yield on an average recovery of 70 per cent in a composting period of 90 days.

A long term study (>10 years from 2003-04 to 2013-14) conducted at ICAR-CPCRI, Kasaragod clearly indicated the possibility of organic farming in coconut under coastal ecosystem. The increase in yield for West Coast Tall variety of coconut was 75 per cent (from pre-experimental yield of 55 nuts/palm/year to 96 nuts/palm/year), while that of Chandrasankara (COD x WCT) was 59 per cent (from pre-experimental yield of 68 nuts/palm/year to 108 nuts/palm/year). The practice of vermicomposting the recyclable biomass in trenches made in the interspaces, application of biofertilizers (Phosphobacterium and Azospirillum @100 g/palm) and raising leguminous cover crop in basins and its incorporation was found to be the best for improvement in soil nutrient status, enhancement of soil microbial population, as well as nut yield and copra content.

10.8. Vermicomposting in Tanks

Vermicomposting of coconut wastes can also be done in cement tanks. The weathered coconut leaves collected from the garden should be kept for two weeks

Figure 2.11: Vermicomposting in Tanks.

after sprinkling with cow dung slurry. Apply cow dung @ one tenth of the weight of dried leaves and release earth worms @ one kg for one tonne of the material. Sufficient moisture is to be provided for the decomposing material by frequent sprinkling of water. Direct sunlight is to be avoided. Vermicomposting will be completed in about 75-90 days. Stop providing water one week before collecting the compost. On an average, 70 per cent recovery of vermicompost could be obtained.

The vermicompost produced from coconut leaves using the technology developed at ICAR-CPCRI is now available by the trade name 'Kalpa Organic gold'.

Figure 2.12: Kalpa Organic Gold.

10.9. Multiplication of *Eudrilus eugeniae* CPCRI Strain

The earthworms can be multiplied in a 1:1 mixture of cow dung and decaying coconut leaves taken in a cement tank or wooden box or plastic bucket with proper drainage facilities. The nucleus culture of earthworms is to be introduced into the above mixture @ 50 per 10 kg of organic wastes and properly mulched with grass, straw or wet gunny bag. Keep the unit in shade and maintain sufficient moisture level by occasional sprinkling of water. The earthworms will multiply to 300 times within 30 to 60 days, which can be used for large scale composting.

Figure 2.13: Multiplication of Earthworm.

10.10. Production of Vermiwash

Vermiwash is a by-product obtained from vermicompost production technology that can be used as a liquid organic manure for improving crop growth and yield. The water-soluble components from vermicomposting tanks may be collected as leachate by passing water slowly through the composting beds or by simple suspension of vermicompost in water. This vermiwash is honey-brown in colour with a pH of 8.5 and contains both major and minor nutrients in appreciable quantity (Table 2.6). Growth promoting hormones like IAA and GA are also present in vermiwash. Vegetables and ornamental plants respond very well to its application. Vermiwash has been found to be effective as foliar spray for growth promotion and bio suppression of pathogens in crop plants. All the physiologically active water soluble components of vermicompost such as humic acids, plant growth regulators, amino acids, vitamins, micro nutrients and microbial cells are extracted in water and is known as vermiwash. Vermiwash produced from actively vermicomposting substrates of coconut leaf + cow dung by *Eudrilus* sp has an alkaline pH, contains

Figure 2.14: Collection of Vermiwash.

major and minor nutrients, growth hormones, humic acid and plant beneficial bacteria.

