TRAINING MANUAL ON COCOA PRODUCTION TECHNOLOGY

Editors

P. Chowdappa

S. Elain Apshara

Nagaraja, N. R.

K. S. Ananda

Organized at:

ICAR-Central Plantation Crops Research Institute
Regional Station, Vittal - 574 243, Karnataka

Sponsored by:

National Institute of Agricultural
Extension Management (MANAGE)
Rajendranagar, Hyderabad - 500 030, Telangana

ICAR-Central Plantation Crops Research Institute
Kasaragod - 671 124, Kerala

TRAINING MANUAL ON

COCOA PRODUCTION TECHNOLOGY

Editors

P. Chowdappa
S. Elain Apshara
Nagaraja, N. R.
K. S. Ananda

ICAR-Central Plantation Crops Research Institute
Kasaragod-671 124, Kerala

ICAR-Central Plantation Crops Research Institute (CPCRI)
Kasaragod - 671 124, Kerala, India
Phone: 04994 - 232893, 232894, 232895, 233090
Fax: 04994 - 232322
E-mail: director.cpcri@icar.gov.in, directorcpcri@gmail.com
Website: http://www.cpcri.gov.in

Published by

Dr. P. Chowdappa
Director, ICAR-CPCRI, Kasaragod

Editors

P. Chowdappa
S. Elain Apshara
Nagaraja, N. R.
K. S. Ananda

February, 2018

Correct citation

P. Chowdappa, S. Elain Apshara, Nagaraja, N. R., K. S. Ananda. 2018. Training Manual on Cocoa Production Technology. ICAR-CPCRI, Kasaragod, Kerala, 106p.

Sponsored by

National Institute of Agricultural Extension Management (MANAGE), Hyderabad

Prepared at

ICAR-CPCRI, Regional Station, Vittal - 574 243, Karnataka.

PREFACE

Cocoa is one of the important commercial plantation crops of India and it is mainly cultivated in four major southern states viz., Kerala, Karnataka, Tamil Nadu and Andhra Pradesh. India produces 18,920 tonnes of dry beans of cocoa from an area of 82,940 ha. The cocoa industry in the country had expanded to a considerable extent in the recent years with the chocolate consuming population increasing every year by 15-20 percent. At present, more than 15 industrial entrepreneurs and firms are existing in the field. The demand for dry cocoa beans is nearly 30,000 tonnes of which the present domestic availability is only about 45 percent. Considering the market growth in the chocolate segment in India, which is about 20 percent per annum, cocoa has great potential to develop in future years.

ICAR-Central Plantation Crops Research Institute (CPCRI) has been a pioneer in research on cocoa in India for more than four decades. The scientific research has resulted in a number of technologies which are being disseminated to the farmers and other clients through various transfer of technology programmes. Scientists of State Agricultural Universities, Subject Matter Specialists of KVKs, Officers of Department of Horticulture/ Agriculture, Other Developmental Agencies and Progressive Farmers are involved in transfer of technologies to farmers and other clients.

I am happy that ICAR-Central Plantation Crops Research Institute, Kasaragod is organising a ten days 'National Training Program on Cocoa Production Technology' at ICAR-Central Plantation Crops Research Institute, Regional Station, Vittal during 15.02.2018 to 24.02.2018 for the benefit of scientists, extension personnel and officers. As part of this, a training manual has been prepared by the scientists covering all the subject matter areas related to cocoa.

I congratulate the course director, co-director, co-ordinator and scientists of ICAR-CPCRI, Regional Station, Vittal for having taken steps to bring out this training manual for the benefit of scientists, extension personnel, officers of KVKs, officers of development departments and those who are interested in updating the cocoa technologies. I am sure that this manual will be a useful resource material for scientists and officers concerned with research and extension activities of cocoa. I acknowledge National Institute of Agricultural Extension Management (MANAGE), Hyderabad for providing financial support to organise this training programme.

(**P. Chowdappa)**
DIRECTOR, ICAR-CPCRI

CONTENTS

1. SIX DECADES OF SERVICE OF ICAR-CPCRI, VITTAL

Nagaraja, N.R. and K.S. Ananda

ICAR-Central Plantation Crops Research Institute, Regional Station at Vittal came into existence in 1970, with a mandate to carry out research on arecanut and cocoa. The efforts on this direction started as early as 1947 through the establishment of ad-hoc arecanut committee by Indian Council of Agricultural Research (ICAR) to study the problems of arecanut industry. Based on the recommendations of the committee, the Central Arecanut Research Station (CARS) was established at Vittal in 1956, which gave a firm foundation for arecanut research. Consequent to the establishment of the CPCRI in 1970, the CARS became the Regional Station of CPCRI. The systematic research on cocoa production technologies was started during 1970. This Regional Station lies in the heart of the major areca growing areas of the country. Vittal is located in Bantwal taluk of Dakshina Kannada district, 48 km away from Mangalore on the Mangalore-Vittal-Puttur road.

Vision

Develop ICAR-CPCRI as a technology generation and repository centre, wherein the Institute strives to showcase, demonstrate and compare world-wide technologies in the commodity chains of arecanut and cocoa to make India the global leader.

Mission

To develop technologies that enhance resource use efficiency, profitability and livelihood security of people who depend on arecanut and cocoa.

Approach

Basic and applied research and transfer the research findings to the farmers and other stakeholders through the collaborative synergy of developmental agencies.

Mandate

- Basic, strategic and applied research to enhance sustainable productivity, quality and utilization of arecanut and cocoa,
- Repository of plantation crops genetic resources and scientific information,
- Transfer of technology, capacity building and impact assessment of technologies,
- Coordinate research and validation of technologies on arecanut and cocoa through AICRP on Palms.

Headquarters

Headquarters of ICAR-CPCRI is located at Kasaragod, Kerala in Kasaragod-Mangaluru highway. During 1916 Central Plantation Crops Research Institute was established as Central Coconut Research Station at Kasaragod and later during 1970 it was brought under Indian Council of Agricultural Research (ICAR) and renamed it as present ICAR-Central Plantation Crops Research Institute. The initial mandate of the Institute was on crop husbandry of coconut, arecanut, cocoa, oil palm, cashew nut and spices. The restructuring process during VII and VIII Plan resulted in the establishment of separate Research Institute/ Centres for Spices, Cashew nut and Oil palm. At present the Institute has countrywide research network with two Regional Stations and three Research Centres. Besides, the institute also hosts AICRP on palms and headquarters of Indian Society of Plantation Crops. Two Regional Stations of ICAR-CPCRI are located at Kayamkulam, Kerala and Vittal, Karnataka and three Research Centres are located at Karnataka (Kidu), West Bengal (Mohitnagar) and Assam (Kahikuchi).

Profile of the station

Area	:	68.34 Ha. (170.85 acres)
Altitude	:	73- 92 m above MSL
Soil	:	Laterite admixed with sand and alluvium
Soil pH	:	5.25
Latitude	:	12º 15^{1}N
Longitude	:	75º 25^{1}E
Climate	:	Hot and humid with annual average rainfall of 3670 mm distributed over 120 days during South West monsoon from June-September.
Max. Temperature	:	25- 40ºC
Min. Temperature	:	16- 23ºC
Rainfall	:	3500- 4000 mm
Agroclimatic Zone	:	12 (West- Coast plains and Ghats)

Germplasm conservation and varietal development

Arecanut

- Comprehensive collection of germplasm of both indigenous and exotic genotypes has been made and screening them under uniform conditions is being done since 1957.
- A total of 176 accessions has been collected which are being maintained in the field gene bank.

- 153 indigenous ecotypes of arecanut collected from different parts of India *viz*., Assam, Goa, Gujarat, Karnataka, Kerala, Maharashtra, Meghalaya, Tamil Nadu, West Bengal and Andaman & Nicobar group of islands.
- 23 exotic accessions introduced from other areca growing countries of the world especially from South-East Asian countries such as Fiji, Mauritius, South China, Sri Lanka, Indonesia, Vietnam, Singapore, British Solomon Islands and Australia. The collections consists of four species *viz., Areca catechu* L., *Areca triandra* Roxb., *Normanbya normanbyii*, *Areca concinna* and one related genera *Actinorhytis calapparia.*
- Systematic breeding works resulted in high yielding varieties *viz.*, Mangala, Sumangala, Sreemangala, Mohitnagar, Swarnamangala, Kahikuchi tall, Madhuramangala, Nalbari and Shatamangala and dwarf hybrids *viz.*, VTLAH-1 (Vittal Areca Hybrid-1) and VTLAH-2 (Vittal Areca Hybrid-2).

Cocoa

- A total of 500 cocoa germplasm collections are being conserved in field gene bank of ICAR-CPCRI, Regional Station, Vittal.
- Hybridization works resulted in development of cocoa hybrids which are vigorous, early and heavy bearing with stable yield *viz.*, VTLCH-1, VTLCH-2, VTLCH-3, VTLCH-4 and VTLCH-5 (Nethra Centura). A clone, VTLCC-1 with standard bean characters and two high yielding clonal selections *viz.*, VTLCS-1 and VTLCS-2 were also released.

Quality planting material production

- The seedlings of all released arecanut varieties and hybrids are raised in nursery and are distributed to the farmers based on request.
- The seed pods, seedlings and grafts of all released cocoa hybrids and clones are distributed to the farmers based on request.
- Both arecanut and cocoa nurseries are evaluated by National Horticulture Board and awarded 4 star rating out of 5.

Utilization of resources

Arecanut

- Agro-techniques for arecanut such as spacing (2.7m x 2.7m), fertilizer dose (100:40:140 g N, P_2O_5 and K_2O, respectively and 20 Kg FYM per palm/ year) and irrigation of 200 liters of water per palm once in 4-5 days through hose are recommended for realizing higher yield and income.

- Drip irrigation in areacnut @ 100% of the pan evaporation at Vittal conditions results in 45% yield increase and 44% saving in water. Through drip irrigation 20 liters of water/ tree/ day is recommended.
- Fertigation of 75% NPK at 10 days interval was highly profitable.
- The yield levels of arecanut can be sustained at around 2600 kg/ ha with organic waste recycling.
- Growing cocoa at spacing of 2.7m x 5.4m in arecanut garden will increase the net return per unit area.
- Vermicomposting of areca wastes using two cultured species of earthworms, *Eudrilus eugineae* and *Eisenia foetida* has been proved to be an efficient method of composting.
- High density multispecies cropping system involving arecanut, cocoa, black pepper and banana had resulted in a higher net return of almost 85-100% over arecanut monocropping system.
- Intercropping of medicinal and aromatic plants in arecanut is recommended to increase the profitability per unit area.
- Mixed farming system including arecanut, dairy and pisciculture (fishes) has been successfully demonstrated at this Station.
- Raising fodder grass like Hybrid Napier or Guinea Grass in one hectare of arecanut garden can support 4 to 5 dairy animals.

Cocoa

- Fertilizer dose of 100:40:140 g N, P_2O_5 and K_2O per palm/ year and drip irrigation of 20 liters of water/ tree/ day is recommended for realizing economic returns.
- Canopy architecture by pruning and training of branches has been standardized for canopy management under intercropping.
- Irrigation once in a week during November-December, once in 6 days during January-March and once in 4-5 days during April-May.
- Nigerian cocoa accessions NC 42/94, NC 23/43 and NC 29/66 possess drought tolerance. The hybrid combinations *viz*., I-29 x NC 42/94 and I-29 x NC 23/43 recorded tolerance for drought based on physiological and biochemical parameters.
- Cocoa genotypes which are rich in antioxidant properties were identified.

Organic recycling

On an average, 5.5-6.0 tonnes of organic wastes/ha/year will be available in arecanut garden. Direct recycling of these wastes does not meet the crop demand immediately. Vermicomposting technique is proved to be an efficient method of composting. To prepare vermicompost, areca wastes are chopped in to small pieces of 5-10 cm. Fill it in tanks alternately with layers of cow dung @ 10% by weight of waste materials. Maintain moisture content of about 30-40%. Incubate for 2-3 weeks and introduce worms @ 1kg

per 1000 kg waste. The wastes are converted into fine granular, odourless vermicompost within 60 days. During this period the earthworm population is doubled. About 8 kg/palm/year of vermicompost meets the crop nutrient demand. The two cultured species of earthworm *Eudrilus eugeniae* and *Eisenia foetida* can be used.

Plant health management

Plant protection recommendations are made from this station for arecanut and cocoa pests and diseases through integrated approaches.

Arecanut Pests

Root grub- Deep ploughing and digging of soil during pre and post monsoon period, collection and destruction of adult beetles during peak emergence, application of neem cake @ 1 kg/palm during pre and post monsoon, release of Entomopathogenic Nematode and spray of Imidacloprid 17.8 SL @ 2.5 ml/L of water in the interspaces of arecanut palms.

Spindle bug- Maintenance of field hygiene, placement of Thiamethoxam 25 WG (2 g) in perforated poly sachets in the innermost leaf axil or spray of Thiamethoxam 25 WG (0.25 g/L) in and around the spindle.

Mites- Maintenance of field hygiene, proper irrigation during summer season, spray of Neem Oil Emulsion (0.5%) @ 5 ml/L of water, two times at fortnightly interval.

Pentatomid bug- Maintenance of field hygiene, spray of Neem Oil Emulsion (0.5%) @ 5 ml/L of water or Imidacloprid 17.8 SL (0.5 ml/L of water) to the tender bunches in affected gardens at an interval of 15-20 days.

Scale insect- Maintenance of field hygiene, spray of Neem Oil Emulsion (0.5%) @ 5 ml/L of water to the tender bunches in affected gardens at an interval of 15-20 days. Release of lady bird beetles, *Chilocorus nigrita* as bio-control agents.

Arecanut Diseases

Fruit rot- Spray of 1% Bordeaux mixture just before monsoon and one or two sprays at an interval of 45 days. Covering the bunches with poly bag prior to monsoon helps in disease control.

Bud rot and Crown rot- Spray or drench the crown region with 1% Bordeaux mixture as a prophylactic treatment during June first week and one more spray during August first week. Remove the infected tissue completely and treat the wound with Bordeaux paste and drench the crowns of surrounding healthy palms with 1% Bordeaux mixture.

Inflorescence die back- Removal and destruction of affected inflorescence, spray of Mancozeb @ 3g/L on inflorescence of affected gardens at an interval of 30-35 days.

Basal stem rot- Improving drainage facilities, isolation of affected palms by digging trenches, drench the root zone with Hexaconazole @ 45 ml in 15 L of water and application of 2 kg of *Trichoderma* enriched neem cake per palm.

Cocoa Pests

Tea mosquito bug/ Mirids- Timely pruning, spray of anyone of the following insecticides such as Lamdacyhalothrin 5 EC @ 0.3ml/L, Bifenthrin 10 EC @ 0.8ml/L, Imidacloprid 17.8 SL @ 0.25/L in rotation at new flushing and flowering season.

Mealy bugs- Proper and timely pruning and spray of Neem Oil Emulsion 5 ml/L. If the severity is more take up spraying of insecticides like Imidacloprid 17.8 SL @ 0.3ml/L or Dimethoate 30 EC @ 1.6ml/L.

Leaf eating caterpillars- Spray of Neem Oil Emulsion @ 5ml/L. Second spray may be given after an interval of 30 days.

Stem borer- Pruning of affected and dried branches and killing of larvae through a bore hole by inserting sharp iron needle, place Chlorpyriphos 0.05% soaked cotton and fasten with polythene strips. Swab Coal tar and Kerosene @ 1:2 in the basal portion of the trunk at about 3 feet height after scraping the loose bark to prevent oviposition by adults.

Rats- Timely harvest and placement of 10 g Bromodialone (0.005%) cake on the branches of cocoa trees at 10 to 12 days interval.

Squirrels- Trapping with wooden or wire mesh single catch 'live' trap with ripe coconut kernel as the bait is effective. Timely harvest of the pods will help in increasing the efficiency of poison baiting as well as trapping.

Palm civet- Poison baiting with 0.5 g of Carbofuran granules using ripe bananas as baits.

Cocoa Diseases

Black pod rot- Spraying of Bordeaux mixture @ 1% at 15 days interval starting from the onset of South-West monsoon is recommended for black pod.

Stem canker- Treating the wound and soil around the base of the cocoa tree with *Trichoderma* Coir Pith Cake (TCPC) is effective in reducing the incidence.

Charcoal pod rot- Spraying 1% Bordeaux mixture to the pods during summer months.

Cherelle wilt- Spraying of Carbendazim @ 0.05% and Mancozeb @ 0.2%.

Zinc deficiency- Foliar spray of a mixture of 0.3% Zinc Sulphate and 0.15% (w/v) lime.

Reaching the stakeholders

The Institute is acclaimed by stakeholders and developmental and extension agencies as nodal center for arecanut and cocoa. Methodology evolved for farmer's participatory research/ extension approach for sustainable income enhancement among small and marginal holdings. Dissemination of technologies are pursued through on-campus and off-campus training programmes, frontline demonstration of cropping/ farming systems, INM, IPM, IDM and post-harvest technologies, exposure visit of clientele, diagnostic field visits, kisan melas, exhibitions, mass communication media and print media. Research-extension-farmer interface are conducted in different locations with the cooperation of other stakeholders.

Training programmes are conducted for Scientists, farmers, technical staff, agricultural/ horticultural officers, self help groups *etc*. based on the need and request. Demonstrations on grafting, pruning techniques, Bordeaux mixture preparation *etc*. are organized. Multi-disciplinary team of scientists visits farmers' fields and give professional advice for solving the problems related to arecanut and cocoa cultivation.

Agriculture Information Centre provides information related to agricultural technologies in the form of folders, charts, models, specimens, photographs, CDs, *etc.* Seminars, Meetings, Field days, Kisan Mela and Exhibitions are organized from time to time based on the need. Important transfer of technology programmes are given below.

Success stories

Arecanut based cropping system

Scientific study on arecanut based cropping system was initiated during 1970s at ICAR-CPCRI. Arecanut based multispecies cropping system is effective for increasing the production per unit area and maximizing the economic returns through better utilization of resources. For convincing the farmers about the technical feasibility and economic viability of cropping system, six demonstration plots were established in Bantwal taluk of Dakshina Kannada district of Karnataka during 2008-09 and ten demonstration plots were established in Belthangady and Puttur taluks of Dakshina Kannada district and Kasaragod taluk of Kasaragod district in the farmer's gardens during 2011-12 by ICAR-CPCRI, Regional Station, Vittal. Overall, the productivity and profitability of arecanut farming has been increased significantly over the years by adoption of cropping system. Training programmes, seminars and field days on 'Arecanut based multispecies cropping system' were organized for the benefit of farming community.

Integrated management of root grubs in arecanut

Root grub is one of the major pests in arecanut which cause economic loss and in severe cases which will result in death of palms. Considering this, ICAR-CPCRI, Regional Station, Vittal had established demonstration plots on 'Integrated management of root grubs in arecanut' with 1 acre each at farmers' gardens at Ujire in Belthangady taluk during 2010- 2013. There was a substantial reduction in number of root grubs at the root zone over the years. The number of root grubs at the root zone of the palm in 2010 was 4.5 which were reduced to 0.4 in 2014. Arecanut yield recorded in 2010 was 1.22 kg/palm/year which were increased to 1.5 kg/palm/year in 2014. There was a substantial increase in yield of about 22.8 per cent in 2014 over 2010. Costs for implementing IPM for managing root grubs was Rs. 38,900 per acre per year. Gross returns realized in 2014 by adopting IPM was Rs. 2,06,250/- which was 136.2 per cent increase over 2010. Hence, increased income by adopting IPM was Rs. 1,67,350/- in 2014. IPM for managing root grubs proved its technical feasibility and economic viability in farmers' gardens. In view of this, package of integrated management practices for root grubs in arecanut is being adopted by farmers in Karnataka with the support of Department of Horticulture**.**

Linkages

ICAR-CPCRI has a history of 60 years of arecanut research and 45 years of cocoa research with high yielding varieties, package of practices, post harvest technologies and research findings. The demand for ICAR-CPCRI technologies like high yielding varieties/ hybrids of arecanut, high yielding hybrids and clones of cocoa from bi-clonal/ poly-clonal orchards, soft wood grafting in cocoa, pruning and training technology for seedlings and grafts of cocoa, vermicomposting using arecanut and cocoa wastes, integrated nutrient management with judicial, balanced and split application of organic and inorganic fertilizers, natural enemies/ predators in areca-cocoa ecosystem and bio-control agents and integrated pests and diseases management practices for arecanut and cocoa has been very high among the farming community and other clientele. Research and extension activities are changed as per the demands of clients *viz.*, farmers, agricultural/ horticultural officers, agro-processors, self help groups, college/ school students *etc*. Assessment and refinement of technologies is done through co-operation of developmental departments/ boards by organizing various programmes with the active participation of farmers.

ICAR-CPCRI, Regional Station, Vittal has very strong linkages with developmental organizations like Directorate of Arecanut and Spices Development (DASD), Kozhikode, Directorate of Cashew nut and Cocoa Development (DCCD), Kochi, Central Arecanut and Cocoa Marketing and Processing Cooperative Ltd. (CAMPCO), Mondelez International Pvt. Ltd., Departments of Horticulture, Farmers Organizations and Self Help Groups (SHG's). These organizations/ agencies borrow technologies from ICAR-

CPCRI and SAUs for transferring them to farmers. They play a vital role in taking the technologies to door steps of the farmers through various schemes/ programmes.

