

Chapter 4

Organic Farming in Cocoa

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1. Introduction

The cocoa tree (*Theobroma cacao* L.), belonging to the genus *Theobroma*, meaning “food of the god’s in Greek, is believed to be originated from several localities in the area between the foot of the Andes and the upper reaches of the Amazon forests (South America) (the subspecies Forastero Amazónico) as well as the rainforests of central America (the white seed subspecies Criollo). Cocoa arrived in Europe through the former colonial powers Portugal and Spain, and was later to be found in Africa. Today, cocoa is cultivated in all of the humid, tropical countries. Though there are several species in this genus, but only one, *Theobroma cacao*, is grown commercially. World over, the vast majority of cocoa (70 per cent to 90 per cent) is grown by smallholder farmers. In cocoa producing countries, it is grown mainly for its beans, processed into cocoa powder, cake and cocoa butter. These products are largely used in the manufacture of chocolates, soaps, cosmetics, shampoo and other pharmaceutical products. The cocoa seeds are highly rich in fat content, and therefore, provide an energy-rich and delicious foodstuff. The natural habitat of cocoa tree is in the lower storey of the evergreen rainforest. Climatic and site requirements place cocoa in the tropical regions of the equator. The climatic factors, including the ambient weather conditions have a direct effect on the morphology, growth, fruiting and general health of cocoa plants.

Over the past few decades, cocoa has increasingly gained considerable attention in the international market as it continues to become one of the most lucrative and heavily traded food commodities in the world. This has paved the way for taking efforts to continuously increase cocoa production across the world, most especially

by the four main growing countries in West Africa—Côte d'Ivoire, Ghana, Nigeria and Cameroon—now together providing about 75 per cent of the global cocoa market. The cocoa market is one of the largest food commodities exported from the developing countries to the rest of the world. The consumers across the globe are aware of the environment an ecological issues and prefer organic products even in chocolates. The certified organic cocoa market represents a very small share of the total cocoa market, estimated to around 0.5 per cent of total production. However, the demand for organic cocoa products is growing at a very strong pace, as consumers are increasingly concerned about the safety of their food supply along with other environmental issues.

The International Cocoa Organization (ICCO) estimates production of certified organic cocoa at 15,500 tonnes. Seventy per cent of the organic cocoa is produced in South America with Dominican Republic as the leading producer. The other countries are: Madagascar, Tanzania, Uganda, Belize, Bolivia, Brazil, Costa Rica, El Salvador, Mexico, Nicaragua, Panama, Peru, Venezuela, Fiji, India, Sri Lanka and Vanuatu. Indian organic cocoa production is largely confined to Kerala and it is done mostly in Idukki and Kottayam districts. It is estimated that about 10-20 per cent of the total cocoa production of over 12,000 tonne in the country is organic. The organic cocoa market is expected to be largely driven by the health consciousness among consumers. However, lack of proper supply of organic cocoa restrains the global organic cocoa market which also leads to increase in price of organic cocoa. There is a huge opportunity in the North America and Western Europe and Japan. Asia Pacific excluding Japan is an untapped market which is also a potential market for organic cocoa. This is attributed to increasing inclination of consumers towards organic products, rapid urbanization, strengthening supply chain for organic cocoa and rising health consciousness among consumers.

Currently, Dominican Republic is dominating the organic cocoa market in terms of production that holds around 70 per cent of the total market share; Peru, Ecuador and Mexico together hold around 20 per cent of the market share in terms of production; rest around 10 per cent is held by Bolivia, Ghana, Brazil and others. Majority of organic cocoa is exported to Western Europe followed by North America. U.K and U.S are the largest manufacturing countries of organic cocoa products in the world, since organic chocolate is more popular in U.K, U.S and Germany and consumers from those countries owe a significant inclination towards organic chocolates irrespective of high pricing of organic products. Organic cocoa has many nutritional benefits such as more fiber, iron, magnesium, copper, manganese and many other minerals. Moreover, it also contains antioxidants, which helps to protect skin. Organic cocoa also helps to improve blood flow and lower blood pressure. Certified organic cocoa producers must comply with all requirements associated with the legislation of importing countries on production of organic products. The benefit for cocoa farmers is that organic cocoa commands a premium price than conventional cocoa, usually ranging from US\$ 100 to US\$ 300 per tonne.

2. Production Scenario

2.1. Global Scenario

Cocoa is grown in 58 countries in around 10 million hectares with an estimated production of 4.36 million tonnes during 2013-14 (Table 4.1). Among the major countries, Côte d'Ivoire has the highest productivity of 660 kg/ha, while the world productivity is 504 kg/ha. The four West African countries *viz.*, Côte d'Ivoire, Ghana, Cameroon and Nigeria contributed for 73.3 per cent of worldwide cocoa production, whereas, Côte d'Ivoire alone accounted 40 per cent. If the production of Indonesia is added to the output, the five countries reach a market share of 80 per cent. Latin America, where the cocoa plant originated, presently accounts for only 16 per cent of worldwide cocoa production. With the exception of Brazil, cocoa production is mainly concentrated in small-scale farms. Cocoa production is therefore highly important for many households, as it is a key source of income and livelihood.

Table 4.1: Production of Cocoa Beans ('000 tonnes)

Region	2012-13	Estimates (2013-14)	Forecasts (2014-15)
Africa	2836	3197 (73.3 per cent)	2984
Cameroon	225	211	220
Côte d'Ivoire	1449	1746	1740
Ghana	835	897	696
Nigeria	238	248	235
Others	89	95	93
America	622	708 (16.2 per cent)	729
Brazil	185	228	215
Ecuador	192	220	250
Other	246	260	264
Asia and Oceania	487	454 (10.5 per cent)	455
Indonesia	410	375	370
Papua New Guinea	41	40	42
Others	36	38	43
World total	3945	4359	4168

Source: ICCO Quarterly Bulletin of Cocoa Statistics, Vol. XLI, No. 2, Cocoa year 2014/15.

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Note: Totals may differ from sum of constituents due to rounding.

2.2. Organic Cocoa

According to SSI Report (2014), organic cocoa production accounted for about 2.5 per cent of the world's cocoa production in 2011, with 103,554 metric tonnes certified from an area of 176,880 hectares. Production is highly concentrated in the Dominican Republic (69.5 per cent), Peru (9.2 per cent), Ecuador (7.5 per cent), and

Mexico (3.1 per cent). About 75 per cent of all production of cocoa (77,539 metric tonnes) was sold as certified during the same year, which is well above the average of 33 per cent across all standards involved in the cocoa sector. The volume of organic cocoa production have almost doubled since 2008 (from 53,730 metric tonnes to 103,554 during 2011), with 60 per cent of the growth coming from the Dominican Republic (Table 4.2.). Demand for Organic cocoa continues to grow, particularly within markets for fine aroma cocoa.

Table 4.2: Area, Production and Sale of Organic Cocoa in Leading Countries of the World (2011)

<i>Name of the Country</i>	<i>Area (ha)</i>	<i>Production (mt)</i>	<i>Sales (mt)</i>
Dominican Republic	94,000	72,000	50,000
Peru	12,000	9,500	9,500
Ecuador	20,000	7,800	5,400
Mexico	13,000	3,200	2,200
Brazil	7,100	1,800	1,500
Ghana	6,700	2,000	1,400
Sao Tome and Principe	3,800	300	200
World Total	176,880	103,554	77,539

Source: SSI Report (2014) page 143.

2.3. Indian Scenario

Cocoa, a beverage crop having high commercial potential, is mostly grown in India as a mixed crop in arecanut and coconut gardens. In the global production scenario, India is a very small player with the production share of a meagre 0.3 per cent. The cocoa industry in the country has expanded to a considerable extent in recent years, with a production of 15,133 tonnes of cocoa from an area of 71,245 hectares and contributes about Rs.2,000 million annually to the GDP of the nation. Although the per capita cocoa consumption in India is very less (0.04 kg/head) in comparison with major cocoa consumers, the consumption is continuously increasing over the last one decade, indicating a bright prospect for the cocoa sector. Taking into consideration the present day consumption patterns and growth of confectionery industry in India at around 15 per cent, the demand for cocoa is likely to increase in the coming years. In India, cocoa is cultivated mainly in the states of Tamil Nadu, Andhra Pradesh, Kerala, and Karnataka (Table 4.3). At present, demand for cocoa beans is higher than the domestic production, necessitating large scale imports to meet the national requirements. India produced 15,133 tonnes of cocoa from an area of 71,245 hectares. Tamil Nadu has the highest area under cocoa (33.6 per cent), followed by Andhra Pradesh (31.1 per cent), and while in the case of cocoa production, Kerala has the major share (41.8 per cent) followed by Andhra Pradesh (37.0 per cent). Indian productivity is 236 kg/ha whereas, the world productivity is

504 kg/ha. The projected demand of cocoa by 2050 is 212 thousand tonnes against the estimated supply of 121 thousand tonnes. With the projected supply, there would be a demand supply gap of 101 thousand tonnes of cocoa beans in 2050. To achieve this target, the cocoa production in the country should increase at an annual growth rate of 7.68 per cent considering the market growth at 20 per cent and the cocoa sector has a great potential to develop in future years.