Table 2.6: Characteristics of Vermiwash from Coconut Leaf Vermicompost

Nutrient	Concentration (ppm)	Nutrient	Concentration (ppm)
N	2.8	P	10.2
K	205	Ca	37.9
Mg	6.5	Fe	Traces
Cu	Traces	Zn	0.07
Mn	0.17		

Field trials conducted in farmers' plots with bitter gourd, cowpea, amaranthus, and chillies indicated that application of vermiwash results in yield of crops on par or slightly lower than the plots that received regular fertilizer inputs. Such application results in healthy plant with lesser pest and disease damage, larger and deep leaf colours, longer ability of plants to stay without wilting in field as well as longer time of remaining fresh in case of amaranthus after harvesting, more freshness of fruits *etc.* There will also be increase in soil microbial populations, soil dehydrogenase, phosphatase and urease enzyme activities and organic carbon content of soil. The population of the nematode, *Meloidogyne incognita* and gall formation could also be checked with application of vermiwash. Vermiwash can be applied either through foliar spray or soil drenching. It should be applied @ 1: 5 dilution. It has been found to be effective as foliar spray for growth promotion and bio suppression of pathogens in crop plants.

10.11. Vermicomposting of Coir Pith

Coir pith, a by-product obtained after extraction of coir fibers from husk, often accumulates as waste around the coir fiber extraction units and cause environmental hazard. Extraction of one kilo gram of coir fibre generates two kilo grams of coir pith. This spongy cork-like material left as such is normally resistant to biodegradation. Approximately 180 g of coir pith is obtained from the husk of one coconut. It is acidic in nature and has low bulk density and porosity. Though coir pith has a number of beneficial properties like improving soil physical properties and moisture holding capacity to a great extent, its direct utilization as manure is not advisable as it contains large amounts of lignin (75 per cent) and phytotoxic polyphenols and less of nitrogen. The C:N ratio is more than 100:1. Hence, it is to be applied to soil only after composting. This coir pith can be converted into compost either through the use of local species of *Eudrilus* or through microbial degradation, and the final product can be used to improve soil physical properties and moisture holding capacity to a great extent. The composted coir pith has near-neutral pH, a C: N ratio in the range nearly 20–27, per cent N and per cent K ranging above 1 and stable CO_2 evolution after 60–65 days of composting. *Pleurotus* spp. also has the capacity to degrade part of the cellulose and lignin present in coir pith by production of enzymes *viz.*, cellulases and lactases. The lignin content also reduces considerably.

Preparation of vermicompost from coir pith on a large scale would bring back both economic and environmental benefits. Composting of coir pith can also be achieved by inoculation of biopolymer degrading microorganisms at 0.2 per cent level. Studies conducted at ICAR-CPCRI have resulted in the isolation of efficient strains of fungi with high lignocellulose degradation capabilities, from naturally decomposing coconut wastes. *Marasmiellus troyanus* and *Trichoderma* inoculations were found to be effective in production of quality compost from coir pith. Co-composting of coir pith can be done using poultry manure, lime and rock phosphate @ 10 kg, 0.5 kg and 0.5 kg, respectively for every 100 kg of coir pith. This brings about bioconversion of coir pith to a final product in 45 days. The composted coir pith can be used as manure in coconut plantations and can increase the capability of soils to store moisture and nutrients. The coir-pith compost, thus, produced using the co-composting technology developed at ICAR-CPCRI has been released by the trade name 'Kalpa Soil Care'.

Figure 2.15: Kalpa Soil Care.

11. Biochar

Biochar is a charred solid material obtained from thermochemical conversion of plant derived biomass in an oxygen limited environment. Biochar could be produced from coir pith and tender nut husks, a waste produced from coir industries and tender nut parlours, respectively, using a charring kiln. Biochar is alkaline in nature

Figure 2.16: Biochar from Coir Pith.

and its application improves C sequestration in soil, promotes microbial activity and soil nutrients and physical properties.

Figure 2.17: Biochar from Tender Nut Waste.

12. Coconut-based Cropping System

In many coconut growing countries, coconut as a mono crop is only marginally productive and profitable and hence, a cropping system involving inclusion of compatible crops is necessary. The interplay of various factors like limited size of holding, number of trees, needs of the family, labour requirement for crop, year round returns, easiness of marketing are some of the considerations for the farmer to diversify his farm operations for higher returns by adopting intercropping, mixed cropping or introducing other enterprises like dairy, poultry *etc.* in the system. Under coconut based cropping system, the same land can be put to use to produce other crops so that the productivity of the land can be increased.