Research-Extension-Farmer Linkage

Various agencies both from research and extension systems strive for the development of arecanut/ cocoa sector and for better impact, such extension activities are to be coordinated at different levels. Research-Farmer-Extension interface programme is an approach for strengthening the Transfer of Technologies (ToT) efforts for the development of sector and the experiences of ICAR-CPCRI in implementing such programme indicate the relevance of strengthening linkages at different levels. Researchers, extension personnel and farmers are brought together on a common platform and the activities for the sustainable development of arecanut/ cocoa are streamlined. ICAR-CPCRI had organized research-farmer-extension interface programmes on coconut, arecanut and cocoa in 13 districts of Karnataka during August 2013 to October 2013 as a collaborative effort with SAHUs, KVKs and Department of Horticulture. Similar interface programmes are being organized in arecanut/ cocoa growing states. The interface programmes could enhance the awareness and knowledge about the technologies for improving arecanut productivity and income of farmers. The experiences gained from interface programmes revealed that the concept of research-extension-farmer interface is sure to enhance the adoption of technologies ultimately leading to farmers' own benefit.

Mera Gaon Mera Gaurav (My Village My Proud)

The innovative initiative 'Mera Gaon Mera Gaurav' by Ministry of Agriculture and Farmers' Welfare, Govt. of India has been planned to promote the direct interface of agricultural scientists with the farmers to hasten the lab to land process. The institute has started implementing the programme in ten villages from October, 2015 as per the guidelines. Training programmes, demonstrations on improved practices, farm advisory visits, mobile advisory services are organized in the selected villages for the benefit of arecanut and cocoa growers. Cutting across all disciplines, farm problems are diagnosed and effective solutions are delivered and showcased in farmer's fields. National priorities such as secondary agriculture, climate change, good agricultural practices and soil and health management of crops are envisaged in this programme.

2. COCOA SCENARIO-PRODUCTION, CONSUMPTION AND MARKETING OF COCOA

C.T. Jose

Area, production and productivity

Cocoa is grown principally in West Africa, Central & South America and Asia. In the early 1970s cocoa production was concentrated on Ghana, Nigeria, Côte d'Ivoire and Brazil, but it has now expanded to areas such as the Pacific region, where countries like Indonesia have shown spectacular growth rates in area and production (Table 1 and Table 2). The world production of 1.18 million tonnes cocoa bean during the year 1961 is increased to 4.47 million tonnes by the year 2016.

Unlike large, industrialized crops, 80 to 90% of cocoa comes from small, family-run farms, with approximately five to six million cocoa farmers worldwide. In Africa and Asia, the typical farm covers two to four hectares (five to ten acres). Each hectare produces 300 to 400 kilograms of cocoa beans in Africa and about 500 kilograms in Asia. Cocoa farms in the Americas tend to be slightly larger and produce 500 to 600 kilograms of cocoa beans per hectare. Yield per hectare varies not only by region, but also by country and by type of cocoa. Côte d'Ivoire with 1.5 million tons of production is the highest producer in the world. Its share of world production has increased from 6% during 1961 to 33% in 2016. Access to new forest land and increased yields from hybrid varieties cultivated during 1970's aided the increase in production. The production & profitability of the country is very high because of cheap land and labour costs combined with average yield at 516 kg/ha.

Ghana is the second largest producer of cocoa beans with 19% of world production. Ghana was the largest producer until the mid 1970. Production declined sharply in next 10 years due to over taxation and economic policy distortions. Policy reforms during 1986 led to the recovery in production. Indonesian cocoa production increased from a meager 0.1 million tons during 1961 to 0.66 million tons by the year 2016. The majority of the increase was from small holders producing at a very low cost. Low production cost, highly competitive marketing system, favourable macro-economic policies and small holders' entrepreneurship are all the positive aspects of Indonesian cocoa sector. Malaysia experienced a rapid expansion in area and production from mid 1970's to early 1990's. Malaysian cocoa production increased from 5000 MT during 1971 to 3,99,000 MT by the year 1991 and after that the production declined sharply to 2000 MT by the year 2016. This was due to relatively low cocoa price in the early 1990's compounded by the problem of labour shortage and the availability of more profitable alternative crops like oil palm. High yielding plantations and efficient marketing system are the positive aspects.

Table.1. Trend in area ('000Ha) under cocoa in different countries

Country	1961	1971	1981	1991	2001	2011	2016
Brazil	474	448	505	668	666	680	720
Cameroon	380	397	426	350	362	670	724
Ecuador	220	219	270	332	430	399	454
Ghana	1756	1500	1200	721	1350	1600	1684
India*	0	0	20	20	16	57	78
Indonesia	7	9	23	184	765	1733	1701
Côte d'Ivoire	260	423	901	1412	1778	2495	2851
Malaysia	1	7	42	399	58	21	17
Nigeria	700	700	700	726	966	1240	838
World	**4403**	**4423**	**4848**	**5686**	**7153**	**10069**	**10197**

Source: http://www.fao.org/faostat/en/#data

Table 2. Trend in production ('000MT) of cocoa beans in different countries

Country	1961	1971	1981	1991	2001	2011	2016
Brazil	156	219	336	321	186	249	214
Cameron	75	139	118	105	122	240	292
Ecuador	44	71	80	100	76	224	178
Ghana	415	470	247	242	390	700	859
India*	0	0	6	6	7	14	16
Indonesia	1	2	13	175	537	712	657
Côte d'Ivoire	85	226	465	765	1212	1511	1472
Malaysia	1	5	49	230	58	5	2
Nigeria	197	257	174	268	340	391	237
World	**1186**	**1639**	**1735**	**2532**	**3218**	**4627**	**4467**

Source: http://www.fao.org/faostat/en/#data

Table 3. Trend in yield (Kg/Ha) of cocoa beans in different countries

Country	1961	1971	1981	1991	2001	2011	2016
Brazil	329	489	665	481	279	365	297
Cameroon	198	350	278	300	337	358	403
Ecuador	200	323	298	303	177	561	391
Ghana	236	313	205	335	289	437	510
India*	0	0	300	300	416	255	475
Indonesia	154	219	584	951	701	411	386
Côte d'Ivoire	327	534	516	542	682	606	516
Malaysia	462	608	1156	577	996	221	101
Nigeria	281	367	249	369	352	315	282
World	**269**	**371**	**358**	**445**	**450**	**460**	**438**

Source: http://www.fao.org/faostat/en/#data

Consumption

Travelling along a global supply chain, cocoa beans go through a complex production process that includes farmers, buyers, shipping organizations, processors, manufacturers, chocolatiers and distributors. Unlike larger, industrialized agribusiness, the vast majority of cocoa comes from small, family-run farms, which often rely on out-dated farming practices and have limited organizational leverage.

Global cocoa demand is very much dependent on the demand of chocolates. Per capita income is an important determinant. United States is the largest cocoa consuming country in the world. Although cocoa is largely produced in developing countries, it is mostly consumed in industrialized countries. United States is the main export destination of the Latin American countries, while Africa sells most of its cocoa to Europe. Asia mostly imports from Indonesia or from Ecuador and other South American countries. For cocoa, the buyers in the consuming countries are the processors and the chocolate manufacturers. A few multinational companies dominate both processing and chocolate manufacturing. The main consumers of cocoa, based on the apparent domestic cocoa consumption, which is calculated as grindings plus net imports of cocoa products and of chocolate products in beans equivalent are shown in Fig.1.

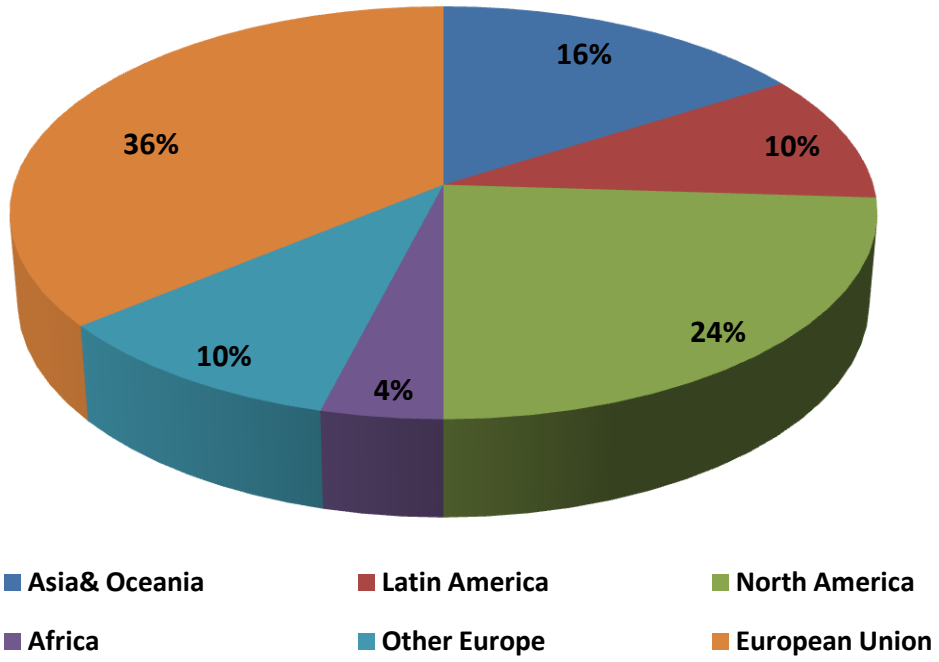

Fig.1. Percentage consumption of cocoa in different region of the world

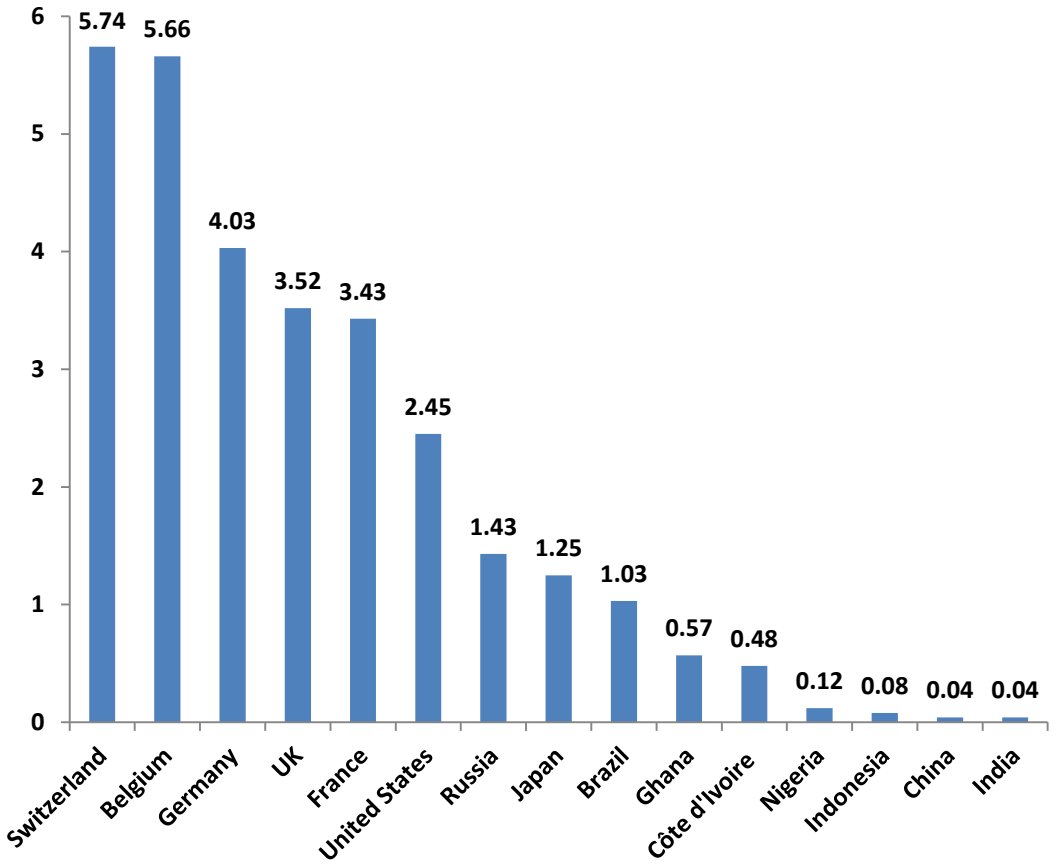

Fig.2. Per-capita consumption of cocoa bean equivalent (in Kg)

Source:HTTP://UNCTAD.ORG/MEETINGS/EN/PRESENTATION/SUC_MEM2014_09042014_ICCO.PDF

Per capita consumption levels are highest in Western Europe and North America. Consumption in Brazil has witnessed remarkable growth in recent times and it is now the 9th largest cocoa consumer in the world. The markets of Western Europe and North America are near saturated markets. They are traditional chocolate eaters and remain the drivers of cocoa consumption with very high per capita consumption. Central/ Eastern Europe and Latin American markets are the emerging markets. Liberalized environment in Central and Eastern Europe since 1990's attracted high investment of confectionary manufactures. Vast potential in Russia, excellent growth rate in Brazil, favorable climatic factors and scope for more innovative range of products are the positive aspects. China and India together can be called as high potential markets. The two countries together have a population of 2.5 billion. Excellent economic growth rates and a growing middle and upper class income may lead to higher cocoa demand. We can find that the main exporters are also the main producers of cocoa beans. Although Brazil is a main producer of cocoa but they are not a large exporter due to the size of their processing industry, which absorbs local production. In Latin America for example, the Dominican Republic exports more cocoa beans than Brazil.

Cocoa powder is essentially used as flavor in biscuits, ice cream, dairy drinks and cakes. Apart its use as flavor it is also used in the manufacture of coatings for confectioners or frozen desserts. Cocoa powder is also consumed by the beverage industry for example for the preparation of chocolate milk. Besides the traditional uses in chocolate manufacture and confectionery, cocoa butter is also used in the manufacture of soap and cosmetics. It is also a folk remedy for burns, cough, dry lips, fever, malaria, rheumatism, snakebite and wounds. It is reported to be antiseptic and diuretic.

Prices

Cocoa prices mainly respond to cocoa supply and demand factors. International prices tend to follow a long-term pattern linked to the cocoa cycle, which has been estimated to be of over 20 years. During cocoa boom periods there is a supply surplus that will result in falling and then stagnating prices. Consequently, low prices due to overproduction generally have a negative impact on harvesting, encouraging farmers to switch to other crops, a factor which again permits world prices to rise. The cocoa cycle is thus characterized by boom and bust effects. Prices experienced an important increase in the 1970s, which encouraged production in countries such as Malaysia and Indonesia. However, since the beginning of the 1980s prices have declined and after 2000, the price shows an increasing trend.

Chocolate manufacturing is a thriving business, in which big companies make high profits. While these companies are competing for ever higher market shares and higher profits, millions of cocoa farmers bear the costs by getting less and less share from the revenues. In 2014, the total global retail value sales of chocolate confectionery reached a staggering 100 billion dollars - an increase of 20 billion from 2012. Cocoa growers today receive about 6% of the price that consumers in rich countries pay for chocolate. In the 1980s their share was 16%, almost three times more than the present share.

The cocoa farmers receive only a part of the world market price for beans, due to local trading structures, taxes and also the quality of the beans. For the last ten years, farmers in Ivory Coast attained only between 40 to 50% of the world market price for their beans. Farmers are rarely organized and lack insight into market trends for cocoa prices. They have to sell their cocoa at prices dictated by the intermediaries. Additionally, farmers' income insecurity is affected by volatile cocoa prices. Volatility in prices often stems from changing supply volumes caused by crop diseases, pest infestation, extreme weather such as drought or political instability and turmoil in the producing countries. While good seasons which produce good crops in the main cocoa producing countries lead to a high supply and can bring about a fall in prices, poor crops caused by crop disease or bad weather conditions in some major regions lead to a low supply and can increase the price. Price changes can also be triggered by factors like food speculation. For speculators

volatile prices are lucrative as speculative trading on future markets can bring about big profits.

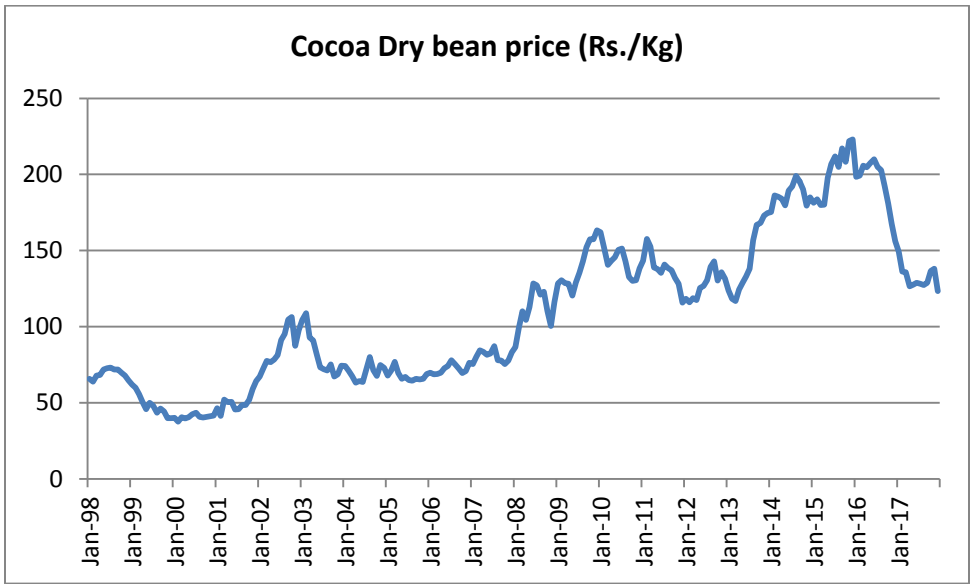

Fig.3. Price trend of cocoa

Source:https://www.indexmundi.com/commodities/?commodity=cocoa-beans&months=240&currency=inr

The consequences of price volatility, together with increasing production costs, are economic insecurity and impoverishment for millions of cocoa farmers. Despite forecasts that the demand for cocoa will rise by nearly 20% in the coming years and the increasing revenues for chocolate companies, many farmers cannot cover their living costs anymore. With limited income and lack of information on market developments, the cocoa farmers and their families are the losers in a lucrative cocoa and chocolate industry.

Import Trade flows

There are two types of cocoa beans. More than 90% of cocoa produced annually can be considered as bulk (or basic) cocoa. Bulk cocoas mostly come from Africa and Brazil, mainly of the Forastero variety. Fine and flavor cocoas have distinctive aroma and flavor characteristics, sought after by chocolate manufacturers. They represent only 5% of world cocoa production.

The International Cocoa Standards require cocoa of merchantable quality to be fermented, thoroughly dry, free from smoky beans, free from abnormal or foreign odors and free from any evidence of adulteration. It must be reasonably free from living insects, broken beans, fragments and pieces of shell and foreign matter and reasonably uniform in size.

Indian Scenario

Cocoa is one of the important commercial plantation crops in India and it is mainly cultivated in four major southern States of Kerala, Karnataka, Tamil Nadu and Andhra Pradesh where the agro climatic conditions are suitable for cocoa. The North East states like Assam, Meghalaya and Arunachal Pradesh are also having congenial climatic conditions for cocoa.

In India, cocoa is mainly grown as intercrop either with coconut or arecanut. In the coconut and arecanut gardens with 40-50% sunlight penetration, cocoa is the most favourable crop to absorb, amicably accommodating and remaining symbiotic to the main crop. The tropical regions of India at present exerting high competition for several crops, the benefit of cocoa to get along with coconut and arecanut garden is an admirable and explorative set up to encourage its cultivation in our country. Its integration with such crop is an added advantage to derive as good an income as possible within the limited resources of land and water besides helping in enriching the soil condition, making it beneficial for both crops in improving the soil conditions and nutrients availability.

India produces just 0.4% of global cocoa production. The trend in area, production and yield of cocoa in India are shown in Table.4. At present the area under cocoa in India is 78,000 ha with a production of 16,050 MT (www.nhb.gov.in).

Table.4 Trend in area production and yield of cocoa in India

Year	Area (Ha)	Production (MT)	Yield (Kg/Ha)
1994	11883	6742	570
1998	12038	5281	440
2002	16130	6780	500
2007	29471	10175	530
2009	31885	10560	535
2011	46318	12954	380
2013	65500	13400	540
2016	78000	16050	475

Source: DCCD, Kochi-2017

Future potential for cocoa development in India

As cocoa is mainly cultivated under irrigated coconut and arecanut gardens, availability of such areas especially coconuts gardens in the states like Kerala, Karnataka, some parts of Maharashtra, Pondicherry, Tamil Nadu, Andhra Pradesh, Orissa and West Bengal will therefore offer considerable scope for its development as these areas are coastal belts

where coconut is grown under irrigated conditions. Of the 15 lakh ha of coconut gardens in India, the coconut areas in Karnataka, Pondicherry, Tamil Nadu and Andhra Pradesh are mostly irrigated in nature. In respect of other states, nearly 30-40% is under irrigation. Therefore not less than 3 lakh ha will definitely be suitable for cocoa as an intercrop, beside the vast land potential available in North East region.