Table 4.3: Cocoa Area, Production India 2013-14

	<i>Area (ha)</i>	<i>Production (mt)</i>	<i>Productivity (kg/ha)</i>
Kerala	13,483 (18.9)	6,320 (41.8)	750
Tamil Nadu	23,959 (33.6)	1,071 (7.0)	500
Karnataka	11,683 (16.4)	2,142 (14.2)	250
Andhra Pradesh	22,120 (31.1)	5,600 (37.0)	450
Total	71,245	15,133	

Figures in the bracket are the percentage share.

ICAR-CPCRI is recognized as the national active germplasm site. The institutes in the traditional zones through three to four decades of research have developed high yielding elite clones and hybrids, with yield range of 1 to 2 kg dry bean/tree and with varying processing qualities. These varieties can contribute effectively as a mother source for the improvement of cocoa productivity in the country. Cocoa clones, specifically suitable to grow under arecanut and coconut canopies and suitable for both the shades have been identified. Of late, the area expansion has occurred in non-traditional zones of Tamil Nadu and Andhra Pradesh, therefore, the challenge is to identify high yielding clones suitable for such locations and also for different cropping systems.

3. Environmental Benefits

A multi-layered forest system continues to be the optimum environment for organic cultivation and, cocoa grown in this type of system, holds enormous potential for environmental and cultural conservation. The environmental advantages would include soil conservation, increased diversity of plants and animals, utilization of local and renewable resources, reduced soil and groundwater pollution and can contribute towards specific habitat conservation. The cocoa tree naturally prefers the shade, especially when young, and can grow in harmony with and in support of the local ecosystem when thoughtfully cultivated by small-scale family farmers using organic production methods. Planting cocoa among other trees, such as fruit trees, provides many benefits such as shade for the cocoa tree, increased biodiversity on the farm, inhibited growth of weeds (reducing the need for chemical herbicides), and additional food and income for the farmer's family. Organic farming also offers opportunities for the diversification of farms and has the potentials to contribute towards rural development.

4. Botany of Cocoa

Theobroma cacao belongs to the family of Sterculiaceae. Cocoa trees attain a height of 8m to 10 m. The blossoms appear in the many year old wood of the leaf axil, on the trunk and on the branches (Kauliflorie). The flowering in cocoa is throughout the year, provided no extreme drought periods or seasonal temperature fluctuations occur. The berries develop within 5 to 6 months from flowering and are pollinated by insects, mainly of the species *Forcipomyia* and *Lasioshelea*. The cocoa fruit has a cucumber-like shape, and is about 25 cm long, 8-10 cm thick and weighs 300-400 g. The shell, which can be up to 20 mm thick, surrounds the sugar-rich, bitter-sweet, acrid pulp. The fruit contains 25-50 almond-shaped, bitter tasting beans or seeds, in 5-8 long rows.

5. Varieties of Cocoa

Three large groups of cocoa *viz.* Criollo, Forastero and Trinitario can be distinguished, each with several varieties and strains: Criollo and Forastero are the types naturally evolved at the centre of origin of this crop, whereas, Trinitarios are considered to be the derivative of a natural cross between Criollo and Forastero. It is hardier and more productive than Criollo. It has a share of roughly 10 to 15 per cent of the total world production and can fertilize self-incompatible species of other groups.

5.1. Criollo

With its strong and fine flavor, the Criollo group produces the highest cocoa quality. This group has characteristic white cotyledons, and originated mostly in Mexico and Venezuela. Unfortunately, the yields are low and, therefore, it is rarely cultivated. The unripe pods of criollo are purplish red, red, turn to yellow or red when ripe. It has pointed fruits, with large seeds, plump and almost round, white or pale violet cotyledons, which are less astringent. Criollo is superior in fruit possessing generally elongated and with distinctly ridged pods. The beans ferment quickly and yields 'fine' cocoa. Additionally, the white seeded Criollo cocoa (in some Latin American countries the "forastero amazónico" is also called "criollo") is much more demanding in terms of its habitat requirements, and improper production practices thus render it much more susceptible to pests and diseases. It can be subdivided into Central American *criollo* and Venezuelan *criollo*.

5.2. Forastero

Due to its high yield, the Forastero group, which is native to the Amazon region, is by far the most widely grown with around 80 per cent of total area under cocoa. It constitutes bulk of world's cocoa and almost all of the production currently coming from Brazil, West Africa and South East Asia is of Forastero. Though it gives high yields, its taste, however, is relatively weak. Forastero cocoa plants are stronger, vigorous and more productive. Unripe pods of Forastero are green, and turn to yellow on ripening. They are inconspicuously ridged and furrowed, with smooth surface, and ends rounded or bluntly pointed. The pod wall is thick. The seeds are flattened, fresh cotyledons deeply pigmented and dark violet giving an astringent

product. The trees are hardy and give high yields. Quality is not comparable with Criollo. The beans take 5-6 days for fermentation.

5.3. Trinitario

The Trinitario is a hybrid of the Forastero and Criollo types originated in Trinidad. These are very heterogenous and exhibit a wide range of morphological and physiological characters. Individual clones show a wide range of characters, from Criollo type to Forastero type. It is difficult to specify the characters of Trinitarios as they have pod and bean characters ranging from those of typical Criollos to those of Forasteros. Usually hardier and more productive than Criollo, the flavour of the best reaches that of Criollo. Of total world production, Trinitario has a share of roughly 10 to 15 per cent. This variety has the capacity to fertilize the species of the other groups which generally face the constraint of being self-incompatible. In addition to these three types, several other subgroups fall under *forasteros*. The best known *forasteros* are the "*Amelonados*", the most cultivated cocoa type in West African countries since the 19th century. The *Amelonados* are self-compatible and the pods have a melon shape with nearly smooth pod surface. Each country has its own unique cultivar. The cultivars vary with the country from where they are introduced and the extent of hybridization. The details of cocoa varieties released from ICAR-CPCRI and Kerala Agricultural University are presented in Tables 4.4 and 4.5. There are thousands of clones in the field gene banks of different cocoa research institutions in the world. Selection and hybridization work in the cocoa growing countries of the world have yielded a large number of clones under each category with distinct and unique features.

The clones are named after the place or the river in the region in which they have been traditionally harvested or the research station where it was evolved:

Some of the important clones coming under each type are:

1. Criollo

- a) RIM 189(MEX)- Rosario Izapa Mexico
- b) ICS39, 40, 45, 47,60,84,89 and 91- Imperial College Selections

2. Forastero

- a) AMAZ 2/1,3/2 (Amelonado) -Amazonas
- b) UF 4,29,36,700,701,703, 705, 710 (United Fruit Company)
- c) SCA 6,8,9, 12 (Scavina)

3. Trinitario

- a) BL Z 9/R (MEX), BL Z 23/R (MEX), BL Z 34/R (MEX), BL Z 52/R (MEX), BL Z 56/R (MEX)- BeLize
- b) UF1,10,168,221,296,613,650,654,666,667,668,676,677,688,707,708,709,711, 712 (United Fruit Company)
- c) ICS 6, 8,16,43,61,95 (Imperial College Selections)

Table 4.4: Details of Varieties Released by ICAR-Central Plantation Crops Research Institute

<i>Name</i>	<i>Tree Characteristics</i>	<i>Pod Characteristics and Yield</i>	<i>Bean Characteristics</i>
VTLCH-1 (Vittal Cocoa Hybrid-1)	Vigorous, early, heavy bearer	50 yellow pods/tree/year Yield: 1014 kg/ha	No. of beans/pod- 42 Single dry bean weight- 1.00g Dry bean yield/tree/year- 1.48 kg Shelling- 13 per cent, Fat content- 53.6 per cent
VTLCH-2 (Vittal Cocoa Hybrid-2)	Early, heavy bearer, BPD tolerant	70 yellow pods/tree/year Yield: 800 kg/ha	No. of beans/pod- 40 Single dry bean weight- 1.15 g Dry bean yield/tree/year- 1.15 kg Shelling- 11 per cent, Fat content- 54 per cent
VTLCH-3 (Vittal Cocoa Hybrid-3)	Early, heavy bearer, suitable for water limited conditions	45 yellow pods/tree/year Yield: 993 kg/ha	No. of beans/pod- 45 Single dry bean weight- 1.07 g Dry bean yield/tree/year- 1.45 kg Shelling- 13 per cent
VTLCH-4 (Vittal Cocoa Hybrid-4)	Early, heavy bearer, suitable for water limited conditions	40 red pods/tree/year Yield: 856 kg/ha	No. of beans/pod- 43 Single dry bean weight- 1.01 g Dry bean yield/tree/year- 1.25 kg Shelling- 12 per cent
VTLCC-1 (Vittal Cocoa Clone-1)	Early, heavy bearer, both self and cross compatible	75 yellow pods/tree/year Yield: 911 kg/ha	No. of beans/pod- 37 Single dry bean weight- 1.05 g Dry bean yield/tree/year- 1.33 kg Shelling- 12 per cent, Fat content- 52.5 per cent
Cocoa selection 1 (VTLCS 1)	Stable high yielder both under arecanut and coconut, withstands biotic and abiotic stress	55 red attractive pods/tree/year Yield: 1700 kg/ha	No. of beans/pod- 42 Single dry bean weight- 1.13 g Dry bean yield/tree/year- 2.52 kg Shelling- 11 per cent, Fat content- 52.1 per cent
Cocoa selection 2 (VTLCS 2)	Stable high yielder both under arecanut and coconut, less incidence of pests and diseases	55 yellow pods/tree/year Yield: 1850 kg/ha	No. of beans/pod- 42 Single dry bean weight- 1.21 g Dry bean yield/tree/year- 2.7 kg Shelling- 15 per cent, Fat content- 53 per cent