The rooting pattern of coconut palm, like other monocots, has a typical adventitious root system and about 74 per cent of the roots produced by a palm under good management do not go beyond 2m lateral distance and 82 per cent of the roots are confined to 30 to 120 cm depth of soil. In coconut gardens with a square system of planting with 7.5 m x 7.5 m spacing, the active root zone of coconut is confined to 25 per cent of the available land area and the remaining 75 per cent of the planted area left unutilized, which could be profitably exploited for raising subsidiary crops. The venation structure of the coconut crown and orientation of leaves allow considerable portion of incident solar radiation to pass through the canopy and fall on the ground. The space utilization of coconut is very low, and therefore, plenty of sunlight falling on the ground remains unutilized. As much as 56 per cent of the sunlight is transmitted through the canopy during peak hours (10.00-16.00 hrs) in palms aged around 25 years. This diffused sunlight facilitates growing a number of crops in the interspaces.

Based on the growth habit of the palm and the amount of light transmitted through its canopy, the life span of coconut palm is divided into three distinct phases. Good light transmission will be there in the initial growth phase of the palms (from planting till full development of canopy *i.e.* up to 8 years) and this period is suitable for growing intercrops with minimal competition. There will be maximum ground coverage (80 per cent) for young palms (9-25 years) with low canopy due to shorter trunk and therefore, the poor light availability in the plantation makes it not suitable for growing of many crops in the interspaces. However, shade tolerant crops could be accommodated as intercrops. Grown up palms above 25 years facilitates gradual increase in the amount of light penetration to the ground and the decrease in ground coverage of canopy makes the condition suitable for raising annual/perennial crops. Such cropping system with cultivation of a variety of biotopes will provide congenial habitats for useful insects and special bees – which both contribute to the fertilising of coconut palms and improve the productivity.The crops are to be selected based on their shade tolerance and amount of solar radiation available. It should not grow as tall as coconut and should not have an economic life longer than the main crop. Availability of resources like rainfall, irrigation facilities, soil characteristics, labour, farmers needs and market demands are some of the factors to be considered while selecting the crop combinations in a coconut based cropping system.

By applying the basic principles of organic farming for designing and developing low cost technologies based on the local resources, soil productivity as well as coconut yield could be considerably improved. These agrotechnologies integrate ecological principles into intensification process and ensure that plant nutrients are in constant and close cycling within soil and plant compartments with minimal losses from the system. Technologies have been developed for production of sufficient quantities of organic matter for recycling, production of high quality composts, conservation of soil organic matter, prevention of loss of nutrients, recovery of lost nutrients *etc*. Enhancement of biodiversity is the primary principle used to evoke self-regulation and sustainability in agro-ecosystems and when biodiversity is restored, a number of complex interactions between soil, soil organisms, plants and animals are established, giving stability to the organic farming system. The integrated farming system in coconut holdings is an interactive practice in which integration of coconut farming with suitable inter/mixed crops, livestock and other allied enterprises are undertaken with the aim of increasing income. The production alternatives can be a single intercrop, a mixture of crops, or a crop/livestock combination which are compatible with each other and other environmental factors. One of the most common farming systems practiced by coconut growing traditional farmers is the coconut-based farming system (CBFS). This is a multiple cropping or crop/livestock production system aimed at maximizing or complementing the benefits that can be derived from coconut. Different crop combinations are recommended by research to suit the availability of resources, sunlight, rainfall, irrigation and soil characteristics. It ensures optimal utilization and conservation of available resources and effective recycling of farm residues within the system. Coconut, being a voracious feeder, removes large quantity of nutrients from the soil for its growth and production of numerous energy giving materials. A bearing palm producing 50 nuts per year removes 390g nitrogen, 100 g phosphorus and 1 kg potash in each year.

Since almost all parts of the palms are used, chances of recycling biomass from coconut are less. Hence, regular application of manures is essential, especially in the traditional areas to compensate this and to maintain the soil fertility at optimum level for sustainable coconut production. Coconut based integrated cropping systems enables better utilization of natural resources and improves the soil fertility due to the continuous biomass addition by the subsidiary crops. Hence, it is recommended as one of the management practices to increase the productivity of coconut by enriching the soil fertility and also for generating higher income from unit holdings.