At present more than 15 industrial entrepreneurs and companies existing in the field demanding nearly 40,000 MT. of cocoa beans of which the present production is hardly 40%. The cocoa growers were quite apprehensive about the price trends prevailed during the latter part of 20^{th} century. This was almost a deterring factor for them to adopt cocoa cultivation. In the light of the increasing competition exerted by several companies the domestic price of cocoa beans is now is about Rs.160 per kg of dry beans depending upon the area of production, quality and quantity.

Conclusion

In view of the potentiality available in the country and the economic liberalization policies of Government of India and rapid rate of consumption in India, cocoa has a great potential to develop in future years. By way of redefining the technologies and making use of available resources and effective transfer of technology measures, the potential areas if converted to better opportunities in the most prevailing tempting trend of prices, the promotion of cocoa in India can be successfully achieved to improve the economic condition of farmers, to meet the needs of the industry and above all to catch a well-placed situation for India in the global cocoa production scenario.

References:

1. www.nhb.gov.in.- National Horticulture Board, Govt. of India.
2. http://www.fao.org/faostat/en/#data
3. HTTP://UNCTAD.ORG/MEETINGS/EN/PRESENTATION/SUC_MEM2014_09042014_ICCO.PDF
4. https://www.indexmundi.com/commodities/?commodity=cocoa-beans & months=240 & currency=inr

3. COCOA GENETIC RESOURCES MANAGMENT AND IMPROVEMENT

S. Elain Apshara

Cocoa (*Theobroma cacao* L.), called as 'Food of Gods' is the source for chocolate and is an important industrial and beverage crop next to tea and coffee. It originated from Amazon basin of South America, where the natives, Mayas, Aztecs and Pipil-Nicaraos roasted and ground the cocoa beans, made into an energy drink called 'xocoatl'. Later the Spanish introduced cocoa into Europe, added sugar and milk and named as 'chocolate', the world's favourite food (Wood and Lass, 1985).

Cocoa was introduced into India way back in 1798 at Courtallam in Tirunelveli district of the old Madras state by East India Company (Ratnam, 1961). Cocoa was distributed then in the Western Ghats hills and plains, mainly the rubber and coffee growing zones of Malabar and Mysore states, having more rainy days and short dry spells (Wood, 1964).

1. History of cocoa improvement

One of the oldest improvement programmes is cocoa breeding, which was started in 1930 by Cocoa Research Unit (CRU), Trinidad. In India, the oldest plantations with Criollo type cocoa were established in Kallar and Burliar Fruit Stations in the Nilgiris in 1930-35 and evaluated for their performance. In 1962, Indian Council of Agricultural Research (ICAR) adopted a policy of introducing and growing Criollo type of cocoa in South India and Forastero type of cocoa in North East India. In 1964, few Malaysian clones were imported and research on arecanut + cocoa and coconut + cocoa mixed cropping systems were conducted at Central Plantation Crops Research Institute (CPCRI), Regional Station, Vittal, Karnataka and at other centres Peechi and Palode in Kerala and Kahikuchi in Assam and proved as profitable cropping models. In 1965, a research-cum-demonstration unit of Cadbury India Pvt. Ltd. was established in Chundale in Kerala (Peter *et al*., 2002). In 1969, systematic research was started in CPCRI with additional introductions of germplasm, followed by Kerala Agricultural University (KAU) in 1979 and then continued at KAU in 1987 with Cadbury India Pvt. Ltd. funding. In 2008, Tamil Nadu Agricultural University (TNAU) has initiated cocoa research with funding from Mondelez International.

2. Cocoa genetic resources and diversity in populations

Theobromo cacao L. the cultivated species of cocoa is a diploid (2n= 20), originally classified under Sterculiaceae and reclassified under Malvaceae family, having a small genome of 380 Mbp. There are 22 identified species in this genus. The three basic types of cocoa are, Criollo, Forastero and Trinitario, which have specific pod and bean characteristics and form the base for many old plantations as well as the new varieties developed by research institutes.

Characters	Criollo	Forastero	Trinitario
Pod colour	Red to Orange (ripe)	Green to Yellow (ripe)	Intermediates/ Mixtures
Pod shape	Pronounced point, thin wall, rough surface	Melon shaped, rounded, smooth, inconspicuous point	Husk texture- hard
Bean colour	White/ ivory cotyledons, plumpy	Pale to deep purple cotyledons, flat	Variable in colour, rarely white
Bean number	20-30/ pod	30 or more	30 or more
Fermentation	Very quick (3 days)	Slow (6 days)	Intermediate
Flavour	Bland & Pleasant	Harsh & Bitter	Mixture
Vigour	Less	Vigorous	Intermediate
Adaptability	Less	Wider	Wider
Reaction to pests and diseases	Susceptible	Tolerant	Tolerant
Types	Central and South American Criollos (Fine cocoa)	Amelonado, Comum, West African Amelonado, Nacional, Matina or Ceylan and Guiana (Bulk cocoa)	Trinidad, Asian hybrids (Bulk cocoa)

Indicators of variability

Expression of diversity is estimated from different indicators of variability especially, the morphological traits which are important for the cataloguing and characterisation of germplasm. Bioversity International has standardized the descriptor status for cocoa, which comprises of 60 characteristics. Characterisation and passport data documentation has been undertaken in thirty year old cocoa collections at CPCRI (Elain Apshara and Rajan, 2009) and national identity numbers (Indigenous/ Exotic Collection, IC/EC No.) were obtained from NBPGR, New Delhi. Developing DUS (Distinct Uniform Stable) testing guidelines for cocoa is underway at CPCRI.

Indicators of morphological variability in cocoa

Tree architecture	Erect, Intermediate and Pendulous growth habits
Leaves	Shades of green and purple, with or without pulvinus in the petiole
Flowers	Colour, Petal diameter, Pedicel length
Fruit shape	Angoleta- deeply ridged, warty, square at the stalk end Cundeamor- bottle necked angoleta

	Amelonado- smooth, shallow furrows, melon shaped, blunt end, slight bottle neck Calabacillo- small and nearly spherical Oblong/ Elliptic/ Obovate/ Orbicular
Basal constriction	Absent/ Slight/ Intermediate/ Strong
Apex form	Attenuate/ Acute/ Obtuse/ Rounded/ Mammilate
Surface rugosity	Absent/ Slight/ Intermediate/ Intense
Prominence of ridges	Slight/ Distinct
Primary furrow depth	Superficial/ Intermediate/ Deep
Husk hardness	Soft/ Intermediate/ Hard
Anthocyanin in ripe pods	Absent/ Slight/ Intermediate/ Intense
Pod size	Big/ Medium/ Small
Beans	Shape, Color, Size
(Wood and Lass, 1985; Bartley, 2005)	

3. Reproduction and flowering pattern in cocoa

Cocoa is a cross pollinated crop, reproduces sexually and this has resulted in lot of variation in the progenies. Vegetative propagation is also practised through cutting, grafting and budding to maintain true to type plants. Cocoa flowers are small and hermaphrodite, appears in large numbers on floral branches called 'cushions' on the shoot on attaining a minimum physiological age of two to three years. The flowering is referred as 'cauliflorous' or truncate bearing. Though cocoa trees produce large number of flowers, only 1-5 percent of the flowers are successfully pollinated to produce a pod.

Incompatibility mechanism

Self-incompatibility in cocoa was first reported by Pound (1932). In cocoa, the pollen tubes develop normally, but the male gamete does not fuse with the female gamete and lead to 'gametophytic' incompatibility. Self-incompatibility is made use of in the design and operation of seed gardens to ensure that seed of a certain desired parentage is produced.

4. Breeding strategies

Systematic and long term cocoa improvement programs are being taken up with the following strategies.

Cocoa breeding strategies

- Introduction : Collection and conservation of germplasm
- Diversity studies : Cataloguing and characterisation
- Selection : Compatibility, breeding lines, desirable traits

- Hybridization : With specific objectives and selected parents
- Progeny trials : Evaluation of hybrids with cross combinations
- Clonal orchards : For F_1 seed production
- Vegetative propagation : Soft wood grafting
- Comparative Yield Trials : Canopies, Clones/ Seedlings, Densities
- Multi Location Trials : Different agro climatic zones
- Resistance breeding : Screening and hybridisation
- Molecular Breeding : Biotechnology and Bioinformatics
- Demonstration gardens : Front Line Demo gardens on cocoa

(Elain Apshara *et al*., 2005; Elain Apshara, 2017)

Objectives

Medium canopy	:	Intercropping system
High pod yield	:	>50/tree/year (stable for minimum 6 years)
Dry bean yield	:	>2 kg/tree/year
Bean size	:	>1.0 g/dry bean
Less shelling	:	10-15%
Nib recovery	:	85-90%
Fat content	:	>50%
Resistance	:	Biotic and abiotic stress

(i) Introduction of germplasm

The basic step in any breeding program is introduction of germplasm from both the primary and secondary centres of origin and distribution. Intermediate Cocoa Quarantine Centre (ICQ,C) at the University of Reading, UK is looking after the safe movement of germpalsm. CPCRI initiated introduction of collections from Malaysia and Nigeria in 1969 and later through ICQ,C, for which NBPGR is the nodal agency. Around 500 collections are being maintained in the National Active Germplasm Site (NAGS) for cocoa at CPCRI, Regional Station, Vittal, Karnataka. The germplasm collections include clones of Amazon, Brazil, Ecuador, England, Ghana, Jamaica, Mexico, Nigeria, Peru and local collections from Kallar in Tamil Nadu, Wayanad/ Idukki in Kerala and Shiradi Ghats of Karnataka. All these are being conserved and evaluated for their precocity, compatibility, adaptability, stability of yield, productivity and quality of produce in the introduced environment.

National Cocoa Germplasm Conservatory (NCGC) at CPCRI, RS, Vittal

S.No.	Place of collection	Year	Material
1	Landas Estate, Malaysia	1968	Seeds
2	Nigeria (*Cola nitida)*	1970	Seeds
3	Nigeria	1975	Seeds
4	Kew Garden, England	1981	Clones
5	Lalbaugh, Bangalore	1982	Clones

6	Mixed clones thro. KAU	1986-1996	Clones
7	Wayanad, Kerala	1997	Clones
8	Reading University, UK	2001-2010	Clones
9	Malaysian Cocoa Board	2007	Seeds
10	Philippines	2009	Seeds
11	Kanyakumari	2010	Seeds
12	Shiradi	2010	Clones
13	Bantwal	2012	Seeds
14	Reading University, UK	2013-2014	Clones
15	Kottayam	2014	Seeds
16	Idukki	2016	Seeds
17	*Theobroma grandiflorum*	2017	Seed
18	*Theobroma pentagona*	2017	Seed
19	Reading University, UK	2017	Clones
20	Kallar, TN	2017	Clones
	Total	**500**	

(ii) Selection breeding

An easy approach in yield improvement is to select superior plants and subsequently developing them into clones. The major selection criteria followed in cocoa are, trees yielding 100 pods/tree/year, pods weighing 350-400 g or more with 35-40 beans having a fermented single dry bean weight of 1 g and with favourable compatibility reaction. Dry bean production is in general considered as a combination of three yield components: bean weight per pod, number of pods per tree and number of trees per hectare. It is expected to be 1 kg and above per tree in a year and productivity is usually assessed over five to eight years in varietal trials. At CPCRI seven high yielding clones VTLC-1, VTLC-5, VTLC-7, VTLC-8, VTLC-9, VTLC-11 and VTLC-30 were selected and utilized as parents in the breeding programmes as well as in establishment of seed gardens. Though individual tree selections are made from seedling progenies they have to be further evaluated in clonal trials for confirmation. To assess the phenotypic value of genotype even in hybrid selection programmes, clonal trials are advised. From the clonal trials three varieties VTLCC-1, VTLCS-1 and VTLCS-2 have been released by ICAR-CPCRI for commercial cultivation in different agro-climatic zones in the country. Genetic analysis on 17 plant, pod and bean characters in 44 Nigerian cocoa clones resulted in selection of superior genotypes for higher performance with traits of high heritability with high genetic advance. Based on pod yield, VTLC-25, VTLC-15, VTLC-18, VTLC-36, VTLC-13, VTLC-37 and VTLC-17 have been identified as heavy bearers with optimal canopy. These clones recorded single dry bean weight of more than 1 gram, 10-15 percent shell, high nib recovery and more than 50 percent fat making them suitable for industries as well (Elain Apshara *et al*., 2009; Elain Apshara and Nair, 2011).

Breeding criteria and traits involved

- ✓ Yield: Ability to adapt in the field, vigour of young trees, no. of pods per tree, bean weight per pod (pod index: no.of pods needed for 1 kg of dry beans), productivity of young trees (earliness) and adult trees, interaction with planting density.
- ✓ Quality: Physical criteria (bean size, shell percentage, butter content, colour of cotyledons), Organoleptic characters.
- ✓ Resistance to diseases: Intrinsic resistance (resistance to infection, colonisation), Escape (period of fruiting, duration of pod ripening, low productivity), Tolerance (ability to produce in the presence of disease).
- ✓ Resistance to insects: Attractiveness, Intrinsic resistance (Antibiosis), Tolerance.

Working procedure for germplasm evaluation trials

Growth parameters (6 clonal trees/ plot or genotype)	**Unit**
Plant height (From base of the tree trunk to tip of the canopy)	m
Girth (Trunk circumference at 15 cm height from base of the tree)	cm
Height at first branching (HAFB) or jorquetting height (From the base of the tree to the first branching)	m
EW (East West spread of canopy) (East side canopy end to west canopy end)	m
NS (North South spread of canopy) (North side of canopy end to south canopy end)	m
No. of fruiting branches (No. of main branches at jorquette and no. of fans per jorquette)	no.
Canopy area Considering cone shaped canopy- πrl, whereas r= EW+NS/ 4 and l= $\sqrt{r^2 + h^2}$, h= canopy height (obtained by plant height- HAFB)	m^2
Prunings weight/ tree - annual (cut branches, both chupons/ fans, leaves together) (upto 12 years in grafted plants)	kg
Pod yield	
No. of healthy pods/ tree during each harvests (6 harvests) and compiled as no. of pods/ tree/ year	no.
No. of diseased/ damaged pods during each harvest	no.
Pod observations in 5 pods/ tree	
Pod weight	g

Pod length	cm
Pod width	cm
Husk weight (husk with placenta)	g
Wet bean weight/ pod (without placenta)	g
Husk: Bean ratio (optional)	
No. of bold beans/ pod	no.
TSS (optional)	^{o}brix
Bean characters- after fermentation and drying	
Dry weight of beans / pod	g
Single dry bean weight or bean index (Dry wt. of 100 beans)	g
Wet: Dry bean ratio (optional)	
Pod index- no. of pods required to produce 1 kg dry beans (1000/ no.of beans x dry bean wt.)	no.
Dry bean yield/ tree/ year	kg
Bean length	mm
Bean width	mm
Bean thickness (Vernier caliper)	mm
Shelling (shell wt./ dry bean wt. x 100)	%
Nib recovery (nib wt./ dry bean wt. x 100)	%
Fat (Soxhlet ethanol extraction)	%
Diseases- during monsoon and post monsoon	
Phytophthora pod rot No. of diseased pods Different grades/ tree	 no. %
Pests- during summer and post monsoon	
Tea mosquito bug, Thrips, Mealy bugs depend on infection	
If severe, grade of infection	0-5
No. of rat/ squirrel attacked pods, if any	no.
Drought tolerance- during summer and post monsoon	
Field screening with Physiological parameters- chlorophyll fluorescence, stomatal conductance, water potential *etc*.	

In the palm based inter cropping systems the pod yield in general is expressed with respect to the canopy area which is mainly maintained as single tier architecture. In the evaluation trials of Trinidad cocoa and Wayanad collections, 5 clones each are selected for high pod and dry bean yield ranging from 2.2 to 3.3 kg/tree/year (Elain Apshara, 2015; 2016) with optimal canopy of 15-20 m^2. Trait specific improvements are being taken up in the current breeding programs. Bean index of 100 beans/100 g *i.e.* dry bean weight of 1 g is considered as standard for grade I beans (GOI, 1997) and so selections are aimed at larger bean size of 1 g and above, which will have high butter content suitable for chocolate industry. CPCRI collected white beaned genotypes and evaluating for quality parameters. Cocoa beans of different clones evaluated at CPCRI for

polyphenols and antioxidant activity exhibited distinct differences a dused for quality improvement. Polyphenols ranged from 82 to 136 mg/g, procyanidin 49 to 64 mg/g, fat content of 24 to 55% and antioxidant activity of 77 to 98% among cocoa clones studied (Senthil Amudhan and Elain Apshara, 2015). Cocoa butter with free fatty acid content (FFA) of 1% or less together with acceptable flavour is the best indication of good quality beans. The percentage of stearic acid is the highest in a range of 30.5% in VTLCP-7 to 44.2% in VTLCP-1.

CPCRI cocoa varieties developed through selection

Characters	VTLCC 1	VTLCS 1	VTLCS 2
Canopy area (m^2)	12	12	15
No. of pods/tree/year	55	55	55
No. of beans/pod	35	42	41
Single dry bean weight (g)	0.9-1.05	1.3	1.21
Dry bean yield kg/tree/year	1.3	2.5	2.7
Dry bean yield (kg/ha)	890	1700	1840
Shelling (%)	12	11	15
Nib recovery (%)	88	88	85
Fat content (%)	50	52	53
Features	Self compatible line suitable for North Eastern Zones	High yielder withstands both biotic and abiotic stress	High bean index, stable yielder withstands both biotic and abiotic stress

(iii) Hybridization

Hybrid vigour between parents showing good combining ability is readily exploited in cocoa improvement programs along with inter-population heterosis.

Progeny Trials

At CPCRI, five progeny trials have been evaluated with 76 cross combinations during 1983-1994 at Vittal, Kidu and Kasaragod centres with objectives of more number of pods, high dry bean yield, big bean size and drought tolerance. Of these, 20 hybrids were identified as best hybrids and further evaluated as clones. Among them 17 progenies exhibited high vigour and cropping efficiency even at early years of development (Elain Apshara *et al*., 2007; 2008). From the progeny trials, four hybrids VTLCH-1, VTLCH-2, VTLCH-3 and VTLCH-4 have been released as improved varieties for cultivation in the country in 2006 the Golden Jubilee year of CPCRI, RS, Vittal and VTLCH-5 is released as Nethra Centura for the centenary year of CPCRI, Kasaragod.

Progeny Trials of CPCRI

Trial	Progenies tested	Progenies selected	Dry bean yield (kg/tree/year)
Progeny I (1983)	5	VTLCP-1	1.01
Progeny II (1984)	25	VTLCP-7 VTLCP-49 VTLCP-50 VTLCP-11	1.48 1.47 1.42 1.39
Progeny III (1987)	13	VTLCP-18	1.08
Progeny IV (1992)	15	VTLCP-29 VTLCP-30	1.25 1.52
Progeny V (1994)	18	VTLCP-26 VTLCP-27	1.33 1.62
Elain Apshara *et al*., 2007			

CPCRI varieties developed through hybridization

Characters	VTLCH 1	VTLCH 2	VTLCH 3	VTLCH 4	VTLCH 5
Canopy area (m^2)	16	15	18	18	16
No. of pods/tree/year	50	50	41	40	66
No. of beans/pod	40	40	41	40	43
Single dry bean weight (g)	1-1.11	1-1.5	1-1.05	1-1.07	1-1.11
Dry bean yield kg/tree/year	1.4	1.5	1.7	1.6	2.5-3.0
Dry bean yield (kg/ha)	959	1030	1150	1090	1500-1800
Shelling (%)	13	11	15	15	11
Nib recovery (%)	87	89	87	87	88
Fat content(%)	54	54	51	51	52
Features	Early stable heavy bearer	Heavy bearer, tolerant to black pod rot	Suitable for water limited conditions	Suitable for water limited conditions	Suitable for high density planting both under arecanut and coconut
Elain Apshara, 2016a					

(iv) Comparative Yield Trial (CYT)

The clones and progenies developed through selection and hybridization programs are multiplied as clones and evaluated under comparative yield trials in different situations. Under high density planting in arecanut garden, five hybrids VTLCP-6, VTLCP-20, VTLCP-15, VTLCP-1 and VTLCP-19 have been identified as best performers even in

their initial years of growth (Elain Apshara *et al*., 2008). Comparative study of parents and progenies as clones, resulted in identification of VTLCP-6, VTLCP-2 and VTLCP-20 and parents VTLC-1 and VTLC-56 as potential high yielders (Elain Apshara, 2013). In another trial, clones suitable for both arecanut and coconut canopies have been identified (Elain Apshara, 2013a) and released as varieties. Under coconut in double hedge system of planting, hybrids VTLCP-22, VTLCP-18 and VTLCP-1 showed the best performance with optimal canopy and high yield (Elain Apshara, 2014). Evaluation of clonal and seedling progenies of selected genotypes has resulted in identification of 4 hybrids and 2 clones for multiplication both as clones and seedlings for utilization in the area expansion programme (Elain Apshara, 2017a).