Table 4.5: Details of Varieties Released by the Kerala Agricultural University

<i>Name of Variety</i>	<i>Pod Characteristics</i>	<i>Pod/Bean Weight</i>	<i>Yield Potential</i>
CCRP 1	Medium, green, turn to yellow on ripening. Constricted at the base, blunt beak at the tip with moderately deep ridges and furrows	Mature pods weigh about 385 g with 46 beans and oven dry bean weight is 0.8 g.	The average yield is about 56 pods per tree per year going up to 72 pods per year on reaching steady bearing
CCRP 2	Medium, smooth, green, turn to yellow on ripening. Spherical pods without any basal constriction and the apex is almost obtuse. Ridges and furrows are almost absent and the rind is very smooth with a thin pericarp	Mature pods weigh 311 g with 45 beans and 0.9 g oven dry weight. Average bean weight per pod is 96.5 g.	The average yield of pods per tree is 53.9, going up to 90 pods per year under favourable conditions
CCRP 3	Medium, smooth, green, turn to yellow on ripening. Pods are elliptic with moderate ridges and furrows. A slight constriction is present at the base. The apex is slightly acute	Mature pods weigh 240 g with 42 beans and 0.8 g oven dry weight. Average bean weight per pod is 94.8 g.	The average yield per tree is 68.5, going up to 80 pods per year under favourable conditions
CCRP 4	Large, purple tinged, turn to deep yellow on ripening. Pods are beaked with a prominent acute tip. Basal constriction is shallow or absent and pericarp is deeply rugose having deep ridges and furrows	Mature pods weigh about 402 g with 45 beans and oven dry bean weight is 1.1 g.	The average yield per tree is 66, going up to 93 pods per year under favourable conditions
CCRP 5	Large, elliptical, green, turn to yellow on ripening. Pods have moderately deep ridges and furrows and apex is almost acute	Mature pods weigh about 425 g with 42 beans and oven dry bean weight is 0.8 g.	The average yield per tree is 38, going up to 55 pods per year on reaching steady bearing
CCRP 6	Very big, green, turn to yellow on ripening. Thick rind, elliptical without basal constriction, with shallow ridges and furrows	Mature pods weigh about 895 g with 48 beans and oven dry weight is 1.9 g.	The average yield per tree is about 50 pods per year, going up to 180 pods per year on reaching steady bearing.
CCRP7	Large, elongated, green, turn to yellow on ripening. Beaked with slightly acute apex and a slight basal constriction, pod surface is rugose with moderately deep ridges and furrows	Mature pods weigh about 526 g with 47 beans and oven dry bean weight is 0.9 g.	The average yield per tree is about 78 pods, going up to 95 pods per year on reaching steady bearing.

Contd...

Table 4.5–Contd...

<i>Name of Variety</i>	<i>Pod Characteristics</i>	<i>Pod/Bean Weight</i>	<i>Yield Potential</i>
CCRP 8 (Hybrid between CCRP 1 x CCRP 7)	Medium, green, turn to yellow on ripening. Almost spherical without any basal constriction and the apex is attenuate	Mature pods weigh 389 g, with 48 beans and oven dry weight is 0.9 g. Average bean weight per pod is 126 g.	The average yield per tree is 90 pods, going up to 131 pods per year under favourable conditions
CCRP 9 (Hybrid between CCRP 1 x CCRP 4)	Medium, smooth, green, turn to yellow on ripening. Almost spherical without any basal constriction and the apex is attenuate	Mature pods weigh 370 g, with 36 beans and oven dry weight is 0.8 g. Average bean weight per pod is 84.9 g.	The average yield per tree is 105, going up to 358 pods per year under favourable conditions
CCRP 10 (Hybrid between CCRP 3 x GVI 68)	Medium, smooth, green, turn to yellow on ripening. Almost spherical without any basal constriction and the apex is attenuate	Mature pods weigh 332 g. with 41 beans and oven dry weight is 1.1 g. Average bean weight per pod is 102 g	The average yield per tree is 79, going up to 154 pods per year under favourable conditions



VTLCC 1



VTLCH 1



VTLCH 2



VTLCH 3

Figure 4.1a: Cocoa Varieties.



VTLCH 4



VTLCS 2



VTLCS 1

Figure 4.1b: Cocoa Varieties.

6. Climatic Requirements

6.1. Geographical Position

Though cocoa grows between 20°N and 20°S latitude, over 75 per cent of the area is distributed within 8°N and S of the equator. Cocoa is grown from sea level up to an elevation of about of 1100-1200 m, wherein most of the cocoa growing areas lie below 300 m MSL.

6.2. Temperature

Cocoa is a crop adapted to the moist, lowland tropics and thrives in a climate where the average temperature of the coldest month is not less than 16 °C and is not colder than 10 °C. If the absolute minimum temperature falls below 10°C for several consecutive days, the yield is likely to be reduced. Defoliation and dieback occur between 4-8°C. Low temperatures below 10 °C damage the sprouting seedlings, while long periods of high temperatures above 30 °C affect the physiology of the cocoa trees, bean characteristics and yield. When the temperature goes beyond 38°C, the pod size gets reduced with smaller beans and lesser butter content. Bean abnormalities like caking, occurrence of high vivipary and low pulp content are common in pods developing at high temperatures especially in summer season. It grows within a temperature range of 15-39°C and optimum temperature range is from 25 to 28 °C. The temperature in most of the cocoa growing areas lies between a maximum of 30- 32°C and a minimum of 18-21°C.

6.3. Rainfall

Rainfall and its distribution is one of the most important climatic factors deciding the cocoa cultivated area. The yield of cocoa trees from year to year is found to be influenced more by rainfall than by any other climatic factor. To ensure good growth, rainfall distribution is more important than the total amount received. In other South American, African, and Southeast Asian cocoa producing countries, rainfall distribution is more or less even. It is so well distributed that about 10 cm of rainfall is received every month, in particular, in Brazil, Ghana, and Malaysia. Ideally, cocoa requires a minimum of 90-100 mm rainfall per month with an annual precipitation of 1500-2000 mm. In most of the South-East Asian cocoa-producing countries, rainfall distribution is more or less even with minor peaks and around 100 mm of rain is received in almost every month. If rainfall is less than 1,250 mm, the crop needs irrigation during the rainless period. Cocoa plants can tolerate three to four months of low rainfall site conditions. In such cases, the cocoa plants display a more distinct rhythm of flowering and fruiting. Shortage of water leads to leaf fall and dieback. Annual rainfall in excess of 2,500 mm may lead to problems such as black pod disease due to more humid conditions. The incidence of vascular streak dieback will be more when rainfall exceeds 2,500 mm. Cocoa is susceptible to longer periods of water logging and poor aeration of soils. Heavy rainfall is the prime cause for the severity of VSD in Papua New Guinea and its rapid spread in India. In India, concentration of the rainfall to 2-3 months aggravates the spread of the disease. High rainfall during pod ripening tends to reduce rate of recovery of

cured beans to as low as 23 per cent. In Kerala, the distribution of rainfall in Idukki and Kottayam is so even and, hence, the pod and bean qualities are very good.

6.4. Relative Humidity

Cocoa needs high humidity throughout the year, and hence, a hot and humid atmosphere provides suitable condition for the optimum development of cocoa trees. Such conditions are prevalent in the tropical lowland between 15° north and south of the equator. The plants grown at lower relative humidity produce small leaves and tend to be curled and withered at the tip. Though the growth of cocoa is favoured by high relative humidity, storage of cocoa beans is affected. When the relative humidity exceeds 80 per cent, the beans absorb moisture and turn mouldy. At higher altitudes (Uganda 1,400 m elevation), cocoa can be grown successfully only within close range to the equator. Strong and steady winds can damage cocoa severely. Areas exposed to such winds are to be avoided.

7. Soil Requirements

The plant can grow in a wide range of soils, and it is predominantly grown on clay loam and sandy loam soils. Very coarse sandy soils are not suitable for cultivation of this crop as its water holding capacity is very poor. To develop a good root system, cocoa requires a deep, well-drained soil, having sufficient water-retaining capacity as well as sufficient organic matter content. Soil containing coarse particles and sufficient quantity of nutrients to a depth of 1.0 m to 1.5 m will be ideal. Avoid heavy soils in high rainfall areas, whereas, light soils in drier areas. Cocoa can grow in soils with pH ranging from 4.5-8.0 with optimum being 6.5-7.0. Excessive acidity (pH 4.0 and below) or alkalinity (pH 8.0 and above) must be avoided. Virgin, freshly cleared forest soils are used for the cultivation of this crop in major producing countries. Hence, soils of most of the cocoa growing regions of the world are rich in organic matter and nitrogen, well-drained. Exchangeable bases in the soil should amount to at least 35 per cent of the total cation exchange capacity. Cocoa is susceptible to longer periods of water logging and poor aeration of soils. One of the most important measures for the improvement and maintenance of soil fertility is the continuous addition of woody (ligneous) organic material, of which large amounts become available every year as a result of pruning measures.