The farming/cropping systems designed based on local resources and needs consider the whole farm as a single unit and all components are given importance in the functioning of the system. These systems create conditions and microclimate suitable for the multiplication and activity of a variety of beneficial organisms. They protect soils from direct sunlight and rainfall and thus preserve soil organic matter reserves. As many component crops are involved, soil resources are utilized to the maximum extent, thus preventing the loss of nutrients from 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. These systems can be adopted even by small scale

Figure 2.18: Cocoa as Mixed Crop with Coconut.

farmers and coconut based homestead farming. Coconut based farming system (CBFS) can be adopted by many small scale farmers as a self sustaining and risk minimizing strategy. The rationale is that the productivity of the coconut land can be increased. In large scale farm operations, CBFS is also adopted because it provides an efficient resource allocation strategy and minimizes input costs. The adoption of CBFS encourages improved husbandry practices, increases the productivity of coconut land, and enhances the viability of coconut ventures.

13. Coconut-based Multi-storey Cropping System

A multi-storey cropping system is a more complex CBFS, developed to accommodate two or more intercrops of different heights, canopy patterns and rooting systems, to maximize the use of available sunlight, nutrients, moisture and land area under coconut, with the fundamental objective of increasing the productivity of coconut land. The high density multispecies cropping system (HDMSCS) involves growing a large number of crops at very high plant population per unit area to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash. They are ideally suited for smaller units of land and aim at maximum production per unit area of land, time and inputs with minimum or no deterioration of land. The salient features of the system are as follows:

- HDMSCS models consist of a large number of crop species with at very high plant density.
- It includes annuals, biennials and perennials.
- The crops selected include cash crops, food crops and fodder crops.
- It includes large, medium, and small canopy crops arranged in a systematic way.
- The soil disturbance should be kept minimum - only slash weeding is done.

Figure 2.19: Coconut-based High Density Multispecies Cropping System.

- 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.

The coconut palm serves as the 'top floor', whereas, perennials such as cocoa, bananas, papaya *etc.*, form the mid-storey crops, and short-growing crops such as spices, vegetables, pineapple, fodder *etc.*, form the ground floor. As coconut palms do not have deep root system, the nutrients that are leached down are lost to the palms. When plants possessing deeper roots and greater root volume are included in the coconut based cropping system, the nutrients available below the root zone of the palms are captured and deposited on the soil surface via shed leaves, fallen twigs and other plant parts. These materials on decomposition release nutrients for the uptake by the palms.The micro climate inside the multi-storeyed cropping system is characterised by lower maximum temperature, smaller diurnal variation and less evaporative demand compared to mono cropping system. Cultivation of different crops in a particular field results in the continuous addition of bio mass and higher level of nutrient supply which have a positive impact on the physico-chemical and biological properties of soil. The beneficial effects of such a system are evidenced by the enhancement of microbial population, improvement of soil fertility status and better utilization of natural resources for the benefit of plant growth and sustainable crop yields.

14. Coconut-based Mixed Farming System

Mixed farming system integrating livestock with crop husbandry is an integral part of the organic production system. It involves cultivation of shade tolerant fodder crops in the interspaces of coconut and integrating animal enterprises like dairy, poultry, fisheries *etc.* and recycling the organic residues and by-products.

Figure 2.20: Mixed Farming in Coconut Garden with Dairy Cows.

Maintenance of livestock and other components as well as production of fodder (feed) needed for them are to be based on organic standards. The animals not only enhance the nutritional status of the household members but also help to augment the farm income by the sale of milk, eggs and other products. While the crop residues and fodder provide animal feed, the manure and litter of the livestock provide renewable sources of organic matter and plant nutrients.They help reduce dependence on inorganic chemical fertilizers and maintain soil health, resulting in a high degree of organic recycling. Such integration will also maximize the beneficial impact of species diversity on soil fertility. Here the system is kept productive by maximizing the complementary and synergistic effects of the components involved.