(v) Multi Location Trial (MLT) and Demonstration plots

To assess the adaptability and stability of hybrids and clones in different agro climatic conditions, multi location trials are important. Elite clones of cocoa are under evaluation in both traditional and non- traditional states, namely Karnataka, Kerala, Tamil Nadu, Andhra Pradesh, West Bengal and Assam, for studying genotype x location x environment interactions. Further, 115 front line demonstration plots were established under participatory research cum demonstration plots scheme in farmers plots as well as in five AICRPP (All India Co-ordinated Research Project on Palms) centres funded by Directorate of Cashewnut and Cocoa Development (DCCD), Kochi and Directorate of Arecanut and Spices Development (DASD), Calicut, for identification of location specific varieties and to tackle the climate change effects.

(vi) Resistance breeding

Black pod rot

India is free of most of the debilitating viral and fungal diseases of cocoa. Since the current cocoa growing area comes under high rainfall zone and the main harvest season coincides with monsoon, incidence of black pod rot caused by *Phytophthora palmivora* is comparatively higher. At CPCRI based on field screening, clones have been categorized into <10%, 10-25% and >25% damage levels. *In-vitro* screening using isolates of *P. palmivora*, *P. capsici*, *P. citrophthora* indicated that collections of Nigerian origin exhibit certain degree of tolerance.

Vascular Streak Die Back

In India, Vascular streak die back (VSD) caused by *Oncobasidium theobromae*, was first reported from Kottayam, Kerala. KAU breeding programme concentrated mainly on production of VSD resistant varieties and developed CCRP-1 to CCRP-10 and also have been utilised for establishment of clonal gardens for seedling supply (Mallika *et al*., 2000).

Tea mosquito bug

Tea mosquito bug (TMB) (*Helopeltis* sp.) incidence became severe during last three years in summer and post monsoon seasons. *Helopeltis antonii*, *H. theivora* and *H. bradyi* are reported in cocoa in South India. Development and use of mirid resistant cocoa varieties is one of the alternatives to chemical control and resistance studies in cocoa have mostly concentrated on assessment of field damage. Damage on flushes, cherelles and pods of individual trees and different grade levels of infection on cherelles and pods are assessed to work out the TMB tolerance among genotypes. Penetrometer readings for determining the hardness of sclerotic layer, thickness at primary and secondary furrows of pod husk have been recorded at CPCRI in 100 cocoa genotypes and interpreted with reference to insect resistance (Elain Apshara, 2013b). Red coloured pods with smooth surface have been identified as tolerant to TMB damage among Wayanad collections at ICAR- CPCRI.

Low Moisture Stress

Cocoa is very sensitive to water scarcity and undergoes a period of low moisture stress for five to six months in its current growing condition in India. Breeding for drought tolerance is unique to our country and is taken up with systematic screening of available germplasm as well as hybridization programs. Screening of accessions is conducted for physiological parameters like stomatal resistance, chlorophyll fluorescence, proline accumulation under stress and by studies on seed germination under low osmotic potential etc. A total of 216 cocoa genotypes have so far been screened for physiological and biochemical parameters under different trials (Balasimha, 1999). In all these studies, field measurements were taken during unstressed (October) and stressed (March) conditions. Few Nigerian collections have been identified as drought tolerant and used for hybridization with high yielding Malaysian collections under two progeny trials. Two hybrids VTLCH-3 and VTLCH-4 have been released as varieties suitable for cultivation under water limited conditions in the country. The application of chlorophyll fluorescence as a tool to screen cocoa for drought tolerance has been confirmed with a series of genotypes at Vittal. Recently, photosynthesis, chlorophyll fluorescence and water potential under stress and non stress conditions were estimated in 11 genotypes from different geographical origins, Columbia, Brazil, Peru, Mexico and Ecuador (Elain Apshara *et al*., 2013). Seasonal and varietal differences were found and transpirational water loss was found to be reduced with increased stomatal closure, which is considered as a favourable drought trait in any crop. Among the 52 new introductions, 5 Amazon and Pound collections have been found to be adaptable to water limited conditions (Balasimha *et al*., 2013) with high yields, which will be further utilized in the breeding programme. Genotypic difference for morpho-physiological criteria, potential antioxidant enzymes and biochemical components depicting drought tolerance in young seedlings were determined with cocoa clones and hybrids under controlled low moisture stress

conditions. From these trials standards and thresholds for several physiological parameters related to cocoa were standardised.

(vii) Biotechnology and Bioinformatics

DNA fingerprinting with RAPD markers has been done at CPCRI earlier on 76 collections and the clones VTLC-11, 67, 83 and VTLC-93 were identified as highly divergent. DNA extraction protocol of cocoa with fully expanded but soft leaves is standardized with modified SDS method. Recently 16 SSR primers specific to cocoa were used to assess diversity in 44 exotic clones of Nigerian origin and both morphological and molecular diversity were assessed in detail (Elain Apshara and Rajesh, 2016). An attempt has been made to identify the markers for drought sensitivity by utilizing susceptible and tolerant parents and progenies of cocoa. Cocoa genome has been successfully sequenced by CIRAD, France and Penn State University, USA along with a group of institutes and 75% of the genomic data is available in the public domain, which has paved the way for analyzing genes related to specific needs. CPCRI hosts one of the Agri Bioinformatics centre under Department of Information Technology and through bioinformatics tools, proteins involved in drought tolerance, *Phytophthora* resistance and carotenoid biosynthetic pathways have been analysed and databases, CocoaESTdb, CocoaSTRESSdb and a Standalone EST microsatellite mining and analysis tool (SEMAT) have been developed (Elain Apshara *et al*., 2013a).

Future prospects

Cocoa improvement has attained a positive phase with the sequencing of its genome. Identifying genes responsible for incompatibility and disease resistance are the main concern of geneticists and molecular biologists. Development of early selection, detection and diagnostic methods for resistance will enable rapid screening of plant material and permit preselection activities. Because of the health benefits of dark chocolates, biochemical constituents and antioxidant properties of cocoa is to be given greater attention in the breeding programs. Farmer's participatory plant breeding and varieties for changing climatic conditions and environment friendly management strategies are to be considered. Adaptability of cocoa genotypes in traditional and non traditional zones should be verified and location specific varieties should be developed. At the National level, expansion of cocoa cultivation with quality planting material of elite clones, collaborative approach between research institutes, universities, state horticulture departments and developmental agencies are required.

References

1. Balasimha D. 1999. Stress physiology of cocoa. *Journal of plantation crops* **27(1):** 1-8.

2. Balasimha D., Elain Apshara S. and Jose C.T. 2013. Genotypic variations in chlorophyll fluorescence and stomatal conductance of cocoa in relation to drought tolerance. *Journal of plantation crops* **41(1):** 40-45.
3. Bartley B.G.D. 2005. *The genetic diversity of cocoa and its utilization*. CABI publishing, UK: 341.
4. Elain Apshara,S. 2013. Comparative performance of selected cocoa parents and progenies as clones in South India. *In*: Proceedings of Malaysian International Cocoa Conference on Innovation and technology driving cocoa productivity/sustainability (eds. Sabariah Samsudin, Samuel Yap Kian Chee and Badrul Hisyam Zainudin), 7-8 October 2013, Sunway Pyramid Convention Centre, Kuala Lumpur. pp.9-17.
5. Elain Apshara,S. 2013a. Performance of selected cocoa (*Theobroma cacao* L.) clones under arecanut and coconut. *Journal of Plantation Crops* **41 (2):** 242- 246.
6. Elain Apshara,S. 2013b. Selecting elite cocoa clones for phenotypic characters including pod wall hardness in India. *In*: Abstracts of Malaysian International Cocoa Conference on Innovation and technology driving cocoa productivity/ sustainability (eds. Sabariah Samsudin, Samuel Yap Kian Chee and Badrul Hisyam Zainudin), 7-8 October 2013, Sunway Pyramid Convention Centre, Kuala Lumpur: 69.
7. Elain Apshara,S. 2014. Performance of elite cocoa clones under coconut in double hedge system of planting. *The Cashew and Cocoa Journal* **3(2):** 13-16.
8. Elain Apshara, S. 2015. Growth and yield performance of Trinidad cocoa collections in Karnataka. *Journal of Plantation Crops* 43(3): 237-240.
9. Elain Apshara,S. 2016. Selection of potential clones from Wayanad cocoa collections. *Journal of Plantation Crops* **44(2):** 124-128.
10. Elain Apshara, S. 2016a. *Cocoa varieties of ICAR-CPCRI*. Extension Folder No. 249, Centenary Publication No. 45, CPCRI, Kasaragod.
11. Elain Apshara, S. 2017. Cocoa improvement programmes of ICAR- CPCRI- A Glance. *The Cashew and Cocoa Journal* 6**(2):** 9-19.
12. Elain Apshara, S. 2017a. Comparative study on clonal and seedling progenies of selected cocoa genotypes. *Indian Journal of Horticulture* **74(2):**168-172.
13. Elain Apshara,S. and Nair,R.V. 2011. Genetic analysis in cocoa collections obtained from Nigeria. *Journal of Plantation Crops* **39 (1):** 200-206.
14. Elain Apshara,S and Rajan,P. 2009. *Profile of cocoa collections at CPCRI, Research Centre, Kannara*. CPCRI, Kasaragod: 61.
15. Elain Apshara,S. and Rajesh,M.K. 2016. Evaluation of exotic cocoa collections in India for their morphological and molecular diversity. *In:* International Symposium on Frontiers in Science and Technology for Cacao Quality, Productivity and Sustainability Penn State College of Agricultural Sciences, University Park, USA, 31 May-3 June, 2016. Book of abstracts: 44.
16. Elain Apshara,S., Ananda,K.S. and Balasimha,D. 2005. Cocoa breeding at CPCRI, India. *INGENIC Newsletter* **10**: 34-37.

17. Elain Apshara,S., Bhat,V.R. and Nair,R.V. 2008. Comparative studies on elite cocoa progenies in their initial years of growth. *Journal of Plantation Crops* **36 (1):** 38- 44.
18. Elain Apshara,S., Bhat,V.R., Ananda,K.S. and Nair,R.V. 2007. High yielding cocoa varieties of the Central Plantation Crops Research Institute, India. *INGENIC Newsletter* **11**: 12-15.
19. Elain Apshara,S., Bhat,V.R., Ananda,K.S., Nair,R.V. and Suma,D. 2009. Evaluation and identification of high yielding trees in Nigerian cocoa germplasm. *Journal of Plantation Crops* **37 (2):** 111-116.
20. Elain Apshara,S., Rajesh,M.K. and Balasimha,D. 2013. Assessment of morphological, physiological and molecular characteristics of cocoa accessions from Central and South America in relation to drought tolerance. *Journal of Plantation Crops* **41 (3):** 389- 397.
21. Elain Apshara,S., Naganeeswaran,S. and Manimekalai,R. 2013a. CocoaESTdb: A comprehensive cocoa Expressed Sequece Tag database. *In:* Abstracts of National Seminar on Applications of Bioinformatics in Agriculture, November 11-12, 2013, CPCRI, Kasaragod: 51.
22. GOI.1997. Cocoa beans grading and marking rules. AGMARK standards. *Gazette of India Part II* **3**:1.
23. Mallika,V.K., PrasannakumariAmma,S., Koshy Abraham, Vikraman Nair,R. and Minimol,J. S. 2000. Evolution of cocoa varieties resistant to vascular streak die back through hybridization. Abstr. Inter. Conf. Plantation Crops. *PLACROSYM XIV*, 12-15 December 2000, Hyderabad: 6.
24. Peter,K.V., Mallika,V.K. and Prasannakumari Amma,S. 2002. Technologies for increasing productivity in cocoa. *In*: Proceedings of national seminar on technologies for enhancing productivity in cocoa. (eds. Ravi Bhat, Balasimha D. and Jayasekhar S.), CPCRI, Regional Station, Vittal: 1-11.
25. Pound,E.J. 1932. The genetic constitution of cocoa crop. First Ann. Rep. Cocoa Res. Trinidad: 9-25.
26. Ratnam,R. 1961. Introduction of Criollo Cocoa into Madras State. S. Indian Hort., **9**: 24-29.
27. Senthil Amudhan, M. and Elain Apshara, S. 2015. A comparative study on antioxidant activity and biochemical profile of exotic cocoa clones. *Journal of Plantation Crops* 43(3): 231-235.
28. Wood,G.A.R. 1964. Cocoa Growing in India. Cadbury Brothers Limited, Publication Department, Bournville, UK: 27.
29. Wood,G.A.R and Lass,R.A. 1985. *Cocoa*. IV Edition. Longman Group Limited, Longman House, Burnt Mill, Harlow, Essex CM20 2JE, England: 620.

4. PLANTING MATERIAL PRODUCTION IN COCOA

Suchithra, M.

The foremost necessity to get sustainable and profitable yield in any perennial crop is the supply of quality planting materials. The production and management of planting materials in the nursery decides the performance of cocoa in the field and ultimately the quality of the produce. The demand for cocoa in Indian chocolate industry and confectionaries is portrayed as 60,000 MT for the year 2025. About 2,20,000 ha have to be brought under cocoa to meet out this demand for which 150.7 million seedlings are required. With the sole aim of encouraging this remunerative crop, intensive area expansion programmes in new areas which are conducive for cocoa are being taken up by Ministry of Agriculture and Farmers' Welfare, Govt. Of India. Under National Horticulture Mission and with central/ state sector schemes through Mission for Integrated Development of Horticulture (MIDH), departments of horticulture/ agriculture in cocoa growing states and regional nurseries identified by Directorate of Cashew nut and Cocoa Development, Kochi (DCCD) are entrusted with the task of raising cocoa nursery, production of seedlings in large numbers and supply to farmers under subsidized rates as well as free of cost. Several propagation methods of cocoa were standardized and followed by research institutes spread over different countries. Cocoa can be multiplied both by seeds and vegetative means. Health and growth of the seedlings in the nursery will decide the performance of this commercial crop in the plantation and so the knowledge on basic and advanced nursery techniques is very important. It is important that officers, extension officials and planters who are new to crop should have the knowledge on both the basic and advanced techniques of nursery practices for cocoa. .

Cocoa propagation methods

Cocoa can be multiplied both by seeds and vegetative means. Seed is the cheapest and simplest propagule of cocoa, which is available in large quantity but, they does not breed true and open pollination results in larger variability. With production of hybrid varieties seedling multiplication become advantageous as they exhibited hybrid vigour. But vegetative means are practiced to get true to type, early bearing nature, to raise known clones, for long term breeding trial of perennial natured crops, to avoid multiplying self incompatible types and to fix the high yielding ability of selected clones and hybrids.

Seed propagation

Self incompatibility

The factor that affects the general fruit set in cocoa is incompatibility which is the failure of fruit setting with the pollen from the same plant (self-incompatibility) or with pollen from other plants (cross-incompatibility). The incompatibility in cocoa is widely

observed as gametophytic, where the pollen tubes develop normally but the male gamete does not fuse with the female gamete.

Method of hand pollination and fruit set

For production of true hybrids with specific objectives and to confirm the compatibility reaction, hand pollination is being practiced. In the natural pollination, too many fruits are normally set for the tree to carry through to maturity. The young developing pod of cocoa is called 'cherelle' and cocoa has its fruit thinning mechanism of 'cherelle wilt' which occurs by yellowing, blackening and shrivelling. The incidence of wilt increases from pollination to a peak at about 50, 70 and 95 days. It takes 5-6 months from pollination to ripening. The mature fruit or pod is botanically an indehiscent drupe which remains on the tree unless harvested.

For production of hybrids with specific objectives and to confirm the compatibility reaction hand pollination is being practiced.

- ✓ In artificial pollination, a flower bud which will open the following day, recognized by its whitish colour and swollen appearance, is selected.
- ✓ The bud is covered with hood of plastic tube/ hose pipe piece 5 cm x 1.5- 2 cm, which is sealed to the bark using materials like plasticine/ glaze putty.
- ✓ The tube is covered with muslin cloth at the top, kept in place with a rubber band.
- ✓ This ensures circulation of air and exclusion of insects.
- ✓ Opened flowers are collected from the desired male parent and stamens are carefully taken out by pushing the corresponding petal.
- ✓ One entire anther with a part of the filament is deposited on the stigma.
- ✓ The style is surrounded by a ring of staminodes and if these are long, removal of two or three staminodes should be done for easy access to style.
- ✓ Emasculation is not necessary due to the presence of self-incompatibility. For selfing, hand pollination is done using stamens from the same flower.
- ✓ The pollinated flowers are labelled using tin foil pieces fixed in the cushion using ball pins.
- ✓ The hoods are removed 24 hrs after pollination and in three to five days, fertilization is confirmed by the visual swelling of the ovary.
- ✓ In order to prevent undue shedding and wilting of fruits from hand pollinations, it is usual to remove all the developing fruits on the tree produced by open pollination.
- ✓ Developing pods are covered with wire mesh after six to eight weeks to protect them from mammalian pests. Where flowers are plentiful a good operator can do 300 pollinations per day along with marking of pollinated flowers, which will be resulting in 150 pods. If unpollinated, the flower abscises within 24 hours and a conspicuous feature of cocoa tree is the heavy loss of flowers at certain time

intervals. A full- grown tree may produce 10,000 flowers in a year of which perhaps 50 to 100 will develop as mature fruits.

- ✓ Estimates of the proportion of flowers pollinated range from 1 to 50 per cent according to the season and number of flowers opening at the time. The pollen dispersal may be upto 40 metres. Most pollination occurs in the morning and artificial pollination should always be done before midday during fine weather.

Seed gardens/ clonal orchards

The objective of raising seed gardens of cocoa is to provide seed of known parentage and proven performance. This is achieved by selecting parents, which are self-incompatible but cross-compatible, multiplying them vegetatively and assembling in seed gardens. With two parents they are called as bi-clonal orchards and with multiple clones as poly-clonal orchards. These well designed gardens will produce hybrid pods through natural cross pollination. It has been estimated that one acre of such a seed garden could produce enough seed to plant 400 acres in the fourth year and 1200 acres by the eleventh year. At CPCRI, Research Centre, Kidu, Nettana, Karnataka, 6 bi-clonal and 1 poly-clonal orchards are established with a total of 1500 trees (Elain Apshara, 2007). These pre-designed and well established gardens exclusively prevent undesirable crosses and produce genetically pure planting materials. Kerala Agriculture University also maintains this type of clonal orchards for supply of F1 seedlings. Currently, research institutes, state departments, AICRP centres and regional nurseries are involved in establishment of seed gardens for systematic area expansion programs.

Selection of mother trees and seed pods

If a seed garden is not available nearby, the criteria for selection of mother trees should be strictly followed. Trees of Forastero type, with green pods when immature and yellow when ripe, may be selected. Pods of Trinitario type is also now widely used in Asian countries. Trees bearing lot of fruits with >70 pods per tree per year, having medium to large pods of not less than 350 g weight, smooth or shallow furrows on the surface without prominent constriction at the neck can be selected. Husk thickness of pods to be more than 1 cm. Pod value (number of pods required to produce 1 kg beans) to be not more than 12. Number of beans per pod should be more than 35. Cocoa pods take 150-170 days from pollination to attain the harvest stage. They remain without damage upto a maximum of about one month on the tree and so the harvest interval may be of 15 days. The stage of maturity is visible from the change of colour of green pods to yellow and red pods to orange. Pods within fifteen days of becoming ripe can be used safely, but immature pods will give poorer seedling growth and possibly leaf abnormalities. Over ripe pods tend to have viviparous germination and rodent attacks will be more if pods are allowed to ripe on the tree. Seed pods free of *Phytophthora,* thrips, mealy bug and tea mosquito bug should be harvested. Pods half eaten or damaged by rats and squirrels can also be avoided. Harvesting of seed pods should be done with a sharp knife, care should

be taken not to damage the flower cushions as flowering in cocoa is cauliflorous *i.e.* fruiting in the trunk. Picking pods by pulling from tree should be avoided which will more often tear away the bark. CPCRI developed a cocoa harvester with light weighted telescopic pipe and blades sharpened at both sides. Well matured seed pods can be broken by hitting against a hard surface or with a wooden hammer and the seeds can be extracted without placenta. Gentle cut with knife may be practiced with due care without damaging the seeds. Ten year old trees are used for seed pod collection if it is of seedling origin and 5 years in case of vegetatively propagated mother trees (Elain Apshara, 2010).

Seed standards and viability

Seeds for sowing should be bold, large, weighing around 3 grams when wet and 1 to >1 gram when dry. The best seeds for sowing are those from the middle of the pod as flat beans may develop at pod ends. Seeds in cocoa are recalcitrant without dormancy period and beans once extracted from pods should be sown immediately before loosing viability. Pods harvested at third fourth maturity can be kept upto 4 days without breaking but once open, the seeds should be sown immediately. Seeds start germination in about a week and will continue for another one week. Epicotyl type germination is noted where cotyledons are taken above ground in the process and is called soldier phase. Healthy seeds from well matured pods usually give a germination of 90 to 95 per cent. The rate of germination of cocoa beans varies with maturity status, bean size and other inherent and external factors. Larger beans hastened germination and if shade is beyond 50% in the nursery it affects the growth and development of seedlings. Cocoa seeds will germinate at any time of the year with adequate irrigation. Seeds of clones begin germination within 10-15 days after sowing and seeds of hybrids germinate in 7-10 days after sowing. Seeds that do not germinate within 15 days after sowing as well as those with dead sprouts can be removed from the nursery. Main harvest season in the traditional zones starts in April-May months and sowing to be completed before onset of monsoon (Elain Apshara and Venkatesh Hubballi, 2012). Continuous showers will affect germination and invite fungal infections. May sown seedlings will be readily available for planting during September-October, the post monsoon season in the high rainfall zones of Kerala and Karnataka. Compact blocks on varieties raised with grafted plants showed second season of bearing during post monsoon season which will be good for nurseries in operation the whole year and it favours planting during June-July with onset of monsoon in low rainfall zones.