8. Conversion of Old Cocoa Farms into Organic

The existing cocoa planted under the canopy of trees in either a primary or secondary forest, could be converted to an organic farm. This conversion should take place within a period of three years during which organic farming practices are carried out and an organic management plan agreed upon between the farmers or their representatives and the certification body, and is strictly adhered to.

9. Establishment of New Cocoa Plantation

When choosing the site for a new plantation, the natural site requirements of cocoa should be followed. Ideal sites are those with alluvial soils, which are not susceptible to water-logging. When creating a new plantation, care should be taken to reproduce as closely as possible the natural structure of forests. This means that

all of the varieties that are to be cultivated along with cocoa in the agro eco-system should be planted either simultaneously or even beforehand. The best method is to leave an area free for natural growth, and to plant tall-growing trees which will rapidly provide cover, such as bananas and to plant the cocoa in-between them at a later date. In this way, the biological activity of the soil is maintained, and the mycorrhiza of the cocoa can begin to develop immediately.

9.1. Time of Planting

Time of planting depends on the climatic condition of the place where cocoa is intended to be cultivated. The young seedlings need moisture for better establishment. The seedlings cannot withstand excess water also. Cocoa can be planted with the onset of Southwest monsoon (May-June) in areas where rainfall intensity and amount is less or at the end of the monsoon (September) in high rainfall areas. If the moisture can be maintained by irrigation, planting can be done at any time of the year.

9.2. Land Preparation

Cocoa can be planted in forest lands by thinning and regulating the shade suitably. It can also be grown in arecanut and coconut gardens as a mixed crop. Since cocoa is a shade-loving crop, all other crops to be mixed with cocoa should either be planted beforehand or at the same time as that of cocoa. If the area had any natural growth, then some trees should be left standing during land preparation. On the other hand, fast-growing plants, which will rapidly provide cover, such as bananas should be planted before cocoa is planted. Different land preparation practices are to be adopted depending on the slope, the preceding crop or previous use of the site, existing vegetation and other factors. Burning the vegetation for field preparation is not recommended. Instead the site should be cleared by slashing and chopping or shredding the hard plant materials and by distributing them homogeneously on the soil surface.

9.3. Preparation of Good Quality Planting Materials

Good quality planting material is an important input to ensure high yield and quality of cocoa. The selected varieties should be good yielding under local climatic conditions, with limited susceptibility to common pests and diseases, and produce the required quality according to the market demand.

Adopt the following for production of good quality cocoa seedlings

1. Identify cocoa trees that give consistent yields. The trees should preferably be selected in the same region in which the plantations are going to be established.
2. Harvest healthy and mature pods only. Good quality hybrid seeds obtained from local research stations can also be used for seedling production.
3. For raising cocoa nursery, enough shade, ample water and protection from wind are essential.
4. Fresh beans should be used for sowing as cocoa seeds lose their viability faster.



Figure 4.2: Cocoa Nursery Seedlings.

5. Rub the seeds with dry sand or wood ash to remove the mucilage and plant with their pointed ends upwards.
6. Sow the seeds in plastic bags (25 cm x 15 cm size with 150 gauge thickness).
7. Prepare soil mixture for the nursery consisting of 40 per cent top soil, 30 per cent compost and 30 per cent sand. A fertile, loam topsoil is ideal for filling the bags.
8. Relatively dense initial shade is recommended (more than 50 per cent). But shade must be decreased, as the seedlings grow.
9. Apart from watering, the plants do not need much attention in the nursery. However, too much watering may promote fungus attack.
10. Seedlings can be kept in the nursery for up to 6 months.

The following points are to be considered for selection of seedlings

1. Only vigorous seedlings based on height and stem girth are to be used.
2. When seedlings are grown under heavy shade, hardening for 10 days by exposing to higher sun light becomes necessary before transplanting.
3. Watering of the nursery beds should be done before lifting seedlings for transplanting to avoid breakage of roots and should be taken along with little earth around the roots.
4. If seedlings are raised in polythene bags, the cover should be removed before planting.
5. The seedling/graft/budded plant should be planted with ball of earth into the centre of the pit, not too deep.

6. While planting grafts, polythene strip tied over graft joint should be removed and the joint should be above the soil.
7. The planting material may be of 4-6 month old seedling or grafted or budded plant.
8. Avoid planting seedlings with twisted or damaged tap root or pot bound plants.
9. For long distance transportation, seedlings can be packed with moisture retaining materials like coir compost.

Softwood grafting is found successful and suitable in cocoa to breed true to type planting materials. These grafts can also be planted in the pits as in the case of seedlings after three months of hardening.

9.4. Spacing

The optimum spacing between cocoa trees is the distance which will give the optimal economic return of cocoa per unit area, always considering the stability of the organic production system. Factors such as labour requirements, establishment costs for the plantation and cost of inputs, possible losses due to pests and diseases *etc.* will also play significant role in finalization of spacing in cocoa plantation. In addition, the spacing is determined by factors such as the vigour of the trees, the soil and climate or the selected planting system. Providing optimum spacing is one of the important factors, which has a direct bearing on the yield of the crop. The optimum spacing for cocoa is one, which will give maximum economic returns. The spacing adopted for cocoa in the major cocoa-producing countries is highly variable and each country has adopted certain spacings which have become traditional. The spacing followed varies from as low as 1.0 m x 1.0 m in Trinidad to as high as



Figure 4.3: Cocoa as Mixed Crop in Coconut Garden.

5.0 m x 5.0 m in Sri Lanka. Although closer spacing usually produces higher yields in the first years after planting, once the canopy forms, the plantation becomes dense.

For the African situation where the less vigorous Amelonado type, which has a long pre-bearing period, is predominantly cultivated and where practically no costly input is used, a closer planting with 1.7 m x 1.7 m or 2.7 m x 2.7 m is beneficial. This will also mean a better crop in the early bearing period. The closer spacing is advantageous in the early years, especially for the unshaded cocoa. For the Amazonian types, a wider spacing in the range from 2.7 m x 2.7 m to 3.3 m x 3.3 m is recommended in Ghana. When cocoa is cultivated as mixed crop, the spacing of cocoa largely depends on companion crops. Among the other cocoa producing countries like Philippines, Papua New Guinea and Malaysia, where cocoa is cultivated along with coconut, the spacing followed in Malaysia is rather a close one, with two rows of cocoa at a plant-to-plant distance of around 2 m in between the 2 rows of coconut.

When coconut is spaced at 8 to 10m, the cocoa population in a hectare would be about 1000. For the space- planted coconut plantation, a row of cocoa at a plant to plant distance of 3 m is recommended for Indian cocoa. When cocoa is to be raised as a mixed crop with coconut, single hedge or double hedge system of planting can be adopted. In single hedge system, cocoa can be planted 2.7 m apart in a single row between two rows of coconut, while in double hedge system it can be planted 2.5m apart in paired rows between two rows of coconut palms. Cocoa is also planted in the interspaces of arecanut. Arecanut is usually planted at spacing for 2.7 m x 2.7 m and the usually adopted spacing of cocoa also is the same. Cocoa can be planted at the centre of four areca palms. The general experience is that such spacing results in crowding of cocoa canopy. Hence, a row of cocoa may be planted in the interspace of alternate rows of arecanut, and then the spacing for cocoa will be 5.4m x 2.7m. While establishing new garden a spacing of 3.3m x 3.3m can be followed for both areca and cocoa. The ultimate spacing and population level will depend upon the extent of canopy development, the variety used and the type of management.

9.5. Planting

If soils are naturally deep enough and are fertile, no significant advantage is seen for making planting pits. However, if soils are gravelly or if hard pan exists within the depth of penetration of roots, the practice of taking pits is advantageous. Cocoa seeds can be sown directly or seedlings planted at any time of the year if soil moisture conditions are suitable. Under Indian conditions, the most ideal time for planting seedlings in the main field is with the onset of pre-monsoon showers in May-June. If the soils are of low fertility, incorporation of manures during filling of pits may be advantageous. In areas where soils are of low fertility and gravelly laterite zones occur at varying depths, it is better to dig pits of 50 cm³ to 60 cm³ and fill with compost. A point to be noted is that cocoa seedlings are to be planted on the soil surface as the feeding roots of cocoa get concentrated in the top 10-15 cm layer of soil, irrespective of the zone at which seedlings are initially planted. Except for India, Malaysia, and the Philippines, cocoa is planted as a mono crop under natural or planted shade trees.

9.6. Shade Requirement

Cocoa is a plant that has originated under shade and has been traditionally cultivated under shade. The shade levels at which this crop was cultivated had been, however, highly variable. The shade requirement of this crop varies widely depending on stage of growth. Cocoa requires as much as 75 per cent shade in the early stages, which is to be gradually brought down to about 25 per cent when it comes to production. The role of the shade is not just to reduce light intensity but also to buffer the micro-environment so that excessive moisture stress in the young plants is avoided. The shade also helps to protect the young plants from the wind. It is possible to cultivate cocoa without shade under Kerala conditions and the productivity could also be higher under shade - free situations. Though the yield of cocoa under open condition, without any shade, may be good in the early years, the yield declines drastically in the long run. The shade in young plants has a major role to play as it decides the early growth of the crop. The shade crop should provide good shade throughout the dry season and not compete with the cocoa roots for moisture and soil nutrients and should be easy to remove later on without damaging the cocoa canopy. Such a plant should not be an alternative host to any insect pests of cocoa and if possible it should be of commercial value.