The suitable grasses for rainfed condition are guinea grass, Congo signal and for irrigated condition, hybrid bajra Napier. The rainfed crop yields about 35-45 t/ha of green fodder, whereas, the yield could be increased to about 75-100 t/ha under irrigated conditions. Intercropping of hybrid bajra Napier Co 3 in coconut and maintained organically produces more than 100 t fresh fodder/ha/year, which would be sufficient to manage 10 milch animals.

15. Plant Protection

15.1. Pests and their Management

The organic production should aim at minimizing losses from pests, diseases *etc.* As organic system of cultivation does not permit use of chemical pesticides for the management of pests, other measures such as use of cultural, mechanical, biological and use of botanical and bio pesticide are to be adopted. Being a perennial crop, coconut is subjected to attack by an array of pests round the year. Even though there are over 750 insect species (including the ones that directly feed and those which are only associated) recorded on coconut palm, only a few are considered to be of economic importance (Table 2.7). All parts of the palm *viz.*, leaves, stem, root, inflorescence and the nuts are subjected to attack by pests. Damage when caused to the leaves, leads to reduction in photosynthetic efficiency and decrease in value for thatching purpose, but when done to inflorescence and nuts leads to direct economic loss. The major insect pests of coconut are rhinoceros beetle (*Oryctes rhinoceros*), red palm weevil (*Rhynchophorus ferrugineus*), leaf eating caterpillar (*Opisina arenosella*), root eating white grub (*Leucopholis coneophora*), Coreid bug (*Paradasynus rostratus* Dist.) and Coconut eriophyid mite (*Aceria guerreronis* Keifer). The important pests of coconut and their management are listed in Table 2.7.

15.2. Diseases and their Management

The coconut palm is affected by a number of diseases, some of which are lethal while others gradually reduce the vigour of palms causing severe loss in yield. As in the case of management of pests, no chemicals are allowed for disease control in organic cultivation. The important diseases of coconut and their management strategies are given in Table 2.8.

Table 2.7: Important Pests of Coconut and their Management

Name of Pest	*Symptoms*	*Management*
a) Rhinoceros beetle (*Oryctes rhinoceros*)	The adult beetle bores through into the unopened fronds and spathes. The affected frond when fully opened shows the characteristic geometric cuts. Infestation on spathes often destroys the inflorescence and thus prevents production of nuts. The beetle breeds in a variety of materials such as decaying organic debris, farmyard manure, dead coconut logs, compost pit etc.	Field sanitation by proper disposal of decaying organic debris. Mechanically extract beetles with hooks without causing any further injury to the growing point of the palm.Apply powdered neem cake or "Marotti cake" (*Hydnocarpus wightiana* Blume) @ 250 g mixed with equal quantity of sand in topmost three leaf axils three times a year or fill the innermost two leaf axils with 12 g naphthalene balls covered with sand at 45 days interval.Treat manure pits and other possible breeding sites with leaves and tender stems of *Clerodendron infortunatum* or with the culture of Metarhizium anisopliae (green muscardine fungus). Spray 250 mg fungal culture diluted with 750 ml water/m^3 of breeding site. The fungus can be mass multiplied on local materials such as coconut water and cassava chips.Release *Oryctes* rhinoceros virus (ORV) infected adult beetles @ 10-15/ha of coconut plantation.
b) Red palm weevil (*Rhynchophorus ferrugineus*)	Young palms below 20 years succumb to severe damage by this pest. Bud rot and leaf rot disease and rhinoceros beetle attack are predisposing factors for red palm weevil infestation. Being an internal feeder, it is very difficult to detect the damage caused by the pest at an early stage. Wilting of the central spindle, presence of chewed fibers and cocoons in the trunk, presence of holes in the trunk with brown fluid oozing out are the important symptoms. The symptom of infestation becomes clear in advanced stages when the crown of the affected palm topples. The weevil multiplies enormously in young coconut plantations causing loss to an extent of 5 to 10 per cent.	Avoid injury to the palms, as they would attract the weevil to lay eggs. Injuries caused by rhinoceros beetle, mechanical injury during cutting of leaves or steps cut on the trunk for climbing give a favourable condition for egg laying. Mechanical injury, if any, caused should be treated with coal tar. While cutting of fronds, leave petiole to a length of 120 cm from the trunk to prevent the entry of weevils through the cut end. Periodically clean the crown to avoid decaying of debris in leaf axils. Remove palm in the advanced stage of infestation, split open the stem and burn. Adopt prophylactic leaf axil filling as suggested for rhinoceros beetle.Set longitudinally split coconut log traps (50 cm length) after smearing the cut surfaces with fermenting toddy or pineapple or sugarcane activated with yeast or molasses to attract weevil. Coconut petiole pieces smeared with fermented toddy kept in pots @ 10 pots/ha also serve as weevil traps. The traps should be placed at dusk and the weevils trapped are destroyed next morning. Install traps with aggregation pheromone to mass trap and destroy the weevils. This technology should be taken up on community basis.