Storage of seeds

Seed pods harvested at correct maturity can be stored in shade upto one week, which favours long distance transports, whereas if stored beyond, viviparous germination will occur which affect the percentage and performance of seedlings. Incidence of pod rot is observed if stored under humid conditions. Fumigation of seed stores with formalin may be followed. Germinability of freshly extracted beans can be extended for some more days by storing in moist charcoal and packed in poly bag for a period of four to six

weeks, which favours transport of beans to far away nurseries instead of pods. In few countries, the beans are mixed with sawdust and the testa is removed; the peeled seeds are treated with a fungicide either by washing in a fungicidal solution or by dusting. The treated seeds are packed in polythene bags, each bag holding about 500 seeds or 1 kg in quantity. It is observed that seed stored by this method preserve its viability without germinating for three to four weeks.

Seeds treatment, sowing and preparation of nursery

When taken from the ripe fruit, the seed is surrounded by a mucilaginous pulp which contains a germination inhibitor. Germination can be speeded up by removing this pulp with the testa which is thin and leathery. The testa is usually called the skin or, when dry, the shell. Rubbing of the beans carefully with dry sand or wood ash to remove the mucilage is practiced in India. Seed dressings with insecticides can be used in very rare occasions with lesser dosage. Sowing is to be done by keeping seeds horizontally and just covering with sand. Shallow sowing is preferable. The normal practice is to plant the fresh beans directly into the bags in nursery for easy loading and transportation. However, germination in sand beds has been advocated in order to obtain more uniform seedlings by planters.

Polybag nursery

To get better root and shoot growth, to make the planting and transportation easy sowing seeds in polythene bags is being followed. Polybags are usually cheaper, more durable and simpler to store. Cane and bamboo baskets, veneer tubes and bags made up of locally available plant materials which are biodegradable are being used in some cocoa growing countries. Polybags of 6”x 9” size, 250 gauge of black colour with around 9 drainage holes filled with potting mixture 2:1:1 Soil: Sand: FYM is standardized at CPCRI. Big poly bags of 30 cm length and 20 cm width can also be used if the seedlings are to be kept in the nursery for longer periods. Organic manures like coir compost, vermicompost, bean shell also been used. There has been a growing interest in the use of cocoa pod husk for industrial and commercial purposes in cocoa producing countries and suggested that cocoa pod husk based compost and suitable top soil in a mixture of 1:2 or 1:3 could be used as potting medium for nursing cocoa seedlings.

Arranging poly bags in rows of 10, bulk of 1000, leaving 1 ft. path between for monitoring and irrigation, supporting with strips of bamboo and covering with shade nets or by thatches during hot season are advisable for good management. The initial shade is usually quite heavy, somewhat in excess of 50 percent but decreases as the seedlings grow. Shade net (75%) nursery with permanent pillars in an area of 2 acres will hold 50,000 bagged seedlings.

Vegetative propagation

Grafting and budding are being followed in multiplication of cocoa in India. Leaf cuttings are also being used in many cocoa producing countries with special potting mixtures and hormones. Scions for grafting and budding are to be collected from high yielding, disease resistant elite plants. Shoots or soft woods having bark and just hardened leaves are selected as scion stick or bud wood. Criollos are less suitable for vegetative propagation than Forasteros. At Kerala and Karnataka bud wood/ scion collection on the day of budding or grafting is followed. Precuring of scion sticks/ bud woods are being followed in few cocoa research institutes. Bud woods are first selected, cutting off of laminae of all the leaves of the selected shoot to a distance of about 30 cm from the tip, after ten days when the petioles have fallen off, these bud woods are cut and used for budding immediately. Bud wood can be stored by dipping in benzyl chloride followed by washing in water and then sealing the cut ends using molten wax. It is then wrapped in moist cotton wool and in turn in wet tissue paper or blotting paper and packed in boxes with wet packing material. The packet is then covered using polythene sheets. With this method storage life of the bud wood can be extended upto ten days and it is advantageous in germplasm exchange programs.

Grafting

Cocoa has been grafted by saddle and wedge graft methods as stock and scion compatibility exists. Soft wood grafting for cocoa is standardized at CPCRI, Regional Station, Vittal with 85% success rate. 3 to 4 months old seedlings raised in polybags can be used as root stocks for grafting. Scion stick of 12- 15 cm length with 2- 3 buds from desirable high yielders are collected on the day of grafting. Root stock stem and scion stick should be of same thickness and physiological age. Grafting can be done by giving a horizontal cut at the upper portion of the rootstock with a grafting knife. Make a vertical slit of 2 to 3 cm down (cleft) on the decapitated root stock. Scion sticks being removed off the leaves should be given a 'V'shaped slanting cut of 2- 3 cm length (wedge) at the bottom. Grafting is done by inserting scion into the stock i.e. wedge into the cleft and tying tightly with a polythene tape of 1.5 cm width over the joint. Graft point should be covered with small polythene pouch, so that the graft joint and the scion stick won't dry up. It can be removed after 15- 20 days of successful graft joint or bud take. Perfect graft joint will occur in one month, polythene strip tied over the joint should be removed after 2 months. Successful graft will be ready in 5- 6 months for field planting. Scion sticks of chupons can be taken if seedling like architecture and lesser pruning is preferred. Whereas for early evaluation works and large-scale commercial production fan branches are preferred, but training and pruning measures should be followed strictly and systematically in its initial years of growth. The emerging shoots from the rootstocks should be removed with due care. October to December season will be the best for grafting and all other seasons are suitable with sufficient irrigation. Grafts will start yielding from the second year onwards. Side grafting of resistant budwood on susceptible

type is being advocated and found as a rapid and reliable method to detect virus infection. Conservation of multiple varieties on a single tree is also possible. High yielding clones identified at CPCRI and varieties are being multiplied and nearly 50,000 grafts/ year are supplied to farmers and developmental agencies. Skilled person is required for selection/ collection of scion sticks and grafting, who can make an average of 300 grafts per day. An average cost of production of 50,000 grafts will be around 2 lakhs with a cost benefit ratio of 1:3. Patch budding is practised at KAU (Vikraman Nair *et al*., 2000).

Transplanting

Only vigorous seedlings are to be used for transplanting based on height and stem girth. Seedling and graft standards are developed for cocoa. When seedlings are grown under heavy shade hardening for ten days by exposing to higher sun light may be necessary before transplanting. If raised in nursery beds, watering should be done before lifting seedlings and to avoid breakage of roots and should be taken along with little earth around the roots. If raised in polythene bags, the poly cover should be removed and the seedlings are planted with ball of earth into the pit. The seedling/ graft/ budling should be planted in the centre of the pit, not too deep. While planting grafts polythene strip tied over graft joint should be removed and the joint should be above the soil. The planting material may be of 4-6 month old seedling or grafted or budded plant. Planting seedlings with twisted or damaged tap root or pot bound plants should be avoided. For long distance transportation seedlings can be packed with moisture retaining materials like coir compost. The length of time for the seedlings to be remained in the nursery will be depending on the time of availability of seeds and the time of planting. In West Africa for instance seed is plentiful in October- December and planting await the rains at the end of March or early April. In these circumstances the seedlings will be kept in the nursery for four to five months at which age the plants will be 40 to 50 cm tall. Planting seedlings of less than 3 months and more than 6 months age may be avoided.

Selection of seed centres

Availability of sufficient number of mother trees, systematic clonal orchards/ seed gardens is the foremost necessity for smooth supply of quality planting materials. Source of mother tree should be of the research results from institutes. CPCRI with its three decades of breeding programs and well established seed gardens meeting the need of planting material in Karnataka as well as northern Kerala. Nurseries at CPCRI, RS, Vittal and RC, Kidu are recognized by National Horticulture Board and accredited to 4 star category for production of cocoa planting materials. High yielding clones/ hybrids/ varieties are being multiplied as seedlings and grafts to the tune of 50,000 each annually. The nursery is in operation throughout the year with sufficient infrastructure facilities. 15,000 seed pods are being supplied from compact blocks of elite clones to CAMPCO and Cadbury (Kraft Foods) for their nursery activities. Cadbury India Pvt. Ltd. Is meeting a target of 10 lakhs seedlings through its nurseries at Puttur, Sullia, Sirsi and Shimoga,

for this the major seed pod source is KAU. With DCCD funding 17 regional nurseries are established with superior mother trees of CPCRI in 5 states viz., Karnataka, Andhra Pradesh, Tamil Nadu, Maharashtra and Goa for multiplication and unhindered supply of quality planting materials.

Regional nurseries

State	No.	Grafts supplied
Karnataka	9	11,250
Andhra Pradesh	2	2,500
Tamil Nadu	3	3,750
Maharashtra	2	2,500
Goa	1	1,500
Total	**17**	**21,500**

Nursery management

Nursery shouldn't be raised in areas susceptible to vascular streak die back (VSD) and collection of clonal materials such as bud or scion sticks from VSD affected trees may be avoided. Poly green house can be utilized for screening, protection and hardening of seedlings. As cocoa is very sensitive to drought daily watering should be done during summer and drainage facilities should be improved during rainy season to avoid die back and seedling blight. Seasonal surveillance and control for pests and diseases should be taken up. Neem coated urea or other composts may be added to enhance vigorous and healthy growth. The nursery should be kept free of weeds to allow good growth of the seedlings. Before taking up nursery works, the basic needs of mother trees, fertile soil, shade and water source should be verified and further implementing the technological advancements related to cocoa, seasonal operations and timely management will enhance production of quality planting materials in sufficient quantity. Certain advanced technologies are used in nursery management in cocoa. These includes,

a) Soil solarization

All potting mixtures should be sterilized before being planted with seed. It is important to kill bacteria and fungi that can infect plant roots, and also weed seeds that can germinate and become a problem. This is easiest and cheapest way of sterilization of potting mixture. Soil solarization by sun drying and covering of potting mixture or nursery bed with black polythene sheet during March- April will enhance seedling vigour and health (Elain Apshara, 2011). Lightly wet the mix so that steam is produced inside the plastic cover, and make sure the mix is no more than 7 centimetres deep. Also ensure the plastic cover is well sealed to prevent heat loss. The mixture should reach 56 degrees centigrade for at least 30 minutes which can be tested with a thermometer. Soil solarization for 45

days and addition of *Azospirillum* or with *Azospirillum* and *Arbuscular mycorrhizal fungi* resulted in superior healthy seedlings and weed free nursery.

b) Biopriming

Biopriming is an advanced technique of application of plant growth promoting microbes to the plant or potting mixture to enhance seedling growth and health. Different microbial cultures isolated from cocoa gardens of various locations are tested for their efficiency and the flourescent pseudomonads, *Pseudomonas putida* biovar A. KDSF 23 and *Pseudomonas sp*. KDSF 7 are identified as suitable for cocoa, which are isolated from cocoa gardens of CPCRI, Research Centre, Kidu. After completion of soldier phase of germination i.e. 1 month after sowing 20 gram of culture powder may be applied in the poly bags. Superiority of organic soil amendments to inorganics is detailed in many studies.

c) Nursery Structure

The most basic function of the nursery is to provide an environment that allows cocoa seedlings to develop quickly, into healthy plants ready for field planting. The nursery must provide:

a) Protection from sun, wind and rain
b) Water and nutrients frequently, and in response to plant growth needs
c) Protection from pests, diseases and weeds

Several designs are possible according to the materials used and the budget available. For a cheaper nursery, use nursery materials such as bamboo or log posts, and wire to make the frame, and stretch shade cloth over this frame. For a longer lasting nursery, use steel posts embedded in concrete, with a wire frame or steel tubing framework. Timber posts are susceptible to termites and rotting. It is also possible to use PVC piping for small nurseries, and galvanised pipe and fitting for any size nursery. In some cases, widely spaced, well pruned upright growing trees (*i.e. Glyricidia, Erythrina*), can be used as the posts, with a wire frame between them. This is only good for shorter term only (less than 12 months) as the trees grow back and become difficult to access for pruning. In all cases, green or black shade cloth with 60- 70% sunlight strength is used ie 30% shaded. The shade cloth must cover the entire roof and all sides of the nursery.

For efficient quarantine, production of seedlings in mist chambers, glass/green houses etc. with automated temperature controls is preferred. Upto 2 months it can be kept in glass/ green house with fine misting and can be taken out after that. Seedlings showed bending with altering temperatures. Labeling with details of date of sowing, age of seedlings, name of varieties, size and health of seedlings is the responsibility of nurseries recognized by National Horticulture Board.

d) Polythene mulching

Covering nursery floor with polythene sheets makes nursery area weed free. Plastic Mulches contribute to weed management in nursery by reducing weed seed germination, blocking weed growth, and favouring the crop by conserving soil moisture and sometimes by moderating soil temperature. Opaque synthetic mulches like black plastic provide an effective barrier to most weeds and are amenable to mechanized application, but they must be removed at the end of the season.

e) Irrigation management

Young seedlings needs lots of water and should be irrigated gently every day in summer and once in alternate days in other seasons. Sprinkler/ micro jet irrigation is suitable for cocoa nurseries during early stages of germination and growth, whereas hose method is the best during later stages. Water supply needs to be readily available, of sufficient quantity and good quality. To estimate your maximum water needs, use the following rule:

- Number plants x volume each bag x 0.05 = litres water per day maximum required.

So for 25,000 bags with 1.8 L volume, watered twice per day with 5% volume watered, we need about 2250 L of water per day. This is about 225 buckets of water, or about 20 minutes with a pump and hose. Half of this amount is used for 1 irrigation per day.

f) Nursery drainage

Good drainage is essential to produce healthy and disease free plants especially in high rainfall zones. Effective drainage must be designed during the nursery construction phase. For drainage to be effective there must be an outlet to carry drain water away from the nursery site. Good drainage also make it easier to move around and work inside the nursery. Drainage channels should be cleaned frequently to remove weeds, waste plastic covers, mud clogs etc. Another way to improve drainage is to have raised nursery beds.

It is recommended to collect seed pods from clonal orchards established by research institutes, seedlings and grafts from recognised nurseries only to reap good harvest from this perennial crop.

References:

1. Elain Apshara, S. 2007. Producing quality planting material of cocoa. *Indian Horticulture* **52(5)**: 6-8.

2. Elain Apshara, S. 2010. *Cocoa Planting Material Production*. Technical bulletin No. 66, CPCRI, Kasaragod. 24 pp.
3. Elain Apshara, S. 2011. Nursery studies in cocoa. In: *Proceedings of seminar on strategies for enhancing productivity of cocoa.* (Eds.) Elain Apshara, S., Jaganathan, D. and Balasimha, D., CPCRI, Regional Station, Vittal. pp. 29-36.
4. Elain Apshara, S. and Venkatesh Hubballi, N. 2012. *Calendar for Cocoa*. Technical bulletin 76, CPCRI, Kasaragod. 30 pp.
5. Vikraman Nair, R., Mallika, V.K., Prasannakumariamma, S., Koshy Abraham and Balasubramanian, P. P. 2000. *Cocoa cultivation- Science & Techniques*. DCCD, Cochin. 82 pp.

5. COCOA PRODUCTION TECHNOLOGY

Najeeb Naduthody

Cocoa, as one among the beverage crops occupied the lower hills of western ghats with tea at top hill and coffee in middle hill when it was introduced into India. Suitable agro climatic condition is a prerequisite for an introduced crop that too a perennial tree to get sustainable yield and quality produce. The productivity of cocoa in terms of dry bean yield is low (450 kg ha^{-1}) due to non availability of sufficient quantity of quality planting material and improper management. Knowledge on basic and advanced cultivation practices of cocoa in the palm based cropping system is important.

Suitable climate

Cocoa is a crop of the humid tropics. Though it grows between 20^0N and 20^0S latitude, the main growing areas are situated within 10^0N and 10^0S. Cocoa is grown from sea level up to an elevation of about 500 m. It comes up best up to 300 m above mean sea level. Ideally, cocoa requires a minimum of 90-100 mm rainfall per month with an annual precipitation of 1500-2000 mm. It grows within a temperature range of 15-39°C and optimum temperature is around 25°C. It cannot be grown in areas where the minimum temperature falls below 10°C and the annual average temperature is less than 21°C. Cocoa needs high humidity throughout the year for optimum growth.

Soil requirement

Cocoa is grown on a variety of soils throughout the world. Laterite soils found in humid tropics are adequately suitable for cocoa growth. Black soils and alluvial soils are also suitable for cocoa if not too wet or too shallow. Soil depth should be about 1.0-1.5 m with sandy or alluvial texture. Organic carbon should be above 2.0 per cent with a C/N ratio not less than 9. It is also important that adequate rainfall and good water holding capacity are present for proper growth of cocoa. The ideal soil for cocoa should have depth-1.5m, organic matter-3.5%, C/N ratio->9, Base exchange capacity->12 me/100g soil, base saturation->35%.

Cocoa is a deep rooted crop and vertical penetration of cocoa roots is up to 3.5 m. About 60 per cent of fine roots are within the first horizon of 50 cm depth. Under monocropping situations, root growth of cocoa was concentrated within 25 cm radius from the tree. The lateral spread of all roots, thick and fine roots within 50 cm radius were 81, 86 and 69 per cent of total respectively. Under mixed cropping situation, 42 per cent of total and 24 per cent of fine roots were confined to 25 cm radius. Lateral spread of active roots was mainly restricted to one meter from the plant, which accounted for 75 per cent of the total root activity. An area of 1.5 m radius around the plant had about 85 per cent of the root activity. Due to tap root system and high CEC (Cation Exchange Capacity) of cocoa

roots, cocoa is highly competitive to main crop. Thus, it is essential to meet the water and nutrient demand of both component crops in mixed crop situations.

Agrotechniques

Optimum spacing

Cocoa is generally grown as an intercrop in coconut, arecanut and oil palm plantations in India. The general recommendation is single hedge system *i.e*., planting one row of cocoa at a spacing of 2.5- 2.7 m in between two rows of coconut spaced at 7.5 m x 7.5 m. If the spacing of coconut is wider two rows of cocoa can be planted. In double row system the row-to-row spacing was 2.5 m. The population of cocoa in single hedge and double hedge systems is 350 and 600 trees per ha (Nelliat *et al*., 1974, 1979). Double hedge system was superior over the single hedge system when coconut spacing is wider (9.0 m x 9.0 m) and cocoa planted with a spacing of 3.65 m. In Asia Pacific nations 3 m spacing between cocoa rows is preferred. Single row of cocoa in between four rows of coconut and 1 each in coconut row is recommended by KAU-CCRP (Nair *et al*., 1994).

In India cocoa is extensively grown under arecanut. Optimum spacing for arecanut is 2.7 m x 2.7 m. Considering the normal spacing of arecanut 2.7 m x 2.7 m as well as combined yield of the two crops, it is safe to select spacing of 2.7 m x 2.7 m for arecanut and 2.7 m x 5.4 m for cocoa (Shama Bhat, 1988; Shama Bhat and Bavappa, 1972). When oil palm is planted in a triangular method at 9.9 or 10.5 m spacing, planting of cocoa at 2.4 m is better for growth and yield compared to oil palm spaced at 8.7 m. Further, it is advisable to plant cocoa at least 2 m away from the base of palm to avoid severe competition between both crops. The shade in oil palm plantations is very high and so square planted oil palm of >15 years old is preferred. If oil palm is widely spaced cocoa can be planted in young gardens.

Method of planting

Pits of 60 cm^3 are to be dug and refilled with mixture of topsoil and organic manure. The main objective of digging pit is to break the hard pan if present in the sub-surface and to loosen the soil in the root rhizosphere for better soil aeration and root growth. Soil aeration is most important for production of fine roots, which are required for uptake of nutrients and water.

Time of planting

It depends on the climatic conditions of the place. Young seedlings need moisture for better establishment. The seedlings cannot withstand excess water also. So in areas where rainfall intensity and amount is less planting will be done on the onset of monsoon. In

areas of heavy rainfall the planting will be done at the end of the monsoon. If the soil moisture can be maintained by irrigation, planting can be done at any time of the year.

Shade

Cocoa, whose natural environment is the lower storey of the forest, requires shade when young and also to a lesser extent when grown up. Young cocoa plants grow best with 50 percent of full sunlight. It grows very well in the partially shaded condition prevailing in the arecanut and coconut gardens. As the tree matures, its shade requirements are reduced.

Nutrition

Nutrient requirement of cocoa depends upon the type of soil it is being grown, and the cultivation practices being followed. So the nutrient application varies with different cocoa growing regions. In general, the nutrient application is made based on analysis of soil or plant or both. The nutrient removal by the crop also makes the basis of fertilizer application to cocoa. The fertilizer recommendation for cocoa under average management is 100:40:140 g of N, P_2O_5 and K_2O per tree per year. Zinc deficiency is predominantly seen in all cocoa growing regions as it is very sensitive to less availability of Zn. In perennial crops, it is difficult to control deficiency of any nutrient after the symptoms develop. In view of this, soil application of Zn @ 10 -20 g per tree once in two years is advisable based on age of the tree.