Young cocoa plants require shading to ensure the right form of growth, and 50 per cent shade will be sufficient. Heavy shade is needed initially, but this must be adjustable in the first few years leaving in the end a small number of trees as shade for the mature cocoa. Low light intensities with heavy shade leads to long internodes and few side branches and the high light intensity make the plant bushy. So appropriate shade is essential for the young cocoa plants for better canopy formation. In traditional cocoa growing countries two types of shade trees are available *viz.* temporary shade trees and, permanent shade trees. Temporary shading is essential during the initial years of planting cocoa. They should be relatively dense allowing not more than 50 per cent of the total light at least for two years after planting. It should be progressively reduced to 25 per cent as the cocoa tree develops, but never before the jorquettes have been properly developed. Temporary shade trees are planted at the same spacing as cocoa, alternating with it. The common temporary shade plants in African countries are banana, cassava or cera rubber (*Manihot glazevii*) and cocoyams (*Colocasia esculenta*). In pure crop situations, permanent shade trees are planted or left without removal at a wider spacing of about 13 to 15 m. The permanent shade tree commonly used for planting in Ghana is *Terminalia ivorensis*. Other trees grown are *Leucaena leucocephala* in Papua New Guinea, Indonesia, *Glyricidia sepium* in Central America, West Indies, Malaysia and Indonesia.

With the combination of permanent and temporary shade plants, the shade level will be high resulting in best vegetative growth of young cocoa plants. Once the cocoa canopy develops and comes to bearing stage, the temporary shade is removed and the increased light stimulates the production. Apart from these, multipurpose trees are also being used as shade trees especially in Asian countries. Coconut, arecanut and rubber are used as shade trees in Malaysia, India and Brazil.

Because of the high proportion of light, which penetrates through the canopy of palms, they are considered most suitable as shade tree for cocoa.

9.7. Weed Management

Weeds compete with the crop for water, nutrients and light. Therefore, the cocoa planted field should be kept weed free. Weeding also increases air circulation and reduces relative humidity and thereby reduces the incidence of black pod disease. The weed control measure commonly adopted in major cocoa producing countries, where cocoa is grown as a sole crop, is manual slashing twice a year at a height of 5 to 15 cm. It was found that near-complete removal of weeds has no additional advantage over slashing. Slashing will have the advantage of less labour intensive compared to clean cultivation. Once the canopy closes and plant start shedding their leaves which normally occurs in 3-4 years, weed growth will be restricted. Under intercropping situations weeding is done two to three times a year.

9.8. Irrigation

As a general management practice, irrigation is not done in any of the major cocoa producing countries because of the well-distributed rainfall in these regions. As cocoa is sensitive to water stress, irrigation is essential for performance of the crop during post monsoon season. In countries where the rain-free period extends from four to six months, irrigation in the summer months will be beneficial. Cocoa is mainly grown as an intercrop in the irrigated coconut and arecanut gardens in South India, where the dry period extends from 4-6 months a year. In such cases, the crop is to be irrigated once in 6 days during January-March, once in 4-5 days during April-May, and once in a week during November- December. Any of the methods of irrigation *viz.* basin, sprinkler, drip may be adopted depending upon the availability of water. Among these, daily one hour drip irrigation using emitters supplying 20- 24 litres of water is the most efficient method in terms of water use efficiency, supplying moisture to the root zone with maximum rhizosphere.

10. Cocoa as an Intercrop

Cocoa is generally grown as an intercrop under other plantation crops like coconut, arecanut and oil palm in Asian countries. Inter planting of coconuts with cocoa is popular in Papua New Guinea, Malaysia and India. In Papua New Guinea, where the coconuts are usually spaced at 9.0 m, cocoa is planted at 4.5 m intervals between and within the rows of palms, which gives 360 trees per ha. In Malaysia, coconut palms are planted at 8.0 m or 9.0 m and two rows of cocoa seedlings are planted between the rows of palms. The cocoa spacing is maintained to have population of 1040 trees per ha. In India the general recommendation is one row of cocoa in between two rows of coconut planted at 7.5 m x 7.5 m. If the spacing of coconut is wider (9.0 m x 9.0 m), two rows of cocoa can be planted in double hedge with a spacing of 3.65 m. When oil palm is planted at a spacing of 9.9 or 10.5 m in triangular method, the cocoa planted with a spacing of 2.4 m in triangular method produces better growth and yield. In India cocoa is extensively grown under arecanut also. The microclimate under arecanut is congenial for cocoa cultivation.

11. Nutritional Management

In general, most of the major cocoa-producing countries do not use manures or chemical fertilizers on a regular basis, as cocoa is cultivated in cleared forest soils rich in humus. The presence of shade trees, the dense canopy development of cocoa, and the large recycling of cocoa litter prevent any substantial soil erosion or loss of nutrients. The demand of shaded cocoa for fertilizer applications is considerably lower than that of unshaded cocoa. Hence, in organic agriculture which does not permit the application of synthetic fertilizers, the cultivation of cocoa under shade is essential. The creation of organic material through mulching and pruning activities is sufficient for an economically viable production. Nutrient requirements for cocoa plants can depend on the stage of growth of plants such as young or mature plants, which are yielding or non-yielding. With respect to nutrient requirements, organic farming practices should be such that the use of synthetic fertilisers under any circumstances should be avoided.

One of the most important measures for the improvement and maintenance of soil fertility is the continuous addition of organic material, both woody and fresh plant materials such as mulches. Part of this material can come from pruning of trees and from harvest residues, for example when composted cocoa pods are returned to the plantation and distributed evenly over the soil surface. By ensuring consistent use of prunings and pods within the plantation, soil fertility can generally be maintained for successful organic cocoa production. Thus regular pruning of trees and maintenance of a multitiered, diverse and densely populated agro-ecosystem is generally sufficient for profitable cocoa production. Organic manures or mulches can be used but their application in large quantities will not be very economical. However, this can be accomplished when leguminous plant species are grown in the border areas of plantation itself. Application of animal manure and compost is very beneficial in cocoa plantations, as they provide nutrients and improve the soil structure and its capacity to hold water and nutrients. Through mycorrhiza-symbiotic association, many palm varieties are in a position to actively break down phosphorus and other nutrients. In addition, they are capable of binding heavy metals in soil, so that their uptake through cocoa is reduced. This is important, since in many cases the heavy metal content of cocoa beans reaches critical levels. Therefore, suitable palms are to be integrated into the cocoa cultivation system.

11.1. Nutrient Recycling in Cocoa Garden

Cocoa tree, which produces leaves throughout the year, is an exhaustive crop that uses large quantities of nutrients, especially K and the nutrient mining is 43.8 kg N, 8 kg P and 64.3 kg K/ha. The biomass production varies with age and growing conditions. The pattern of biomass accumulation of cocoa is different in arecanut and coconut due to differences in population density and growth habits. In India, cocoa intercropped in coconut plantation adds organic material through litter fall to the extent of about one to two tonnes/ha/year. Pruning of cocoa plants could contribute about 8–10 kg/tree of organic biomass and litter fall will be about two to three kg/tree/year. The available recyclable biomass from cocoa (which includes pruned biomass, leaf litter and pod husk) could be around 0.7 to 0.8 million tonnes. In Brazil,

where cocoa plantations are under different agro-ecosystems, the recyclable biomass production is about 6 to 8 tonnes/ha under shading and 8.5 tonnes/ha under open conditions. By recycling organic wastes available from the cocoa gardens, it could supply around 540 t, 72 t and 244 t of N, P and K every year. The cocoa leaves from the garden can be converted into vermicompost using earthworms. The composted leaves were found rich in nutrients, including micronutrients, which was more than the normal compost. A recovery of 74 per cent could be obtained in case of vermicomposting. Though cocoa waste biomass such as pruned and fallen leaves, as well as pod husk contain relatively higher K concentration of 1.2 per cent to 3.0 per cent, the vermicompost made out of them has lower K content. In addition to this and as mentioned above, it is essential to return the (composted) cocoa pods to the plantation after removing the beans.

12. Maintenance of Mature Cocoa Farms

For any organic cocoa farm to be economical, there should be suitable conditions for growth and yield, based on the organic farming practices. Proper maintenance of cocoa trees during the early stages of growth improves later yields of the plantation. For good development, young cocoa plants need favourable growing conditions with the soil protected from the sun, little competition from weeds, proper pruning, adequate shade and improved soil fertility. Maintenance of existing cocoa farms will be economical only if optimal conditions for growth and yield are provided. A farm with complete cocoa canopy rarely needs more than occasional attention to clear the vegetation at the field's edges and in pockets within the farm. This would also require that weeds, pests and diseases are effectively controlled, cocoa trees regularly pruned accordingly, shade correctly adjusted and, appropriate manures are applied. A practice such as the regular pruning of cocoa trees and the correct adjustment of shade and adequate organic nutrients would lead to optimal yields in an organic cocoa farm and should be encouraged.