Contd...

Table 2.7–*Contd...*

Name of Pest	*Symptoms*	*Management*
c) Leaf eating caterpillar (*Opisina arenosella*)	Leaf eating caterpillar commonly occurs in the coastal and backwater tracts. In recent years, it has assumed severe proportions in interior tracts as well. The caterpillars live on the under surface of leaflets inside silken galleries and feed voraciously on the chlorophyll containing functional tissues. This affects the health of the palm adversely by reducing the photosynthetic area and results in reduction of yield. The severity of infestation by this pest will be marked during the summer months from February to June. With the onset of southwest monsoon, the pest population begins to decline. In severe outbreaks of leaf eating caterpillar, the older leaves of the palms are reduced to dead brown tissue and only three or four youngest leaves at the centre of the crown remain green. In case of severe infestation, the whole plantations present a scorched appearance.	Cut and burn the heavily affected and dried outer most 2 to 3 leaves. Adopt biological control by periodical release of larval/pupal parasitoids such as *Goniozus nephantidis, Elasmus nephantidis* and *Brachymeria nosatoi.* Combined release of the parasitoids is required in multistage condition of the pest.
d) 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, and sweet potato etc., grown as intercrops in coconut gardens. In coconut nursery, the grubs feed on the tender roots and tunnel into the bole of the collar region resulting in drying up of the spindle followed by yellowing of the outer leaves and gradual death of the seedling. In older coconut plantations continuous infestation by the grub results in yellowing of leaves, premature nut fall, delayed flowering, retardation in growth and reduction in yield.	Collect and destroy adult beetles during peak period of emergence in May–June to reduce the population.

Contd...

Table 2.7–*Contd...*

Name of Pest	*Symptoms*	*Management*
e) Coreid bug (*Paradasynus rostratus* Dist.)	Coried bug occurs in coastal areas and in high ranges of Kerala. Apart from coconut it feeds on tamarind, cashew, cocoa and guava. The peak population occurs during post monsoon period. The adults and nymphs feed by desapping the contents on buttons and developing nuts below the perianth region. The feeding points develop to brownish necrotic lesions, which later turn to furrows or cracks. The symptoms are easily identified by cracks and gummosis. Severe damage leads to nut fall and malformation of mature nuts.	Apply neem based bio pesticide on the newly opened inflorescence.
f) Eriophyid mite (*Aceria guerreronis* Keifer)	Mite feeds on the upper portion of the developing nut that is covered by perianth. Feeding by mites in this zone causes physical damage to cells. The feeding sites that grow downward from the perianth appear as longitudinal patches and later develop into triangular yellow patches, turn brown, develop longitudinal fissures and finally appear as warts and develop into longitudinal splits on the surface of nuts. The liquid oozing from these patches dries and as a result dried decayed matter is noticed. The damage affects the quality of husk and dehusking becomes difficult.	Adopt phytosanitary measures in coconut plantations like crown cleaning. Collect and destroy all the fallen buttons of the affected palm. Spray neem oil-garlic-soap emulsion @ 2 per cent concentration (200 ml neem oil, 50 g soap and 200 g garlic mixed in 10 litres of water) or commercial neem formulation azadirachtin 0.004 per cent (Neemazal T/S 1 per cent @ 4 ml per litre of water) during April-May, October-November and January-February. Apply the spray solution as fine droplets on the perianth region and general surface of developing nuts of 1-6 months old bunches with hand sprayer or rocker sprayer.