Biomass production

Cocoa is a tropical tree and it produces leaves throughout the year. The biomass production varies with age and growing conditions. Cocoa normally produces 14 kg leaf and pruned biomass, 4 kg pod husk and 2 kg beans per year on dry weight basis. This comes to about 9.1 t leaf, 2.6 t pod husk and 1.3 t beans per hectare. Cocoa under coconut adds litter fall to the extent of 818 to 1985 kg/ha/year (Chowdappa *et al*., 1999).

Nutrient uptake by cocoa

For a crop yielding about 2 kg of dry beans (about 60 pods) per tree per year, the average crop removal by pods would be around 96.8, 11.4 and 191.2 g each of N, P and K. One cocoa tree removes 479 g N, 36 g P and 429 g K per year which includes nutrients removal by leaves, pod husk and beans (Table 1).

Table 1. Nutrient removal by cocoa crop

Nutrient	Nutrient exported through 1000 kg dry beans	Nutrient removal at yield level of 2 kg dry bean/ tree	
		per tree	per hectare (650 trees)
N	48.4 kg	479 g	311 kg
P	5.7 kg	36 g	23.4 kg
K	95.6 kg	429 g	279 kg

Based on this nutrient removal pattern, the present K recommendation for cocoa seems insufficient. Nitrogen and phosphorus demand of cocoa can be met from other sources like atmospheric N, organic matter, irrigation water and rainfall interception. As potassium is not organically bound and not supplied by other sources, it is necessary to apply K in frequent split doses during December to May. The present K dose can be doubled if dry bean yield is more than 1.0 kg per tree.

Method and time of application of nutrients

The root studies have shown that majority of the feeding roots of cocoa are concentrated on the surface and horizontally they traverse from 1.0 to 1.5 meters. Thus nutrients have to be applied on the surface of the soil in the cocoa basin and mixed in the soil without damaging the roots to prevent the nutrient losses. The basin size will be smaller for young cocoa plants. The fertilizer should be applied when the soil has sufficient moisture.

The time of application is decided by the moisture availability in the field and stage of the crop. In unirrigated crop fertilizers can be applied just before monsoon coinciding the months of May- June and after monsoon (September- October). When the crop is irrigated the pre-monsoon application can be advanced to February- March. As far as possible the fertilizers should be applied before main flush period, before flowering and two months before the peak of the main harvest. Cocoa in the first year of planting should be given 1/3rd of the recommended dose of fertilizer for adult tree. In the second year 2/3rd of the recommended dose and from third year onwards, full dose of fertilizer should be given.

Irrigation

Cocoa is generally a rainfed crop in the traditional cocoa growing countries. In India it is grown under coconut and arecanut as an irrigated crop. As rainfall occurs only from June to October, the remaining period remains dry. Hence, irrigation is essential for performance of the crop during post monsoon season. When it is grown as a mixed crop with arecanut, the crop is to be flood or hose irrigated once in a week during November-December, once in 6 days during January- March and once in 4-5 days during April- May with about 175 liters of water.

The studies conducted showed that drip irrigation was better than sprinkler irrigation with respect to growth of the cocoa plants. Sprinkler irrigation is not advisable to cocoa as this will affect the pollination. Drip irrigation requirement of cocoa can be computed by considering the following thumb rule. Based on modified penman method, it is derived that one mm of pan evaporation is equivalent to 3.3 lit of water. This implies that 20 lit of water per day per tree are required through drip irrigation if evaporation is 6 mm. Thus, water requirement is less during winter and increases during March- May.

Pruning

Cocoa has an interesting and specific plant habit of branching in tiers. After germination, vertical or orthotropic growth of main shoot continues, at a certain height the growth of the main stem ceases, forms five lateral plagiotropic branches or fans and this process is called 'jorquetting'. Further vertical growth (chupon) continues on the main stem below the whorl of fan branches. This pattern continues until the tree reaches an average of 20 m height in wild. But in the intercropping systems, single tier canopy is maintained and managed with proper training and pruning measures. Genotypes with medium vigour, small stature and canopy spread are being selected for easy management and evaluation.

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. The main objective of pruning is to maintain the shape of the cocoa plant to make it more productive and efficient. Formation pruning and maintenance pruning are the two types of pruning generally practiced in cocoa.

Formation pruning

This is practiced for the young cocoa plants. The objectives of this pruning are adjustment of height of the first jorquette and control of vertical growth. Generally first jorquette is formed at a height between 1 and 2 meters. For easy operations in the field the preferable jorquette height is 1.5 to 2.0 meters. 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 will be removed at an early stage to facilitate upward growth. The jorquettes have five fan branches. But added advantage of cutting the fan branches is not seen unless the branches are weak. Cocoa plants derived from fan branches tend to produce low and brushwood like canopy. Under such circumstances, the best formation pruning method is to leave 3-4 branches low down. 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. All the chupons arising from below the jorquette have to be cut regularly to maintain the height. The trees with pruning though produced less yield in the initial years at later years the advantage of not pruning was not significant.

Maintenance pruning

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. Sanitary pruning includes removal of all unnecessary chupons, dead branches, epiphytes, climbing plants, ant nests, diseased and rodent damaged pods, and over ripe pods.

Harvesting

Cocoa produces flowers from the second year of planting onwards and the pods take about 140- 160 days to ripen. Each pod will have 25- 45 beans embedded in a white pulp (mucilage). Generally Cocoa gives two main crops in a year *i.e*., April- June and September- January, though off- season crops may be seen throughout the year especially under irrigated condition. Ripe pods are to be harvested without damaging the flower cushions by cutting the stalk with the help of knife. The harvesting is to be done at regular intervals of 10- 15 days. The damaged and infected pods are to be separated to ensure better quality of beans after processing. The harvested pods should be kept for a minimum period of two days before opening for fermentation; however, the pods should not be kept beyond four days. For breaking the pods, wooden billet may be used. After breaking the pods crosswise, the placenta should be removed together with husk and the beans are collected for fermentation.

References:

1. Chowdappa, P., Biddappa, C. C. and Sujatha, S. 1999. Efficient recycling of organic wastes in arecanut (*Areca catechu*) and cocoa (*Theobroma cacao*) plantation through vermicomposting. *Indian J. Agric. Sci*. **69**: 563-566.
2. Nair, R.V., Virakthmath, B.C. and Mallika, V.K. 1994. Management of cocoa. In: *Advances in Horticulture Vol. 9- Plantation Crops and Spices* Part – I (eds. Chadha, K.L. and Rethinam, P.) Malhothra Publishing House, New Delhi - 110 064. pp 563–575.
3. Nelliat, E. V., Bavappa, K. V. A. and Nair, P. K. R. 1974. Multistoreyed Cropping. A new dimension in multiple cropping for coconut plantations. *World Crops*. **26**: 262-266.
4. Nelliat, E. V., Gopalasundaram, P., Thomas Verghese, P. and Sivaraman, K. 1979. Mixed cropping in coconut. *In*: *Multiple cropping in coconut and arecanut gardens*. (eds. Nelliat, E. V. and Shama Bhat, K.). Technical Bulletin Series 3. CPCRI, Kasaragod. pp 28-34.
5. Shama Bhat, K. 1988. Growth and performance of cacao (*Theobroma cacao* L.) and arecanut (*Areca catechu*) under mixed cropping system. *Proc. 10th Intern. Cocoa Res. Conf*. Santo Domingo, Dominican Republic. pp 15-19
6. Shama Bhat, K. and Bavappa, K.V.A. 1972. Cocoa under palms. *Proc. Conf. Cocoa and Coconuts in Malaysia*, Kuala Lumpur. pp 116-121.

6. PROCESSING METHODS AND PRODUCTS OF COCOA

Najeeb Naduthody and Suchithra, M. and S. Elain Apshara

Cocoa is a crop of small holders which is giving an additional remuneration along with the main crops arecanut, coconut and oil palm. Presently cocoa cultivation is widely taken up through contract farming with buy-back arrangements and smooth procurement facilities at farm gate or at collection centres by cooperative units and private firms like CAMPCO and Cadbury India Pvt. Ltd. (Mondelez International), Jindal Cocoa and Amul etc. Small chocolate units are using the cocoa bars or chocolate blocks of companies and making into value added products with nuts, raisins and other edible materials. To overcome the risks on non- procurement and marketing failures knowledge of processing of cocoa is important. In order to bridge the gap between the farm price and product price growers should know about the farm level primary and secondary processing of cocoa as well as the steps involved in chocolate making. Post-harvest cocoa processing is a very crucial aspect of cocoa production as it determines mostly the quality of cocoa beans.

Pre harvest and harvesting

Cocoa bears its crop over several months of the year depend upon the prevailing agro-climatic conditions. At Karnataka and Kerala two peak periods are noticed during May-July and October- November. At Tamil Nadu the peak is observed in November and in Andhra Pradesh during April- June. Pods develop during dry season tend to yield smaller beans and lesser fat. In the cocoa growing regions of India the days for maturity ranges from 135- 170 with different types of cocoa. Only fully matured pods as indicated by change of colour and when the pods give out a metallic sound when tapped, may be harvested. Though pods can be harvested as colour changes, the pods may remain on the tree without damage up to a maximum of about one month.

Pods are harvested using various forms of knife. Care has to be exercised to avoid damage to the flower cushion when pods are harvested. A special knife for harvesting cocoa pods has been designed at CPCRI. The curved blade is made of steel with both edges sharp and is attached to a long Aluminium handle.

Harvesting may be done at 7- 10 days intervals. Fallen, disease infected, immature, over ripened and partially ripened pods are to be discarded. Harvested pods should be kept for 2- 4 days before they opened. For breaking the pods, wooden mallet or hitting the pods against hard surface may be resorted. The use of metallic knifes should be avoided to prevent damage to the beans. The placenta in the pods should be removed and only the beans with adhering pulp should be collected for fermentation. Beans have to be put for fermentation as early as possible after removing from the pod. For transportation of wet beans non-metallic containers may be used.

Properties of Cocoa beans

The matured cocoa beans possess following properties

Initial moisture content	:	52-55 %
Final moisture content	:	6-8 %
Recovery of dry beans in terms of wet beans.	:	35-40 %
Weight of 100 dry beans	:	100-110 gms
Fat content	:	55-58 %
Acidity	:	5.8 (Good quality)

Primary processing or Curing

Curing of cocoa beans is a very important primary process in cocoa processing. It comprises of two unit operations namely fermentation and drying. The chocolate flavour is developed in the beans during this process.

Fermentation

The objective of fermentation is not to get rid of this pulp, but to help develop chocolate flavour. It also conserves heat for chemical changes inside the bean, for which the fermenting mass should be covered, at the same time air should pass through. The colour of the inside portion of the beans changes from purple or violet to light brown. The chemical changes occurring during the fermentation of the beans are very complex. From this, it is evident that proper fermentation is possible only if the beans have matured so that sufficient pulp sugar is developed for the chemical changes. The raw beans are bitter and astringent which will give chocolate aroma after fermentation. The duration of fermentation depends on the type of cocoa; Criollo cocoa with white beans, requires only two or three days, whereas Forastero cocoa, with dark mauve beans, requires six days.

A number of factors influence the duration of fermentation. Season and changes in weather are important through their influence on temperature and humidity. Fermentation is better in dry season compare to wet season in terms of acidity, bean weight and percentage recovery. Beans from unripe pods cannot be fermented. During early stages of fermentation heat is produced by the action of anaerobic microorganisms. The beans are killed by the combined effect of heat and acetic acid and cocoa aroma and flavour develop. Under fermentation will result in greater bitterness and astringency. Over fermentation will result in more acidity, dull coloured nib and little chocolate flavour. There are different low cost methods of fermentation;

Traditional methods

Among the various methods adopted for fermentation in different cocoa producing countries Heap, Box and Tray methods are considered as the standard methods.

1. Heap method

This method involves heaping a mass of not less than 50 kg of wet beans over a layer of banana leaves on a sloppy floor to allow drainage of sweatings. The heap is covered using banana leaves. On the second day the heap is covered with gunny bag to conserve the heat produced during the fermenting process. The heaps are dismantled and the beans are mixed on the third and fifth days and again kept in position. It needs about six days for the completion of fermentation and the beans can be taken out for drying on the seventh day.

2. Box method

The traditional box method employs a series of boxes of a size suited to the quantity of pods harvested and the beans extracted. The boxes are made of wood and have holes in the bottom to allow the sweatings from the pulp to drain away and air to enter. Wooden boxes of 1.2 m x 0.95 m x 0.75 m size will hold 1 tonne of wet beans. Beans are placed in a box to a depth no more than 75 cm and are covered with banana leaves to conserve the heat. The beans should be mixed every alternate day by moving them from one box to the next and a minimum of three boxes are required.

3. Tray method

The other method of fermentation is relatively new is the tray method which so far has only been used for Forastero types of cocoa. In this method the beans are placed 10 cm deep in trays which are stacked one on top of the other in tiers of 12. This method has several advantages; the beans do not require mixing, trays are convenient to handle and the duration of fermentation is reduced from six to four days. Wooden trays of size 90 cm x 60 cm x 13 cm with reapers fixed at the bottom with gaps in between are filled with beans. Each tray can contain about 45 kg wet beans. Six such trays are stacked one over the other and an empty tray is kept at the bottom to allow for drainage of sweating. After stacking the beans, the top most tray is covered with banana leaves. After 24 hours of setting the stack, trays are covered with gunny sacking to conserve the heat that develops. On the fifth day the beans can be taken out for drying. The minimum number of trays required to be stacked is about six but as many as 12 trays can be used simultaneously.

Small scale methods

Three methods usually employed for small quantities of beans are mini tray, box and basket methods (Kumaran *et al*., 1980; 1981; Prasannakumariamma *et al*., 2002; 2002a; Minimol *et al*., 2011). The best method among these is the tray method.

1. **Mini tray method**

A convenient tray can be of 25 cm width, 60 cm length and 10 cm deep with slatted split cane bottoms divided into a number of sections by means of wooden partition that will fit into appropriate grooves at required distances. About 10 kg of wet beans may be required to load one tray fully. The capacity of the tray can be adjusted depending upon the availability of beans by keeping wooden plank in appropriate grooves. At least four or five trays are needed for successful fermentation.

2. **Small basket method**

In this method, bean lots ranging from 2-6 kg can be fermented successfully. Mini baskets made of bamboo matting, closely woven with 20 cm diameter and 15 cm height can hold 2 kg beans. For slightly larger lots proportionately deeper baskets may be used (eg. For six kg, the depth may be about 40 cm). The baskets are lined with one or two layers of torn banana leaves to facilitate drainage of sweatings. Wet beans are then filled, compacted and covered with banana leaves. The baskets are placed on a raised platform to allow the flow of drippings. After 24 hours, it is covered with gunny sacking. The beans are to be taken out and stirred well on the 3^{rd} and 5^{th} day after the initial setting. Fermentation will be completed in six days and the beans can be taken out for drying on the seventh day.

3. **Gunny bag method**

Cocoa can be fermented satisfactorily in clean plastic gunny bags also. Beans are filled loosely, tied and allowed to drain sweatings for one day. The gunny bags are heaped one over the other and insulated properly to conserve heat. The beans are shaken and mixed thoroughly without opening the bag on 3^{rd} and 5^{th} day and repacked. The beans are taken out for drying on the 7^{th} day.

End point of fermentation

Well fermented beans will be plumb and filled with reddish brown exudates. The testa becomes loosened and detached from the cotyledons. When cut open, the cotyledons will have a bleached appearance in the centre with a brownish ring in the periphery. When 50% of beans show the above sign, that lot can be considered as properly fermented.

Drying

The fermented beans can be dried either in the sun or by artificial means. Sun drying can be done in thin layers of 2-3 cm. depth and stirring from time to time. If drying is too slow there is the danger of beans getting mouldy and consequent development of off flavours. The beans must therefore be skin dry within 24 hours. On the other hand too

quick drying using artificial driers may lead to the beans remaining acidic. When the beans are dried properly, they produce a characteristic cracking sound on compressing a fistful of beans in the palm. The more scientific method is to use moisture meter. During drying, the moisture content is reduced from 55 to 7%.

Sun drying

The beans can be dried on mats or concrete floors. Beans are spread in one or two layers thickness and turned over periodically to expose the beans uniformly to the sun. The beans are heaped during night hours. Under normal sunny weather drying is completed in four to five days, if cloudy, takes 7-10 days.

Artificial drying

As far as possible sun drying should be adopted which gives superior quality produce when compared to that by artificial drying. During periods when sunshine is not available, artificial drying could be adopted. While drying in mechanical driers, care must be taken to avoid exposure of beans to smoke and fumes and the temperature should not exceed 60^0C.

Storage

Dried beans with moisture content of 6 to 8 per cent may be packed in polythene lined gunny bags. Flat and broken beans should be removed before storage. The store should be sufficiently ventilated and the bags should be kept on a wooden platform with a space of about 15-20 cm below the wooden planks set over the floor without touching the walls. The humidity should not exceed 80 per cent so as to prevent mould development and pest incidence in beans. Under Kerala and Karnataka conditions, beans can be stored safely for about 2 months.

Secondary processing

Different stages are involved in secondary processing which leads to various products from cocoa.

Alkalization

The dried beans are alkalized in a solution of 1% Sodium bicarbonate (10g in 1 litre of water for 1 kg beans) for 3 hours. The beans are then dried in sun for 1-2 days. Alkalization is adopted to reduce the acidity, increase dispersability of powder and add deep colour to the powder.

Roasting

The alkalized and dried beans are then roasted in pans or roasters depending upon the quantity, for about 20-30 minutes. The end point of roasting can be judged by the cracking sound of the beans and the development of characteristic chocolate smell. After roasting, the beans are spread out.

Kibbling

The term indicates the chopping of roasted beans into small pieces called cocoa nibs and separation of the testa/ outer cover from the roasted beans. It can be done manually with the help of a small knife.

Grinding

The nibs (seeds without testa) are then ground into paste in a grinder or colloid mill till a fine consistency is achieved. The product obtained is called 'cocoa mass'. The mass is semi solid due to the high content of a fat (57%) in the beans.

Separation of cocoa powder and butter

To make different cocoa based products cocoa butter is to be separated from the cocoa mass. The separation is done using a cocoa butter extractor, which works on the principle of a hydraulic press. The cocoa mass is poured into a cloth bag, tied at the top and placed at the base of the cylinder. When pressure is applied the butter oozes out through the holes and gets collected in the vessel at the bottom. The powder obtained from the cloth bag is called 'cocoa press cake'. This cake can be powdered and sieved to get 'cocoa powder'. Chocolate is prepared by grinding cocoa nibs along with cocoa butter and sugar in a definite proportion. The cocoa butter and cocoa powder are used for preparing different types of chocolates and delicacies.

Quality requirements of chocolate manufacturers

Quality includes flavor, purity or wholesomeness, consistency, yield of edible material and cocoa butter characteristics.

Flavour

It is the intensity of cocoa or chocolate flavor. The variety, cocoa cultivation practices followed and post-harvest handling will play a vital role in determining and maintaining the quality of flavor. Bulk cocoa possesses a good strong chocolate flavor. The off flavors normally detected are mouldy, smoky off flavours, acid taste, bitterness, astringency and contamination. Prolonged fermentation, inadequate or slow drying, presence of moisture

during storage or humid conditions will favour growth of moulds and develop mouldy flavour. Germinated beans and damaged beans prone to get more moulds. Over fermentation and smoke during drying due to bad design, faulty operation or poor maintenance of dryer causes smoky off flavour. A high degree of acidity is usually associated with pH of 5 or less. Excessive acid taste experienced with deep box fermentation, multiple turning and too rapid drying. Control of pH or continuation of fermentation for an extra period of 4-5 days may reduce the acid taste. Bitterness and astringency are related with variety, nature of tree grown and lack of fermentation. Contamination from other products such as copra, rubber, oil based fuels, chemicals, paints etc. are sometimes absorbed by cocoa beans either in storage or through vessels used for transportation and causes off flavours. High fat content of cocoa acts as an effective absorbent for such contamination.

Purity or wholesomeness

Beans should be free of any harmful impurities. Pesticides used on trees should be of approved chemicals, in correct quantity and safe to avoid pesticide residues. Inadequate and slow drying cause bacterial contamination and insect infestation affects the purity. Cleaning and grading should be done to avoid foreign materials such as pieces of pod husk, placenta, stones etc. Insect infestation with moths and beetles during storage may be avoided with fumigation. Jute sacks used may contain mineral oil which is used to soften jute fibres may affect the beans. Food grade vegetable oil should be used.

Consistency

Within the bulk cocoa consistency is being obtained by mixing both good and poor quality beans.

Yield of edible material

Yield of nib and cocoa butter is important.

a) Bean size and uniformity There are 3 categories
   >100 beans per 100 g; 100-110 per 100 g; >120 per 100 g
b) Shell% - The shell should be strong enough to remain unbroken under normal handling, free from adherent matter and less in percentage (10-15%).
c) Fat% - Cocoa butter is the most valuable part of the bean which affects the price depends upon grade of cocoa beans.
d) Moisture content should be 6-7%.
e) Broken beans should be minimal.