12.1. Pruning

Cocoa trees produce more branches and leaves than they need in order to be strong enough to compete with other trees. The more branches a tree grows, the more energy and "food" it must provide to these branches which reduces the size and number of pods that reach maturity. The best cocoa tree has one stem only and two or three main branches, with enough side branches and leaves to capture most of the sunlight. Removing unnecessary branches by pruning is, therefore, important for increasing production and reducing pests and diseases. The basic aim of pruning cocoa trees is to encourage a tree structure that allows sunlight to filter through to the main branches and trunk (what is known as a jorquette) to stimulate flowering, facilitate harvesting, more productive and efficient. Pruning is an important operation in cocoa especially when it is grown as an intercrop. It is a regular practice in all the cocoa growing countries except in West Africa. When cultivated as mixed crop under palms, a maximum of two-storey canopy architecture may be maintained. Cocoa trees should be pruned regularly to maintain a good canopy shape. It is optimum to have a canopy area of 15-20 m². Cocoa plants are grown under the shade of arecanut and coconut plantations. It is, therefore,



Figure 4.4: Pruning of Cocoa Plants.

necessary to regulate the canopy size and shape of plants so that the main crop is not affected. Proper and systematic pruning is essential in cocoa cultivation. The proper pruning of cocoa ensures adequate ventilation in garden; maintain tree height, makes spraying and harvesting operations easier. Pruning is usually done annually in July-August. Pruning reduces the number of unnecessary branches, and allows more light and wind to pass through the branches which reduces pest and disease levels and also amenable for easy harvest of pods.

Formation pruning and maintenance pruning are the two types of prunings generally practiced in cocoa.

12.1.1. Formation Pruning

Formation pruning is done in young plants, mainly to adjust the height of first jorquette. It is mainly to shape the canopy for desired shape, which should be umbrella-shaped. Normally the height at which the jorquette is formed depends upon the shade condition in the garden. Low shade intensity leads to jorquette formation at lower height. When the jorquette is formed at lower height, it has to be removed at an early stage to facilitate upward growth. This pruning will decide the number of jorquettes per tree, fan branches per jorquette and height of first jorquette. For pruning the seedling material, first adjust the height of first jorquette for easy cultural operations. A low jorquette will make it difficult to carry out cultural operations. Hence, a jorquette at 1.5 m to 2.0 m height is preferable. However, the jorquette-height varies significantly from tree to tree. The decision to control vertical growth depends upon the cropping system and the convenience of the farmer. Generally the vertical height is restricted to first jorquette. It has been found that increasing light intensity decreases the jorquette-height.

Presently, emphasis is being given to planting of graft materials obtained from soft wood grafting method using high yielding cocoa clones. For pruning the graft

material after first year of planting, primary pruning should be done to obtain a supporting framework of one or more upward growing main stems. Then drooping or inward growing branches are to be removed. Secondary pruning is suggested to develop well shaped canopy and desired canopy should be maintained in umbrella shaped form with about 3.8m to 4.2m spread and 2.7m height depending upon the space and main crop in which cocoa is under planted/grown. All the chupons arising from below the jorquette have to be cut regularly to maintain the height. If there is any damage to the jorquette, then only the chupons is left for the development of next jorquette. It is important to note that the maximum leaf area should be maintained with pruning practices to avoid self-shading. The strongest of the re-growing chupon can be selected and all others removed. In due course, this chupon will produce a jorquette at a higher level.

Vegetatively propagated plants generally form a jorquette at ground level. Fan branches should be limited to 3 to 4 to allow more light to enter and decrease the humidity within the canopy. Basal chupons should be removed at regular intervals and all lower branches that form or bend below the jorquette should be trimmed off. Furthermore all branches within 60 cm of the jorquette, all old and diseased branches and branches growing into the centre of the tree canopy should be removed. This should be done at regular intervals through maintenance pruning. All prunings should be left in the field to rot down, except the diseased ones.

12.1.2. Maintenance Pruning

Removing new shoots and new branches that are not needed for the health and strength of the tree throughout the year is called maintenance pruning. Maintenance pruning can be done at any time of the year. This pruning is done on mature trees to maintain the health and vigour of the tree by cutting all the diseased and unproductive branches, which is called sanitary pruning and to maintain the structure of the tree, which is called structural pruning. Sanitary pruning also includes removal of all unnecessary chupons, dead branches, epiphytes, climbing plants, ant nests, diseased and rodent damaged pods, and over ripe pods. Chupons must be removed very often. It is also necessary to prune infected branches with diseases like witches broom or vascular streak dieback. Structural pruning is done to shape the canopy to desired size and architecture. In either case care must be taken, when removing large branches to ensure that exposed wood surface is not damaged, to prevent the entry of fungi or insects. Apply recommended organic fungicides immediately after the pruning.

13. Plant Protection

Cocoa can be affected by many pests and diseases, which thrive well in the warm and humid climates where cocoa is commonly grown. However, with proper understanding and implementation of a natural agro-ecosystem, pests and diseases can be effectively managed. The loss due to pest and disease in cocoa could be as high as 30 per cent to 40 per cent of global cocoa production. Diseases are usually caused by different kinds of fungi or may be viral, while pests affecting cocoa are predominantly insect pests but can also include birds and mammals. Combating

of cocoa diseases and pests will be the major challenges for the success of organic cocoa farming in many countries. In an organic production system, the application of synthetic pesticides is not permitted, and hence, the conditions in the cocoa plantation have to be developed in a manner wherein the infestations of pests and diseases can be largely prevented. Organic practices would require that diseases and pests are to be managed using methods that would avoid the use of synthetic chemicals. However, in exceptional circumstances where all non synthetic methods have been used and are unable to remedy the situation, chemicals within a list agreed upon between the certifiers and the farmers could be used to solve the situation. The manner in which such chemicals are used and the reason for them being used should be well documented through a method agreed upon between the farmers or their representatives and the certifying bodies.

Accurate pest management, dependent on a strong scouting, often referred to as monitoring or surveying of pests, is essential in any pest management programme. The cocoa farmers should know the conditions of their crop and the pests in the field so that they can determine the best actions to adopt for their management. Most pest and disease infestations have been found to occur under the following conditions:

- a. Cultivation of cocoa as mono crop with a small number of shade trees and species (in conventional cocoa production only 25 to 40 trees per hectare of mostly the same species are recommended).
- b. High density of vegetation due to very close planting between the different varieties in a system and failure to thin and prune the trees.
- c. Unsuitable site (water-logging, too dry, no possibility for deep root development of plants)
- d. Poor and degraded soils, which lack organic material
- e. Unsuitable shade management.
- f. Deficiencies in plantation hygiene: Non-removal of diseased pods, branches and leaves.
- g. Unsuitable harvest practices: Irregular harvesting.

Lack of air, excess moisture as well as physical disorders of the cocoa plant (inadequate nutrition) often cause fungal diseases. In many cases, effective and sustainable control can only be achieved through improvement of the entire plantation system, especially shade management.

Generally proper management of pests and diseases can be achieved by:

- a. **Using disease resistant and pest tolerant varieties** - Cocoa varieties with tolerance to black pod disease and swollen shoot virus disease are available.
- b. **Ensuring field hygiene** - This is probably the single most important method for managing key cocoa diseases. All diseased or infected plants, pods and other plant parts should be removed from the plantation and destroyed. Regular removal of diseased pods can suppress the black pod

- disease. To ensure healthy planting material, shoots should be taken from non-infested trees and plantations only.
- c. **Regulating cocoa tree height, pruning and shade management** - Removal of some branches of cocoa and shade trees by pruning and proper maintenance of the height of the cocoa trees will allow light to penetrate to the centre of the tree, and will increase air circulation. Such cultural operation makes the conditions unfavorable for the black pod disease. Removing shade trees with a shorter life cycle than cocoa at the end of their life cycle is an important measure to be undertaken in this aspect.
 - d. **Maintaining soil fertility** - To ensure general health of trees, efforts are to be taken for improving soil fertility, particularly where cocoa is grown on poor soils with low nutrient levels.
 - e. **Proper weeding** - Weeding increases air circulation and reduces the humidity in the plantation and thereby reduces the incidence of diseases, particularly the black pod disease.

Table 4.6: Pests of Cocoa and their Management Practices

<i>Name of Pests</i>	<i>Symptoms of Pest Infestation</i>	<i>Control Measures</i>
Mirids or capsids (<i>Sahlbergella singularis</i> <i>Distantiella theobroma</i> <i>Helopeltis</i> spp. <i>Monalonium</i> spp.)	Most important insects in many of the cocoa cultivating areas of the world Most significant effect on cocoa farming in the West African Region Sucking insects and damage young shoots and pods thereby reduce yield Brown or black sap lesions that are later infested by disease Young cocoa trees are very vulnerable to pest attack when they are grown without shade	Keep the canopy of cocoa complete and protect nests of predatory ants
Mealy bugs (<i>Planococcoides njalensis</i> <i>P. citri</i> Kokoo sumor)	Adult females and young ones feed on the tender shoots, flower cushions, flowers, cherelles and pods Colonization of seedlings and young plants cause retarded growth and excessive branching at undesired height Causes cushion abortion and wilting of cherelles Act as vectors of cocoa swollen shoot virus (CSSV)	The population build up of the bugs is more during the summer months. Avoid unscrupulous cutting of trees
Tea mosquitoes (<i>Helopeltis antonii</i>)	Damage the pods and the infested pods develop circular water soaked spots around the feeding punctures They later on turn pitch black in colour Deformation of pods also occurs because of multiple feeding injuries	Mechanical control
Thrips (<i>Heliothrips selenothrips</i>)	Brown spots on dry or silvered leaves	Avoid nutritional imbalance, poor soil conditions and sudden change of shade level

13.1. Pests and their Management

Though many insects and non-insects are known to feed on cocoa, only a few are of economic importance and many of them have geographical isolation and, thus, the number of major pest species in any one area tends to be low. Cocoa is affected by more pests in West Africa than any other country. The most common pests of cocoa are mirids or capsids and mealy bugs. The details of pests of cocoa and their management are given in Table 4.6.