Table 2.8: Diseases of Coconut and their Management

Name of the Disease	*Symptoms*	*Management Strategies*
a) Bud rot (*Phytophthora palmivora*)	☆ The first visible symptom is withering of the spindle leaf marked by pale colour. ☆ The spindle turns brown 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 may spread to adjacent leaves, producing a dead centre with a fringe of living leaves. ☆ 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 monsoon when the temperature is low and humidity is high.	☆ Cut the palm which are in the advanced stage of disease or died due to the disease and burn the infected crown ☆ As a prophylactic measures spray 1 per cent Bordeaux mixture to all the palms in the garden in the disease endemic areas ☆ 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 polythene covering till normal shoot emerges. Later remove the cover as the shoot grows ☆ Destroy infected tissues removed from the affected palm by burning. ☆ Spray 1 per cent Bordeaux mixture on spindle leaves and crown of palms around the infected area to prevent the disease spread. ☆ Provide adequate drainage in gardens and avoid over crowding.
b) Root (wilt) disease Phytoplasma. The disease is transmitted by lace bug *Stephanitis typica* and the plant hopper *Proutista moesta.*	☆ The important visual diagnostic symptoms are abnormal bending or ribbing of the leaflets (flaccidity), general yellowing and marginal necrosis of the leaflets and unopened inflorescences. ☆ The nuts are smaller and the kernel is thin. ☆ The oil content of copra is also reduced.	This disease is not lethal but only debilitating. ☆ As no curative measure is known at present, the approach will be to manage the disease in the already infected gardens. ☆ To reduce the loss due to the disease, the strategy would be to contain the disease by improving the health of affected palms and increasing the yield through proper manuring and other agronomic practices. ☆ Cut and remove all affected palms in mildly disease affected areas. ☆ In the heavily disease affected tracts, remove severely affected uneconomic adult palms (those yielding less than 10 nuts per palm per year) and all diseased palms in the pre-bearing age.

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Table 2.8–*Contd...*

Name of the Disease	*Symptoms*	*Management Strategies*
		☆ Adopt improved management practices in the affected gardens to enhance the yield of palms. ☆ 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. ☆ Grow suitable inter and mixed crops. ☆ Basin management with green manure crops. ☆ Irrigation during summer months. ☆ Leaf rot disease which is usually noticed in root (wilt) affected palms can be controlled by applying *Pseudomonas fluorescens* or *Bacillus subtilis* either alone or in combination @50 g in 500 ml water to the axil of spindle leaf ☆ Replanting with progenies of disease free elite palms located in hot spot areas. ☆ Follow strictly all the prescribed prophylactic measures for other pests and diseases.
c) Leaf rot (*Exserohilum rostratum* and *Colletotrichum gloesporioides*)	☆ Symptoms appear as minute water soaked angular spots on spindle leaves ☆ They enlarge, coalesce and cause spindle rot	☆ Cut and remove rotten portion of the spindle and two adjacent leaves. ☆ Since leaf rot affected palms are prone to pest attack, filling the youngest three leaf axils with a mixture of powdered neem/marotti cake with equal quantity of sand or placing naphthalene balls (12g/palm) and covering with sand three times a year may be adopted. ☆ Apply *Pseudomonas fluroscens* or *Bacillus subtilis* either alone or in combination as explained above
d) Stem bleeding (*Thielaviopsis paradoxa*)	☆ 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	☆ Remove water stagnation (if it is a problem) and apply 5 kg neem cake fortified with *Trichoderma* per palm along with other organics during September-October