Cocoa butter characteristics

Cocoa butter with a free fatty acid (ffa) content of 1% or less together with acceptable flavour is preferable. If beans are stored more than 3 months fat degradation will be there leads to rise in ffa.

Processing of cocoa at industries

Industries like CAMPCO collect both wet and dry beans from cultivators through collection centres in different cocoa growing areas as well as at the farm and factory gate (www.campco.org).

Stage 1. The cocoa beans are cleaned to remove all extraneous material.

Stage 2. To bring out the chocolate flavour and colour the beans are roasted. The temperature, time and degree of moisture involved in roasting depend on the type of beans used and the sort of chocolate or product required from the process.

Stage 3. A winnowing machine is used to remove the shells from the beans to leave just the cocoa nibs.

Stage 4. The cocoa nibs undergo alkalization, usually with potassium carbonate, to develop the flavour and colour.

Stage 5. The nibs are then milled to create cocoa liquor (cocoa particles suspended in cocoa butter). The temperature and degree of milling varies according to the type of nib used and the product required.

Stage 6. Manufacturers generally use more than one type of bean in their products and therefore the different beans have to be blended together to the required formula.

Stage 7. The cocoa liquor is pressed to extract the cocoa butter leaving a solid mass called cocoa press cake. The amount of butter extracted from the liquor is controlled by the manufacturer to produce press cake with different proportions of fat.

Stage 8. The processing now takes two different directions. The cocoa butter is used in the manufacture of chocolate. The cocoa press cake is broken into small pieces to form kibbled press cake which is then pulverized to form cocoa powder.

Stage 9. Cocoa liquor is used to produce chocolate through the addition of cocoa butter. Other ingredients such as sugar, milk, emulsifying agents and cocoa butter equivalents are also added and mixed. The proportions of the different ingredients depend on the type of chocolate being made.

Stage 10. The mixture then undergoes a refining process by traveling through a series of rollers until a smooth paste is formed. Refining improves the texture of the chocolate and reduces the particle size of sugar and cocoa to around 30 microns.

Stage 11. The next process, conching, further develops flavour and texture. Conching is a kneading or smoothing process. The speed, duration and temperature of the kneading affect the flavour.

Stage 12. The mixture is then tempered or passed through a heating, cooling and reheating process. This prevents discoloration and fat bloom in the product by preventing .

Stage 13. The mixture is then put into moulds or used for enrobing fillings and cooled in a cooling chamber.

Stage 14. The chocolate is then packaged for distribution to retail outlets.

Cocoa products

Cocoa is being enjoyed as candies, baked goods, desserts (cakes, cookies, puddings and ice creams), beverages, sauces for seafood and poultry. Quality of the chocolate depends upon the amount of solids remaining after processing in the final product (www.cadburyindia.com, www.mondelezinternational.com).

Cocoa powder

It is being prepared in two forms. Alkalized cocoa powder contains potassium carbonate, sodium carbonate, magnesium which neutralizes the naturally occurring acids and makes the powder easier to dissolve in liquids. Sweetened cocoa powder is often mixed with hot mild or water to produce hot chocolate or hot cocoa and unsweetened one is being used in baking.

Milk chocolate

It is sweet mild-flavoured type of chocolate contains powdered or condensed milk and has approximately 20 percent cocoa solids. Many candy bars are made with mild chocolate.

Dark chocolate

It is called as ‘bittersweet’ chocolate. It contains a high percentage (75%) of cocoa solids and little sugar. This semisweet chocolate has a rich, intense flavour found in candies and chocolate chips used in baking.

White chocolate

It is made from cocoa butter added with milk, sugar and vanilla extract, similar to chocolate in texture and it is very sweet.

Unsweetened chocolate

It contains upto 75% cocoa solids without sugar or milk. It is used mainly for baking because although it has a chocolate flavour it is too bitter to eat.

Baking chocolate

Both semisweet and unsweetened baking chocolates are available. Baking chocolate is being sold in 28 g squares which are convenient to use in recipes.

High quality chocolate

It refers to the brown or dark brown chocolate with high gloss being used in speciality candies having high percentage of cocoa solids.

References:

1. Kumaran, K., Nair, P.C.S. and Nair, R.V. 1980. Studies on the methods of curing for small quantities of cocoa beans. *Indian Cocoa Arecanut & Spices J*. **4**: 42-44.
2. Kumaran, K., Prasannakumari,S. and Nair, P.C.S. 1981 Experiments on small scale fermentation of cocoa beans II. Effect of the different factors for aeration on the extent of fermentation and quality of cured cocoa beans. *Proc. PLACROSYM III.* Cochin. pp 125-137.
3. Minimol, J. S., Prasannakumari Amma, S. and Lalitha Bai, E. K. 2011. Technology for farm level processing of cocoa- an analysis. In: *Proceedings of seminar on strategies for enhancing productivity of cocoa.* (Eds.) Elain Apshara, S., Jaganathan, D. and Balasimha, D., CPCRI, Regional Station, Vittal. pp. 153-157.
4. Prasannakumariamma, S., Malllika, V.K. and Nair, R.V. 2002. Harvesting and post harvest technology. In: *Cocoa* (Ed. Balasimha, D.), CPCRI, Kasaragod.
5. Prasannakumari Amma, S. Malllika, V.K. and Vikraman Nair, R. 2002a. Harvest and post harvest technology. In: *Proceedings of national seminar on technologies for enhancing productivity in cocoa.* (Eds). Ravi Bhat, Balasimha, D. and Jayasekhar, S. CPCRI, Regional Station, Vittal. pp. 111-119.
6. www.campco.org.
7. www.cadburyindia.com.
8. www.mondelezinternational.com

7. BIOCHEMICAL COMPONENTS OF COCOA AND THIER BENEFITS ON HUMAN HEALTH

M. Senthil Amudhan and Pankaja, B.D.

Cocoa and chocolates have lots of health benefits. Biochemical compounds, the polyphenols in cocoa have well known antioxidant biological activities and beneficial effects on cardiovascular system and also interact with the organoleptic traits of cocoa.

Cocoa beans

The cocoa pod contains 20 to 60 beans, embedded in white pulp. The beans are the main ingredient of chocolate, while the pulp is used in some countries to prepare a refreshing juice. Each seed consists of two cotyledons (the nib) and a small embryo, all enclosed in a skin (the shell). The cotyledons store the food for the developing plant and become the first two leaves of the plant when the seed germinates. The food store consists of fat, known as cocoa butter, which amounts to about half the weight of the dry bean. Another most noted active constituent is theobromine, a compound similar to caffeine and polyphenol which constitute 10-12% of the whole bean's dry weight. The beans are fermented, which causes many chemical changes in both the pulp surrounding the beans and within the beans themselves. These changes cause the chocolate flavour to develop and the colour to change. The beans are then dried and despatched to processors as the raw material for the production of cocoa mass, cocoa powder and cocoa butter. The first stage of processing includes roasting the beans and shell removal. After roasting and deshelling an alkalising process can take place, to alter flavour and colour. All these processing procedures are important for the quality of the produce (Andres-Lacueva *et al.,* 2008).

Nutritional aspects

Cocoa and chocolates are rich in minerals including magnesium, iron and highly concentrated source of energy. During the World War II soldiers were given with three chocolate bars a day because of its high nutritional value. One bar (41g) of chocolate provides 10-20% of recommended daily dietary value and the healthy components listed below are being absorbed readily by the body without wastage.

Calories	207
Carbohydrate	24.4 g
Fat	14.0 g
Fibre	2.20 g
Protein	1.60 g
Magnesium	46.0 mg

A growing number of clinical studies indicate that regular ingestion of polyphenol-rich cocoa exerts a range of effects potentially favourable to vascular health. There is recent evidence that the epicatechin content of cocoa is primarily responsible for its favourable impact on vascular endothelium.

Biochemical composition

The physics and chemistry of cocoa beans and cocoa products are very complex, changing throughout the development of bean and depending on the type of processing it receives. Catechin, epicatechin and procyanidines are the main polyphenols present in cocoa contributing to bitterness and astringency of cocoa and these are the main polyphenols in fruits as well. These monomers can form links between C4 and C8, allowing them to assemble as dimers, oligomers, and polymers of catechins, the so-called procyanidins. Procyanidins are also known as condensed tannins, which, through the formation of complexes with salivary proteins, are responsible for the bitterness of cocoa. There are different products involved in the processing of cocoa to chocolate and their biochemical constituents contributed to the health benefits of cocoa.

1. Cocoa mass or liquor

Cocoa mass is produced by grinding the nib of the cocoa bean and the quality of the liquor depends on the beans used. Manufacturers often blend different types, Criollos, Forasteros and Trinitarios beans to gain the required quality, flavour and taste. The cocoa liquor can undergo further roasting and alkalisation to alter the colour and flavour which will also alter its chemical composition. The cocoa mass contains 600 components and the major constituents are given below:

Composition of cocoa mass

Cocoa butter	54.5%
Protein	11.5%
Fibre	3-10%
Organic acids & aromas	9.5%
Cellulose	9.0%
Tannic acids & colour	6.0%
Water	5.0%
Mineral salts	2.6%
Theobromine	1.2%
Sugars	1.0%
Caffeine	0.2%
Source: ICCO	

2. Cocoa butter

Cocoa butter is the most valuable part of the bean, which affects the price paid for a particular mark or grade of cocoa beans. The fat or cocoa butter can be extracted from the bean in a number of ways. Each bean contains a significant amount of fat (40-50%) as cocoa butter. Pure press butter is extracted from the cocoa mass by horizontal presses. A solvent extraction process can be used to extract butter from the cake residue left after the expeller process; this type of butter must be refined. Cocoa butter obtained by pressing the cocoa nib exhibits the properties of brittle fracture below 20°C, a melting point about 35°C with softening around 30-32°C. Cocoa butter is composed of a number of glycerides. The quantity of fat and its properties such as melting point and hardness depend on the variety of cocoa and the environmental conditions.

To assess the suitability of varieties of cocoa for the processing industry, fat content was estimated in cocoa germplasm collections, hybrids and elite clones conserved at CPCRI, Regional Station, Vittal, by petroleum ether extraction method using Soxhlet apparatus and expressed in percentage. Among 44 collections of Nigerian origin 21 clones recorded more than 50 per cent fat which is considered as desirable character for industrial value of cocoa. Beans of the clone VTLCN-43 had the highest fat content of 55.27%. Among 11 Malaysian collections the fat content ranged from 40 to 55%. Among the local collections of Lalbaugh and Wynad, the highest fat contents were only 45.79 and 38.69%. Among elite clones, VTLCC-1 had 55.74% fat under arecanut and VTLCP-1 had the highest fat content of 52.7% when grown under coconut. Among 21 hybrids, 11 showed >50% fat. Fat content of clones differed significantly with locations and growing environments.

A comparative estimation of fat in open (sun drying) and oven dried beans were done in 14 elite clones. The fat content in beans dried in open ranged from 21.32 to 37.83% whereas, the beans dried in oven recorded a high percentage of fat ranged from 37.59 to 58.53%. Summer season beans showed lesser size and fat content than the monsoon beans. Some beans were collected from Andhra Pradesh and the fat estimates showed that the beans of coconut garden recorded a highest of 44.53% fat compared to beans of oil palm shade which has 40.06% fat. Tamil Nadu beans also showed lesser percentage of fat contents. We have assessed the fat contents of demonstration gardens in Karnataka and Kerala as well. Humid condition favours the size and ultimately the fat content of beans, but care should be taken to reduce the fungal attack during drying. It is observed that size of the bean is directly proportional to the fat content, so the dry bean size should be of more than 1 gram to get higher fat contents.

Fatty acid profile of cocoa varieties

Cocoa butter with free fatty acid (ffa) content of 1% or less together with acceptable flavour is the best indication of good quality beans prepared and stored properly.

Prolonged storage may cause fat degradation and rise in ffa concentration. Type of fatty acids in 18 hybrids and 10 elite clones was assessed in freshly prepared beans at CPCRI. From the fatty acid profile it was clear that there are 11 fatty acids *viz*., lauric, myristic, palmitic, palmitoleic, stearic, oleic, linoleic, arachidic, eicosapentaenoic, behemic and lignoceric acids involved in quality of cocoa beans. The fatty acids palmitic, stearic, oleic, linolic and arachidic acids were present in all the accessions invariably. The percentage of stearic acid was the highest among all in a range of 30.50% in VTLCP-7 to 44.20% in VTLCP-1 followed by oleic, linolic and arachidic acids and these hybrids have high industrial and health values. Myristic acid was present in only one accession. The other fatty acids differed among the accessions in percentage of expression.

3. Cocoa powder

Cocoa powder is formed from cocoa mass. Presses are used to remove some of the fat and leaving a solid material called cocoa press cake. These cakes are then crushed to form cocoa powder. The processing can be altered to produce cocoa powders of different composition and with different levels of fat. Composition of cocoa powder will vary depending on the roasting, alkalisation and pressing processes undertaken.

Biochemical composition of cocoa powder

Cocoa butter	11.0
pH (10% suspension)	5.7
Ash %	5.5
Water soluble ash %	2.2
Alkalinity of water soluble ash as K_2O in original cocoa %	0.8
Phosphate % (as P_2O_5)	1.9
Chloride % (as NaCl)	0.04
Ash insoluble in 50% HCl	0.08
Shell % (calculated to unalkalised nib)	1.4
Total nitrogen %	4.3
Nitrogen % (corrected for alkaloids)	3.4
Protein Nitrogen corrected for alkaloids x 6.25 %	21.2
Theobromine %	2.8

Health benefits of cocoa

1. **Vasodilatation:** The endothelium is a continuous, smooth, non thrombogenic surface of all blood vessels that exhibits a highly selective permeability in its healthy state. It synthesizes and releases a broad range of vasoactive substances. Functional impairment of the vascular endothelium in response to injury causes endothelial dysfunction associated with cardiovascular disease which is recognized as an early

event in the development of atherosclerosis, and is associated with decreased bioavailability of the vasodilator nitric oxide. It was concluded that the cardio-protective mechanisms, including vasodilation, is by the major polyphenols of cocoa, the epicatechin and catechin.

2. **Modulator effect of cocoa on platelet dysfunction:** Platelet dysfunction is another hallmark of atherosclerotic vascular disease. Interestingly, in addition to providing antioxidant vitamins, certain fruits and vegetables may also protect against thrombosis because of their high polyphenol content. Several studies have demonstrated platelet inhibitory properties of cocoa. Stearic acid, a saturated fat commonly found in chocolate, reduces mean platelet volume, an index of platelet activation, in humans.

3. **Inflammation and immune function effects:** Inflammation and increased oxidative stress promote endothelial dysfunction and atherogenesis. Nitric oxide normally inhibits nuclear transcription factor (NFkB), which binds to the promoter regions of genes coding for pro-inflammatory proteins such as cytokines and adhesion molecules. In endothelial dysfunction may be manifested decreased bioavailabilty of nitric oxide. Excess intracellular ROS in oxidative stress also activates NFkB. Cocoa flavonoids may prevent activation of NFkB and subsequent cytokine transcription by diminishing intracellular ROS.

4. **Impart insulin resistance:** Cocoa polyphenol influence directly insulin resistance and in turn, reduce the risk for diabetes. Cocoa may induce pancreatic β-cell regeneration and stimulate insulin secretion, have a hypoglycemic effect, and improve glucose tolerance.

5. **Blood pressure:** Raw cocoa is able to control the blood pressure level due to the antioxidant contained in cocoa which promotes the production of nitric oxide. This substance is essential in relaxing the blood vessel so heart is not forced to work too hard and the blood pressure could be controlled (Grassi *et al.,* 2008).

6. **Source of antioxidant:** Antioxidant has prominent role in fighting the free radicals that could cause some chronic diseases. Antioxidant found in raw cocoa is relatively higher even compared to green tea and red wine, however, dairy found in most chocolate product is blocking the absorption of antioxidant (Lee *et al*., 2003).

7. **For healthy brain:** Cocoa is also considered as super brain food due to the presence of rich flavanol, which is beneficial to maintain the healthy brain. Function of cocoa makes sure that the blood flow to brain and provide the oxygen so brain will function optimally.

8. **Control cholesterol:** The hypocholesterolemic effect caused by cocoa has significant effect in reducing the cholesterol level by rising the production of HDL and at the same time reducing the production of LDL that could cause some serious problems from heart problem up to the accumulation of blood clot in the artery.

9. **Reduce the level of triglycerides:** Many studies have shown that there is a significant reduction of triglycerides level for those who are currently consuming raw cocoa as part of their daily diet.

10. **In diabetes treatment:** Besides hypocholesterolemic, cocoa is also having hypoglycemic effect which affect the regulation of sugar in the blood stream. Cocoa could improve the insulin resistance so it is highly recommended for those who are currently suffering diabetes type 2 and at the same time improve the glucose metabolism to optimize the absorption.

11. **Inhibit cataract:** Cataract is one of the conditions that could be prevented naturally just by consuming cocoa. It is due to the proanthocynidins contained in cocoa that will help in inhibiting the formation of cataract.

12. **Asthma treatment:** Asthma is not only about respiratory issue but one of the effects of allergen reaction. Cocoa contains xanthine and theophylline which is valuable to cure various allergies.

13. **Promote wound healing:** Cocoa has therapeutic properties that are efficient to promote wound healing. It is due to cocoa is also able to fight infections that is could occur from a wound by eradicating the bacteria that caused it.

14. **For weight loss:** Processed chocolate could cause weight gain but the raw cocoa is surprisingly having an opposite effect which is very effective for weight loss. First, cocoa is able to shrink appetite so it is easier to control the diet and second cocoa is beneficial in improving body metabolism to make sure all nutrients are absorbed optimally to avoid the accumulation of excess and unnecessary properties.

15. **Anti-cancer:** As the natural source of antioxidant cocoa has role as anti-cancer preventing development of cancerous cells.

16. **Treatment of anemia:** Copper deficiency causes anemia and cocoa is a natural source of copper. It improve the haemoglobin level as well.

17. **Fight fatigue:** Oxidative stress cause fatigue. Cocoa has calming and attenuating effect that will release some neurotransmitters like anandamide, serotonin and phenylethylamine in the brain, which will combat the fatigue condition effectively.

18. **Prevent alzheimer:** Alzheimer occurred when brain cells are suffering from degeneration. As the natural trigger of neurotransmitter and natural source of antioxidant that could accelerate the cell regeneration, preventing alzheimer disease.

19. **Good for liver:** If not consumed daily, cocoa is good for liver since it is rich of fiber and capable of removing unnecessary properties from colon and function as natural detox in liver (McKim *et al*., 2002).

20. **Preventing blood clot:** Blood clot is accumulated in the artery that is the main cause of cardiovascular conditions because blood clot will disturb the blood circulation and once the blood circulation is disturbed heart will be forced to work harder and the oxygen distribution is not optimal. Cocoa will promote the production of HDL which will bind the blood clot and prevent the accumulation.

21. **Reduce the risk of stroke:** Stroke is one of the conditions caused when brain is not getting enough oxygen due to the disturbance of blood flow. Furthermore, cocoa has properties that act as anti-platelet like flavonoid, which will assist in reducing the risk of stroke attack.

22. **Mood booster:** Drinking a glass of hot cocoa assist in relieving stress. Cocoa contained flavonols, which are good for mood and has anti-depressant effect.

23. **For depression:** Cocoa has anti-depressant effect due to the flavanols as well as anandamide that is effective as mood enhancer. Cocoa could trigger the endorphin release which is the happy hormone.

24. **Treat chronic constipation:** Constipation that is not treated properly could lead to chronic constipation and cocoa could assist in treating this through its high fiber content. Fiber contained in cocoa will encourage a better bowel function by increasing the flow or bowel movements.

25. **Good for skin:** Since ancient time cocoa has been used to as part of skin treatment, it could decrease the side effect caused by UV ray and at the same time enhance the elasticity by making sure skin cells are hydrated and oxygenated and the antioxidant properties will promote the regeneration of new cells.

26. **Rich of magnesium:** Besides copper, cocoa is also rich of magnesium so it is also effective to treat all kinds of health conditions caused by magnesium deficiency. Furthermore, consuming it in daily basis will maintain human body from lacking of magnesium in long term.

27. **Healthy snack during PMS:** Pre Menstrual Syndrome (PMS) could cause mood swings that could be annoying sometimes because of drop in serotonin level. Consuming cocoa during PMS will provide the calming effect.

28. **Prevent premature aging:** Polyphenol found in cocoa is similar with antioxidant found in green tea, which already well known worldwide is able to prevent premature aging and make one feel younger.

29. **Energy booster:** A cup of hot cocoa in the morning is good to boost energy. It is because the magnesium in cocoa is able to optimize the function of oxygen and regulate blood pressure.

30. **Protection from osteoporosis:** All foods rich in magnesium are good for bone health and able to fight osteoporosis significantly and cocoa is one of the super food which top the lists.

31. **Prevent sunburn:** Consuming at least 20 g cocoa is less affected by UV ray and could stay two times longer than those who don't consume cocoa under direct exposure of sun without getting sunburn.

32. **Good for oral organ:** Processed cocoa has sugar ingredients which causes tooth decay but raw cocoa has the opposite effect and even more effective than fluoride in protecting teeth enamel.