Some of the other pests of cocoa are:

The red stem borer of coffee is found to bore into the branches and trunks of cocoa trees. The portion of branch above the point of entry of the pest dries up. Control of the pest is best achieved by pruning off and destroying the attacked branches.

Aphids colonise on the underside of tender leaves, succulent stem, flower buds and small cherelles. Heavy infestation brings about premature shedding of flowers and curling of leaves.

The larvae of Stem girdler beetle tunnel the bark first and penetrate deeper making galleries. On younger trees, the pest attack occurs at the jorquette, which normally results in the drying or breaking of the portion above. Mechanical extraction of the larvae is suggested as control measures under organic cocoa cultivation.

Leaf eating caterpillars and leaf eating beetles are some of the other pests of cocoa.

13.2. Diseases and their Management

Details of important diseases of cocoa and their management practices are given in Table 4.7.

14. Harvesting

The most essential quality characteristics of cocoa will be decided based on correct processing, which begins with the harvesting process and ends with the storing of the processed product. A wrong step in any of the post-harvest operation leads to poor quality beans. The harvest can begin when the fruits are completely ripe and turn yellowish or reddish orange in color. In many Trinitario types, with their red and dark violet fruits, this can be recognized by an orange discolouring of the pod. Since the amount of flowering and pods set are higher at periods of high temperature, the main harvest will take place several months after such a period. Depending on the temperature, pod ripening can take between 4.5 to 7 months from flowering. Depending on the region and weather conditions, there are usually one or two harvesting phases, which are spread out over several months. In order to achieve a uniform ripeness of the fruits harvested, to avoid overripe pods in the trees, harvest all the ripened fruits every 2-3 weeks. The best way to avoid harming the bark is to cut off the fruits at the base of the blossom with a sharp knife or other suitable instrument.

Table 4.7: Diseases of Cocoa, Symptoms and their Management

Name of Disease	Disease Symptoms	Control Measures
Swollen-shoot virus	Virus is a major problem in Ghana and Nigeria Swellings on roots, chupon and jorquette shoots Red vein-banding of young flesh leaves, leaves develop interveinal chlorosis; trees look generally yellow Pods become mottled, smoother and rounded in shape with fewer beans Virus is transmitted by mealybugs	Inoculating trees with a mild virus strain Use resistant varieties Control of mealybugs Removal of infected plants and of adjacent trees
Black pod disease (<i>Phytophthora palmivora</i> , <i>P. megakarya</i> , <i>P. capsici</i>)	Occurs during rainy season when humidity is high and the temperature is constantly optimum. Fungus infects seedlings, flower cushions, pods, shoots, leaves and roots Initially small, chocolate brown circular lesion(s) anywhere on the pod surface Spots develop into brown patches which spread over the whole pod surface and turn black, and hence the name White or yellow sporulation over infected areas Fishy smell On some varieties cankers are formed; pink-red discoloration below diseased bark Root infection is important part of annual cycle	Reduction of overhead shade to reduce relative humidity and to improve aeration Regular weeding Regular harvesting of mature pods Removal of infested plant parts, particularly fruits or pods In emergency cases: spraying copper, sulphur or bentonite compounds before disease builds up Periodical spraying of 2 per cent epiphytic bacterium (<i>Pseudomonas fluorescens</i>) Cut off infested bark
<i>Moniliasis</i> / <i>Moniliophthora</i> pod rot (<i>Moniliophthora roreri</i>)	Fungus mainly appears in South America Infections on young pods Dark brown spots appear one month after infection and gradually cover whole pod White sporulating mycelium	Reduction of shade Frequent removal and destroying infected pods Use of more resistant varieties Application of lime to stem application of copper fungicides Applying epiphytic bacterium (<i>Pseudomonas aureoginosa</i>)
Witches'-broom disease (<i>Marasmius perniciosus</i> , <i>Crinipellis perniciosa</i>)	Fungus mainly appears in South America and some West Indian islands Major symptom being the brooms; thicker branches with short lateral shoots Abnormally thick stalks of flowers Distorted young pods; black speckles on old pods Small pink mushrooms on dead brooms	Regular removal and disposal of diseased material Identification and removal of susceptible trees Using resistant trees

Contd...

Table 4.7–Contd...

Name of Disease	Disease Symptoms	Control Measures
Vascular streak dieback (<i>Oncobasidium theobromae</i>)	Fungus mainly appears in South East Asia First yellowing of one or two leaves on the second or third flush behind the growing tip Falling of diseased leaves Short shoots grow from leaf axils after fall of leaves Bundles of black vascular streaks inside diseased stems The disease is spread by spores produced on diseased branches, which are released only at night under certain specific climatic conditions and are dispersed by wind	Use of Amazon type of cocoa Removal of unwanted branches Prepare nurseries away from diseased cocoa field Prune diseased branches around 30 cm below diseased xylem and remove Regular pruning of chupons on the trunk
Black root disease (<i>Rosellinia pepo</i>)	Fungus appears mainly in the West Indies Infected roots are covered with grey mycelium which later turns purplish black Trees wilt and leaves die Root diseases usually arise from residues of felled trees	Removal of the infected tree with all the roots Removal of adjacent trees
Charcoal pod rot (<i>Botryodiplodia theobromae</i>)	Pods of all ages are susceptible. The infection appears as dark brown to black coloured spot and the affected spots turn black and remain on the tree as mummified fruit. The internal tissues become rotten and the affected beans turn black. Spores appear in masses forming a soot. Infection takes place through wounds	Spraying with one per cent Bordeaux mixture is recommended to control this disease.
Pink disease (<i>Pellicularia salmonicolor</i>)	The presence of a pinkish powdery coating on the stem. It causes wilting of shoots, shedding of shoots, shedding of leaves and finally drying up of the branch. The disease persists from season to season through dormant mycelium inside the bark and in the cankerous tissues.	It could be checked by pruning the affected branches and swabbing the cut ends with Bordeaux paste. Regular spraying of 1 per cent Bordeaux mixture is also recommended for management of the disease.
Canker (<i>P. palmivora</i>)	The cankers appear either on the main trunk, jorquettes or fan branches. The initial symptom is the appearance of a greyish brown water soaked lesion on the outer bark. A reddish brown liquid oozes out from these lesions, which later dries up to form rusty deposits. The tissues beneath the outer lesion show reddish brown discoloration due to rotting. When these cankers girdle the main stem or branches, dieback symptoms appear and ultimately the tree dies. The infection may also spread from the infected pod to the peduncle and then to the cushion and bark.	The disease can be managed in the early stages by removing the infected tissues and applying Bordeaux paste. All infected pods should also be removed and destroyed. The drainage system is to be improved in the garden, if the disease appears.

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Table 4.7–Contd...

<i>Name of Disease</i>	<i>Disease Symptoms</i>	<i>Control Measures</i>
Cherelle rot (<i>Colletotrichum gloeosporioides/other factors</i>)	Large number of two to three months old and developing fruits (pods) known as 'cherelle' dry up and remain on the tree as mummified fruit and this type of drying of pod is commonly referred as cherelle wilt. The shrivelling and mummifying of some young fruits are a familiar sight in all cocoa gardens. In the early stages the fruits lose their lusture and in four to seven days the fruits shrivel. The fruits may wilt but do not abscise. Many factors are associated with this malady. The most important factors are: insects, diseases, competition for nutrients, over production etc.	The management practices depend upon the nature of the causative factors involved.



Figure 4.5: Harvested Mature Pods.

In case the fruits are harvested when overripe, germination can already have begun in the pod. A large number of already germinated cocoa seeds will not pass a quality control, and for this reason, overripe and diseased fruits should not be mixed together with healthy cocoa fruits, but are to be processed separately. Ripe pods should be harvested as soon as possible in order to minimise attack by fungal diseases or animal pests such as squirrel and rodents. Harvesting too late leads to overripe pods with the pulp drying up, and in extreme cases, the beans may start to germinate. Lack of pulp will not give a good fermentation. Also, germinated beans will not ferment well, and the hole caused by the emerging shoot will allow mould inside the bean. Pods that are still green or partly green have more solid pulp (with less sugar content) and the beans may be hard to break up. Unripe pulp gives rise to clumps of beans and leads to poor fermentation. Therefore, harvesting unripe pods produces beans of low quality. After harvesting, unopened pods can be kept for about 5 - 7 days before opening, as storage allows the pulp to increase in sugar content, which causes faster fermentation. Storing pods for longer than 7 days may allow mould to damage the beans and/or encourage the beans to germinate. Pods are to be opened for the removal of the beans. To reduce the risk of damaging the beans, the pods are to be cracked on a hard surface (stone or wood) or by hitting them with a piece of wood. It is important to separate the beans from the placenta. Either the pods are opened in the field and only the beans moved for fermentation or the pods are transported and opened near the fermenting kegs.