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Table 2.8–*Contd...*

Name of the Disease	*Symptoms*	*Management Strategies*
	✰ The tissues below the lesions rot and turn yellow first and later black. Leaves in the outer whorl turns yellow rather prematurely, droop and dry ✰ Production of bunches is affected and nut fall also is noticed. The trunk gradually tapers at the apex and crown size becomes reduced	
e) Thanjavur wilt/ Ganoderma disease (*Ganoderma lucidum* and *Ganoderma applanatum*)	✰ 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, brackets of fungus causing the disease are seen on stumps	✰ Apply 50 kg organic manure and 5 kg neem cake fortified with *Trichoderma* 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 (remove dead palms, bury the affected roots and bole in a pit) ✰ Intercropping of banana is desirable as the root exudates of banana are found to inhibit the growth of pathogens
f) Leaf blight or Grey Leaf spot (*Pestalotia palmarum*)	✰ 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	✰ Cut and remove older affected leaves and spray the foliage with 1 per cent Bordeaux mixture ✰ Combined application of talc-based powder formulation of *P. fluorescens* to soil (50 g/palm/year) along with neem cake (5 kg/palm/year)
g) Mahali or fruit rot and nut fall (*Phytophthora palmivora*)	✰ Shedding of buttons and immature nuts are noticed ✰ Water soaked lesions appear on buttons near the stalk which later develop and result in the decay of the underlying tissues ✰ The disease caused by the fungus appears as whitish webby growth on the surface of the affected part	✰ Collect and burn the affected shed nuts ✰ Spray 1 per cent bordeux mixture to the bunches just before the onset of monsoon

16. Harvesting and Post-harvest Management

16.1. Harvesting

Twelve months old coconuts are to be harvested both for copra preparation as well as seed nut purpose, while for tender nut purpose; the nuts are to be harvested at 7 to 8 months stage. The maturity of nuts shall also be considered for harvest depending up on the value addition to be made using kernel, coconut water *etc.* Six to eight harvests, on an average, can be made in a year depending on the yield of palms.

16.2. Post-harvest Management

Fresh coconuts: Coconuts which are intended to be sold fresh should be harvested before they are completely ripe, as they will contain up to 95 per cent coconut water. In order to export fresh coconuts, it is recommended to remove thick fibrous husk of the coconuts immediately after they are harvested by keeping a small portion of the fibre on the upper side of the nut. Organically produced coconuts are not allowed to be treated with methyl bromide or ethylene oxide, or with ionising rays for long storage.

16.2.1. Making 'Cup Copra'

In order to make 'cup copra' the fibrous husks are removed from the freshly harvested coconut fruits. Later they are split open into two parts using a heavy knife and washed in clean, cold water to remove any foreign particles and fibres. Then they are briefly pre-dried by placing them out in the sun on racks, mats or in solar dryers. This drying facilitates easy separation of meat from the shell. The split open nuts should be kept for drying as soon as they have been opened, as any delay will result in the meat turning reddish-brown and deterioration of quality of copra. After about two days of sun-drying, the fruit meat (kernel) is usually hard enough to be removed from the hard shell. In a period of about 4-5 days, the entire drying process will be completed and copra removed from the shell. Before the copra is packed, they should be cleansed of any foreign particles (stones, sand, fibre residues *etc.*).

16.2.2. Making Ball Copra

In order to make 'ball copra', ripe coconuts are stored in the shade for about 8 to 12 months. In this way, the coconut water is gradually absorbed, and the coconut meat shrinks and dries, so that it begins to rattle around when shaken. When the meat begins to rattle, the fibres and shell are to be carefully removed. Before it is packed, the copra should be cleansed of foreign particles (stones, sand, fibre residues *etc.*). There are specific varieties suitable for making ball copra (*e.g. Kalpa Ganga*).

16.2.3. Manufacturing Dried, Grated Coconuts

In order to make dried, grated coconuts, the brown shell around the copra is removed, the meat washed with clean, cold water, then sterilised, grated, dried, and if necessary, sieved into grades. The grated, dried coconuts are to be sorted into different grades according to their grain size.

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