15. Post-harvest Management

The following are some of the very important aspects to be considered in the post-harvest handling of cocoa beans:

1. Avoid injuring the beans during pod-splitting (pods cut open to extract the beans);

2. Wet cocoa beans should undergo fermentation for 7 days in order to kill the seeds and enhance the chocolate flavor;
3. Dry under the sun or by a mechanical dryer;
4. Dried beans are kept in gunny sacks and stack on raised platforms. Avoid damp conditions to control fungus attack which lower the bean quality.

15.1. Fermentation

The beans must be fermented as soon as they are removed from the pod. Fermentation has the following objectives:

1. Remove the mucilage (pulp) attached to the beans.
2. Kill the embryo so that the beans cannot germinate and give the beans a good taste when roasted.
3. Encourage chemical changes within the bean, which produce the substances responsible for developing the cocoa/chocolate flavour needed by chocolate manufacturers.
4. Reduce the moisture content of the beans.

Fresh cocoa seeds are enveloped in a white, fruity-sweet pulp that composes up to 15-20 per cent of the fruit's weight. They consist to 80 per cent of water, 10-15 per cent glucose and fructose, as well as 0.5 per cent non-volatile acids (mainly citric acid) and pectin, and have a pH-value of 3.5. The seeds have a strong, bitter taste, which is caused by the dark violet-coloured anthocyan constituent in the seeds. It is only with the beginning of the fermentation that these bitter parts are chemically transformed, when seeds begin to take on a chocolate brown colouring, and the first signs of the typical aroma begin to develop. The fruit pulp of the cocoa beans offers excellent living conditions for microorganisms that play an important role during the entire fermentation process. As the process commences, the fermentation is dominated by yeast fungi which produce alcohol. The fruit pulp begins to disintegrate, and flows away. The fermentation tanks, therefore, are to be constructed and set up so that the fruit pulp juices can drain away.

Large harvests also produce large quantities of juice, which is not allowed then to flow directly into the environment. It must either be processed, or disposed of in a soakage or sewage pit. This is very important in an organically cultivated cocoa plantation. Fermentation can be carried out in two ways.

1. Traditionally the beans are heaped or wrapped in banana leaves. Every second day, the banana leaf packages are turned over to ensure even fermentation. The size of heaps is determined by the need for a sufficiently high temperature of 40 °C to 50 °C to permit liquid to drain out and air to circulate freely around the beans. Flavour development begins when the temperature of the beans is raised to a high enough level during fermentation.
2. A second way of fermenting the cocoa beans is by placing them in wooden tray stacked on top of each other and covered. This ensures better fermentation. Waste water from the fermentation process should



Figure 4.6: Fermentation of Beans.

be properly disposed off to avoid environmental pollution of the organic farm.

The temperature does not get high enough to start flavor development in a fermentation heap if small quantities of less than about 70 kg are used, whereas, while in heaps of more than 150 kg, aeration becomes restricted. The first part of the fermentation is done by bacteria that do not need air. Therefore, the first two days the heap is not mixed. The second part of the fermentation process is done by bacteria that require air. Therefore, after the first two days the heap must be turned/mixed thoroughly every day to allow air to reach all the beans. The end of the fermentation process is reached when most of the beans are brown. When 75 per cent of the beans have pale cotyledons in the centre with a brown ring, the fermentation process should be stopped. Fermentation usually will be completed within 3 to 5 days for Criollo cocoa, whereas, it takes 6 to 8 days in the case of Forastero cocoa. The relationship between colour, degree of fermentation and flavor is given in Table 4.8.

Table 4.8: Relationship between Colour, Degree of Fermentation and Flavor in Cocoa

<i>Colour of Beans</i>	<i>Degree of Fermentation</i>	<i>Flavour of Roasting</i>
Brown	Fully fermented	Strong cocoa flavour, balance of acidity, astringency and bitterness
Brown/purple(mauve)	Partly fermented	Good cocoa flavour, higher acidity, astringency and bitterness
Purple	Low fermentation	Low cocoa flavour, strong acidity, astringency and bitterness
Greyish or black	Unfermented	Absence of cocoa flavor, predominantly acid, astringent and bitter. Overall sour flavor

15.2. Drying

After the fermentation process is finished, any unripe or damaged beans are to be sorted out. The remaining fermented beans must be dried to prevent deterioration, reduce the growth of mould and to improve the flavour. Dried cocoa beans are easier to be stored and transported. The initial moisture content of around 55 per cent must be reduced to around 6-7 per cent before the beans are stored. Enzymatic transformation processes continue to take place during the drying process, whereby the contents are oxidised, and the cotyledon inside the seeds' shells turns a brown colour, and the typical aroma of chocolate develops. In addition, the surplus acetic acid evaporates. It is important to dry the cocoa beans carefully, in order to maintain a certain stability and storability. Drying is done by spreading them out in a thin layer on the mat in the sun on concrete floors or raised mats. Any foreign matter found should be removed from the beans while they are spread out. Sunlight will increase the browning process and also the development of aroma. Slow, careful drying in the sun can take up to 7 days.

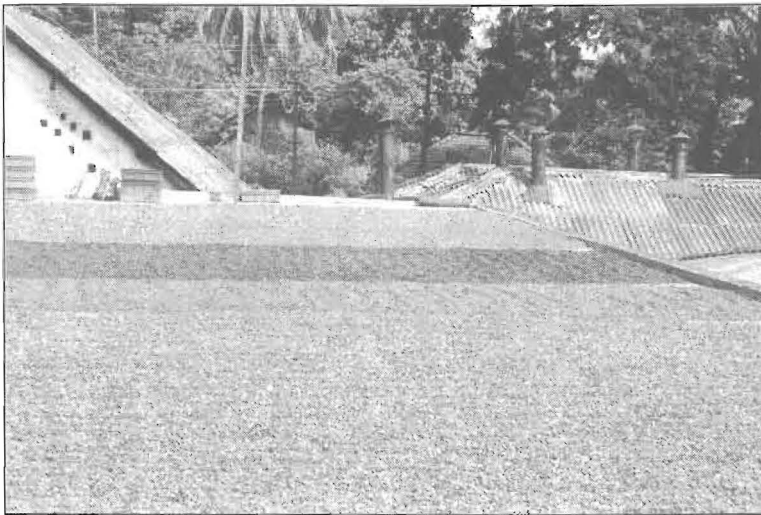


Figure 4.7: Drying of Beans.

It is important to turn the cocoa beans by often raking to ensure that the beans are dried uniformly and carefully. Drying apparatus that utilise warm air are recommended for use in those regions where it is often cloudy during the harvest season. It is important to note that the cocoa should not come into contact with the fumes from the fuel – as this would adversely affect their taste and smell, and therefore, their quality. Well-dried beans should have a moisture content of about 6 to 7 per cent. Beans with a moisture content of more than 8 per cent become mouldy, while beans with moisture below 5 per cent become brittle. A properly fermented and dried bean should be brown in colour when the bean is cut into half. All flat, broken and poorly fermented beans should be removed before packing dried beans into air permeable bags.

15.3. Bagging of Dried Beans

The beans are usually bagged in bags of 60 to 70 kg.

For exporting, the bags should provide the following information:

- ☆ Name and address of producer/packer, country of origin
- ☆ Designation of product, quality class
- ☆ Date of harvesting
- ☆ Weight
- ☆ Lot number
- ☆ Destination with address of trader/importer
- ☆ Clear information on organic certification (standards applied, certifying agency, year of conversion or full organic status).

The bags are to be kept in dark, dry and well ventilated stores at low temperatures.

Short term: ca. 16 °C and 55 per cent humidity;

Long term: ca. 11 °C and 55 per cent humidity.

If the organic cocoa is being stored with conventional cocoa (mixed store), confusion has to be avoided by carrying out suitable measures such as:

1. Training of and instructions to storekeepers
2. Clear labelling in the store (e.g. green colour for organic)
3. Keeping of store book in which arrivals and departures of goods can be clearly distinguished.

15.4. Storage

Dried cocoa beans can be stored for years in temperate climates; on the other hand, due to the high temperature and humidity in the tropics, stored cocoa rapidly gets attacked by storage pests and moulds, because dried cocoa easily absorbs moisture. In regions with 80 to 90 per cent humidity, the moisture content of cocoa beans often increases to more than 10 per cent and as a result, cocoa loses its storage capacity. Therefore, the storage area should always be well-ventilated and the inside temperature should remain below the outside temperature. The cocoa should be stored in air-permeable sacks on the production site for only a short time, whereby the sacks should be stacked on wooden planks or boards. The use of sacks made of organic material (jute) should be avoided, if these have been treated with pesticides. Organic production does neither allow the treatment with methyl bromide nor the application of any synthetic storage insecticides.

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