33. **Treat coughing:** Theobromine found in cocoa is effective in treating cough.

34. **Improved memory:** A cup of cocoa boost the energy supply and improves the metabolism so oxygen will be distributed to the brain optimally to improved memory.

Cautions of Cocoa

1. **Caffeine in cocoa:** Cocoa like coffee provide energy in the morning with its caffeine content but should be consumed in moderation to have good night sleep.

2. **Kidney issue:** High content of magnesium may affect those who have kidney problems.

3. **Allergic reaction:** Allergic reaction may be checked in some people who are allergic with chocolate consumption through skin and sensitive stomach.

4. **Drug interaction:** Caffeine can interact with certain drugs which should be taken cautiously.

The investigations on the biochemical components, antioxidant, vasodilatory, blood-pressure lowering, anti-platelet, and anti-inflammatory effects of cocoa and chocolate provide exciting new evidence into the potential vascular benefits of polyphenol-rich foods. Balance and moderation are important in a healthy diet and must be considered in chocolate consumption also, which is high in calories and fat. Dark chocolates with more of cocoa solids play a major role in present day diet and these foods represent plentiful sources of polyphenol when relished in moderation with a healthy and active lifestyle will be good for our heart and general health.

References:

1. Lee, K.W., Kim, Y.J., Lee, H.J. and Lee, C.Y. 2003. Cocoa has more phenolic phytochemicals and a higher antioxidant capacity than teas and red wine. *J Agric Food Chem*. **51(25):**7292-5.
2. Andres-Lacueva, C., Monagas, M., Khan, N., Izquierdo-Pulido, M., Urpi-Sarda, M., Permanyer, J., Lamuela-Raventós, R.M. 2008. Flavanol and flavonol contents of cocoa powder products: influence of the manufacturing process**.** *J Agric Food Chem*. **56(9):** 3111-7.
3. McKim, S.E., Konno, A., Gäbele, E., Uesugi, T., Froh, M., Sies, H., Thurman, R.G. and Arteel, G.E. 2002. Cocoa extract protects against early alcohol-induced liver injury in the rat. *Arch Biochem Biophys*. **406(1):** 40-6.
4. Grassi, D., Desideri, G., Necozione, S., Lippi, C., Casale, R., Properzi, G., Blumberg, J.B. and Ferri, C. 2008. Blood pressure is reduced and insulin sensitivity increased in glucose-intolerant, hypertensive subjects after 15 days ofconsuming high-polyphenol dark chocolate. *J Nutr*. 138.
5. Naomi Osakabe, Megumi Yamagishi, Midori Natsume, Akiko Yasuda and Toshihiko Osawa. 2004. Ingestion of Proanthocyanidins Derived from Cacao Inhibits Diabetes-Induced Cataract Formation in Rats. *Exp Bio Med.* **229(1):** 33-39.

8. SOIL SAMPLING AND MANAGEMENT OF NUTRIENT DEFICIENCIES IN COCOA

Karthika, K.S. and Priya, U.K.

Soil sampling in cocoa gardens

Soil is considered to be the soul of infinite life. Understanding our soils in a better way would help in improving the crop yields. A sound soil test report is essential to understand the nutritional status and physical properties of soil restricting crop growth. Nutritional management practices based on soil test reports would help to overcome non judicious application of fertilizers and in turn would improve soil health, crop health and the yield. Accuracy of soil test reports depends largely upon the method of sampling. A fair sampling will provide accurate test reports. Due to the variability in soils it is impossible to devise a single method of sampling. Sampling method should be chosen according to the need.

Time of soil sampling

Soil samples for analysis should be collected preferably during April-May. Sampling immediately after heavy rains should be avoided.

Materials required for sampling

Soil auger or core sampler, polythene sheets or polythene covers, spade, marker pens, labels. Equipment used for sampling should be rust free and also free from any adhered soil, fertilizer or chemicals.

Soil sampling in existing plantations

- Trees should be selected in criss-cross manner in the field.
- Soil samples should be collected about 2 ft (60 cm) away from the base of the tree from both directions of the same tree, from two depths, 1 ft and 2ft respectively.
- Soil from each depth should be collected separately.
- Remove big stones and undecomposed organic matter from the samples.
- After mixing, divide the sample to four equal parts.
- Discard the opposite ones till sample quantity is half kilogram.
- Shade dry by spreading on paper or in plastic tray.
- Samples should be brought to the concerned laboratory in polythene bags.
- Label the soil collected from different areas and depths.

Spade method or V-cut method

In this method of soil sampling, a V cut is made with the help of a spade such that the spade penetrates at least 1 ft to 1.5 ft deep to the soil. A layer of soil is scraped along the V cut and the soil sample thus collected is used for analysis.

Soil sampling for new plantations

- Sampling should be done preferably from three different depths 1ft, 2ft and 3ft depths.
- Samples can be taken in criss-cross manner (or randomly) depending on the size of holding.
- Generally for one acre holding 10-20 samples can be collected and 5-10 composite samples can be made by mixing soils of same depths together.

Notes:

1. While sampling, care should be taken to avoid the immediate basin.
2. Weeds and litter should be removed with spade before inserting the soil auger.
3. Sampling in the borders, near to cow dung pits and fertilizer store houses should be strictly avoided.
4. The samples collected to prepare a composite sample should be from locations more or less of same topography, same soil colour and texture and moisture regime.
5. If not, samples should be collected separately from each stretch of plots that show variations like, plots at different elevation, soil colour, under intercropping or under different moisture conditions.
6. Samples taken from different sites and different depths should be separately kept to avoid mixing.
7. More the number of samples collected from the field more will be the accuracy in the fertility status.
8. Soil samples should not be kept in direct sun.
9. Soil sampling should be repeated once in three to five years.

Importance of leaf analysis

Leaf samples should be collected from palms/ trees from basin of which soil samples were collected to arrive at precise recommendations.

- Third mature leaf from tip should be collected.
- Collected leaf samples should be handed over to the concerned lab on the same day by placing in paper covers.
- If it is not possible, leaf samples must be placed in clean perforated plastic bags or brown paper bags and kept in refrigerator but not in freezer.

Nutrient disorders

Nutrient disorder can either be in form of nutrient deficiency or in terms of nutrient toxicity. Former is caused due to the inadequate level of nutrient supply from the soil arising due to reasons like improper, inadequate and unbalanced application of fertilizers or nutrient sources. Nutrient toxicity may be occurring due to injudicious application of fertilizers or due to certain soil physic-chemical conditions that prevail in the particular area like water logging or certain factors like soil pH.

Nutrient disorders can prima facie identify by the peculiar deficiency or toxicity symptoms that are exhibited by the cocoa plant. Nevertheless the actual disorder can be ascertained only with proper soil testing results that are obtained from soil testing laboratories. After identification of the actual deficient or the toxic nutrient, only the management should be undertaken in cocoa gardens.

Nutrient deficiency disorders

Nutrient deficiencies most common among major nutrients in cocoa gardens is with respect to potassium. Nitrogen and phosphorus deficiencies are seen in lesser frequencies in well maintained gardens compared to the occurrence of potassium deficiency. Deficiencies of secondary nutrients like calcium, magnesium and sulphur occur to a lesser extent in cocoa gardens. Calcium deficiency is one of the causes for cherelle wilt in cocoa. Foliar and soil application of calcium resulted in decreased cherelle wilt and increased number of cherelles carried to maturity. Disorders due to micronutrients are also reported in cocoa. Important micronutrient disorders reported are Zinc (Zn) and Iron (Fe) deficiencies. Of all these disorders, Zn deficiency is common in India. The earliest remedy for Zn deficiency is foliar spraying with a solution of 300 g of zinc sulphate and 150 g of lime in 100 litres of water. Spraying of 1 to 1.5% $ZnSO_4$ can correct the deficiency symptom. For Boron deficiency monthly spraying of Solubor is recommended. For Iron deficiency foliar spraying with 1% aqueous iron sulphate shows correction of symptoms.

Deficiency and toxicity symptoms of different nutrients

Visual symptoms of nutrient deficiency can also indicate the fertilizer requirement of cocoa. Several studies have been conducted to know the symptoms of nutrient deficiency and toxicity. Based on these works Murray (1975) has given simple key for identification of symptoms.

Symptom appearance in cocoa plants

Whole plant		Older leaves		Young leaves	
Deficient	**Toxic**	**Deficient**	**Toxic**	**Deficient**	**Toxic**
Nitrogen Sulphur Phosphorus	Boron	Calcium Magnesium Potassium	Aluminium Chlorine Iron	Iron Manganese Copper Zinc Boron Molybdenum Calcium	Zinc Manganese Copper

Nutrient deficiency symptoms in cocoa

Nutrient	Deficiency symptoms
Nitrogen	Leaves are pale yellow in colour, reduced in size, older leaves showing tip scorch and petioles showing acute angle with stem.
Phosphorus	Plant somewhat stunted in growth, mature leaves paler towards tip and margin, followed by tip and marginal scorch. Young leaves markedly reduced in size, stipules frequently persisting after leaf abscission, young leaves showing acute angle with stem.
Potassium	Pale yellow areas formed in interveinal region near leaf margin, quickly becoming necrotic but only fusing with each other after some time, progress of marginal necrosis much more rapid between veins, yellow zone on inner surface of invading necrotic zone.
Calcium	Necrotic areas commencing in interveinal region near leaf margin quickly fusing into continuous marginal necrosis of older leaves. No necrotic lesions in advance of main marginal necrotic zone, unaffected area showing oak leaf pattern.
Magnesium	Necrotic areas commencing in interveinal region near leaf margin, quickly fusing into continuous marginal necrosis of older leaves. Prominent bright yellow zone in advance of necrotic area and islands of necrotic tissue often appearing in advance of main wave of necrotic tissue. Unaffected areas of the leaf paler green than usual and forming oak leaf pattern.
Sulphur	Leaves of whole plant pale yellowish or yellowish green in colour, but no marked reduction in size. Yellow blotches on older leaves. New flush leaves normal in size, at first bright yellow in colour with no green associated with the veins, later becoming pale yellowish green as in older leaves.
Iron	Younger leaves showing darker green veins against paler green background, or showing green tinted veins against pale yellowish white or almost completely white ground, developing tip scorch.

	Symptoms less marked in leaves of previous flush-older leaves frequently showing narrow marginal and tip scorch.
Manganese	Younger leaves pale yellowish or yellowish green, later developing blurred chlorotic pattern in which the tissues in the vicinity of the midrib, main laterals and tertiary veins are prominently green against pale background, followed by scorching of the tip and distal margin.
Copper	Leaves on young flush small but normal in shape, young shoots frequently showing signs of wilting. Sudden collapse of tissues at tip of leaf, collapsed tissues remaining green for some time, later forming brown edge with apex directed towards midrib. No marked chlorotic pattern.
Zinc	Very young leaves showing prominent dark red veinlets with considerable distortion, leaf very narrow in proportion to length, margin often wavy and leaf sometimes sickle-shaped with small chlorotic patches in distinct row on each side of midrib and main lateral veins.
Boron	Young leaves reduced in size, pale, hardening with marked reflexed curvature and/or spiral twisting, thick to the touch and brittle; old leaves of healthy appearance.
Molybdenum	Young leaves thin and translucent, developing mild chlorotic mottling more marked in interveinal region, later developing marginal scorch.

Nutrient toxicity symptoms in cocoa

Nutrient	Toxicity symptoms
Boron	Older leaves showing pronounced marginal scorch and necrotic areas in vicinity of wounds, younger leaves cupped downwards, showing green in vicinity of veins, with broad chlorotic interveinal areas later greening slightly and developing necrotic tip and margin.
Aluminium	Paler or yellowish areas in the interveinal region of the distal end (tip) of leaf with tip scorch progressing very slowly. Rarely, some blackening of the interveinal region towards the base of the leaf. All symptoms confined to older leaves only.
Chlorine	Pale yellow areas developing in the marginal interveinal regions quickly fusing to form a continuous scorch, advancing more rapidly in interveinal areas. Tissues in advance of scorched area showing various shades of dark green and grey. Scorch proceeding slowly and necrotic areas in vicinity of wounds. This can be confused with the calcium deficiencies above.
Iron	Pale yellow zone on each side of the midrib of older leaves, rapidly spreading necrotic areas formed in vicinity of wounds, no marginal or tip necrosis.
Zinc	Young leaves showing olive green appearance or pale green areas scattered over surface of leaf.

Manganese	Youngest mature leaves showing irregular pale green or yellowish areas on darker green background with or without some veinal necrosis, no tip or marginal scorch and no symptom on older leaves.
Copper	Young leaves showing dark olive green colour with upraised veinlets and puckering of lamina along midrib. Younger mature leaves showing pale green areas distributed at random over leaf surface.

Nutrient Management

Fertilizer application should be carried out according to soil test reports. Balanced application of fertilizers 100:40:140 g of N, P_2O_5 and K_2O per plant for a year in two split doses during April-May and September-October for fully grown rain fed tree.

The degree of symptom expression and correction largely depends upon the method, time of application and also the frequency of application. These parameters can only be suggested by detailed soil and plant tissue analysis and other field parameters. Above listed are the most common disorders that are seen in major cocoa growing tracts of India. Certain field specific disorders may rise in plantations that may show similarities with above said symptoms and hence practicing the management measures should be taken only after following standard soil testing.

9. INTEGRATED DISEASES MANAGEMENT IN COCOA

R. Thavaprakasa Pandian, M. Chaithra and P. Chowdappa

Cocoa production is severely hampered by several biotic and abiotic factors which directly or indirectly ruining the quality and quantity of cocoa beans. Among that, diseases play a crucial and inevitable role in reduction of cocoa yield. Diseases of cocoa account for more than 30 per cent of the potential yield losses. In India, a detailed survey of cocoa gardens was conducted in Kerala, Karnataka, Tamil Nadu and Andhra Pradesh states from 1980 onwards revealed that diseases like seedling blight, black pod, stem canker, cherelle wilt and vascular streak die-back (VSD) can be considered as the major problems in India based on the extent of damage and nature of disease (Chandramohanan and Kaveriappa, 1981; Chowdappa *et al*., 2014). Among them, black pod disease is considered as a serious concern across the cocoa growing nations (Chowdappa, 1995). An outline of different cocoa diseases and/ or disorders along with the management strategies are summarized below.

A. Diseases in cocoa:

1. Seedling dieback/ seedling blight (*Phytophthora palmivora* Butler)

Seedling dieback or seedling blight is very common in cocoa nurseries of Kerala, Karnataka and Tamil Nadu during rainy season. Younger seedlings are highly susceptible to the disease.

Symptoms:

Defoliation and dieback are the characteristic symptoms of this disease. Infection starts from the tip of the stem and proceeds downwards as dark brown to black water-soaked linear lesions. Infection spreads to the entire stem causing wilting, defoliation and ultimate death of the seedlings. Infection also noticed in grafted or budded region and proceeds on both the sides.

Management:

- Field sanitation practices like removal and destruction of infected seedlings should be strictly followed.
- Sowing seeds before the onset of monsoon will reduce the disease. Also providing improved drainage and proper shade helps in disease management.
- Solarisation of potting mixture under hot sun or covering with transparent polythene sheets during summer months kills the pathogen inoculum.
- Bio-priming of cocoa seeds with 20 g *Pseudomonas* microbial culture is also effective in managing the disease.

- Soil drenching with Bordeaux mixture (1%) or copper-oxy-chloride (0.2%) just before the onset of monsoon and thereafter at frequent intervals provides good control over the pathogen.

2. Black pod disease or pod rot (*Phytophthora* spp.)

Black pod disease or pod rot was noticed in Guyana and West Indies and referred as black cocoa. In India, black pod was first reported in 1965. Annual losses due to black pod may ranges from 30 to 90 per cent. Black pod disease occurs during rainy season when humidity is high and the temperature is constantly optimum. In India, it occurs in all the cocoa growing areas of south India during the South-West monsoon period and the maximum incidence occurring in July-August.

Phytophthora is an oomycetous hemi-biotrophic plant pathogen with a wide host range and vast distribution. Previously, all the isolates of *Phytophthora* from cocoa were classified as *P. palmivora*. This species has been recognized as one of the most important pathogens in the tropics attacking many plantation crops, including cocoa, rubber, black pepper, coconut, pineapple, citrus, avocado, papaya, as well as many ornamental plants. *P. palmivora* is present in most countries and is an important part of the black pod complex, while *P. megakarya* is present in several countries in West Africa. However, *P. megakarya* appears to be more virulent than *P. palmivora* and is becoming dominant species in West Africa, moving from Nigeria and Cameroon into countries where it has not been reported previously. In the major cocoa-growing region of Bahia, Brazil, three species have been implicated: *P. palmivora*, *P. capsici* and *P. citrophthora*.

Symptoms:

Pods or cherelles (immature pods) may be infected at any place on the surface, but infection is most often initiated at the tip or stem end. The disease causes a firm, spreading, chocolate-brown lesion that eventually covers the whole pod. Pods damaged by rodents/ insects or injured while harvesting, pruning or cultural operations are more prone to infection by the pathogen. The beans inside the pod may remain undamaged for several days after initial infection of the husk, thus frequent harvests may prevent much yield loss. The beans in the infected pods approaching ripeness may escape from infection because they are separated from the husk on ripening.

In advanced infections, a whitish growth of the fungus is produced over the affected pod surface, after 15 days of infection *Phytophthora* invades the internal pod tissues, causes discoloration and shrivelling of the cocoa beans. The whole pod turns chocolate-brown to black colour, hence the name ‘black pod disease’. Diseased pods eventually become black and mummified. Pods which are touching the soil surface get infected directly. Therefore, the disease spread from pods at the lower part of the trunk to the upper part.

The disease develops faster in moist and rainy conditions. It is especially serious in dense farms with heavy shade. During dryer seasons, the disease survives in rotten, dried pods (mummies) and in cankers. The fungus also survives in soil in the form of resting spores (Oospores). Spreading of spores can happen through raindrops falling from sporulating infected pods to pods lower on the tree or rain splashes from infested pods or spores on the ground surface near the tree, or through activities of insects such as ants, or rodents such as rats or squirrels.

Management:

- Strict field sanitation practices include phytosanitation, removal and destruction of infected pods and fallen leaves should be followed.
- Regular pruning of the branches should be carried out in order to facilitate the entry of sun light.
- Prophylactic spraying of Bordeaux mixture (1%) at 45 days interval starting from the onset of south- west monsoon helps in reduction of disease incidence.

3. Stem canker (*Phytophthora* spp.)

Symptoms:

On the bark area, round to oval shaped dark brown discoloration will be formed. Later reddish brown colour oozing will comes from the infected area. Advanced stage of infection results in girdling of infected stem. If infection noticed at the collar region, it spreads fast and infects the root system. Hence, water and nutrient uptake will be severely impaired. Yellowing and wilting of the foliage will be noticed under severe infection.

Management:

- Strict field sanitation practices should be followed as described earlier.
- Pruning before the onset of monsoon and application of 10 per cent Bordeaux paste after pruning will avoid the infection.
- In case of mulching practices, trunk covering should be avoided or mulching 1 foot away from the trunk helps in disease reduction.
- Good drainage facilities should be provided to avoid further spread of the disease.
- Wound treatment and soil application with *Trichoderma* coir pith cake (TCPC), helps in long term management of the disease.

4. Cherelle wilt

Symptoms:

Large number of cherelle or young pods of 2-3 months old will dry up and remain on the trees as mummified fruit. February-May considered as critical period for infection. Two kinds of cherelle wilts are observed *i.e.* physiological and pathological wilt.

Physiological wilt: It is due to the effect of the natural thinning mechanism of cocoa. The physiological wilt begins as general yellowing followed by browning and blackening of the entire pod.

Pathological wilting: It is caused by *Colletotrichum gloeosporioides.* Initially, small, circular water-soaked lesions will be noticed on anywhere of the stalk/ pod surface. Later, it spreads towards the tip of the pod. Sunken spots with diffused yellow halo will be observed in advanced stage of infection. Also pinkish slimy mass will be produced on the lesion and mummified pods.

Management:

- Strict field sanitation practices should be followed.
- Fungicidal spraying with carbendazim @ 0.05% or mancozeb @ 0.2% was found effective in managing this disease.

5. Vascular streak dieback (*Oncobasidium theobromae)*

Symptoms:

Yellowing of one or two leaves generally on the second or third flush behind the shoot apex with typical scattered green islands is the most distinguishable feature of this disease. Affected leaves dry and falls off by leaving the other leaves remain intact. The disease can easily be diagnosed in the field by splitting the diseased stem to observe the longitudinal brownish streak due to infection of xylem vessels by the pathogen.

Management:

- Strict field sanitation practices like removal and destruction of the diseased plants, burning of the fallen leaves etc. should be followed to avoid the inoculum build up.
- Pruning of infected branches from 30- 40 cm below the infected region and applying 10 per cent Bordeaux paste will help in disease spread.
- Prophylactic spray of 1 per cent Bordeaux mixture or 0.25 per cent copper-oxy-chloride (COC) twice a year during May- June and October months helps in effective disease management. Soil drenching with 0.25 per cent COC will reduce the inoculum build up in the soil.

6. Charcoal pod rot (*Botryodiplodia theobromae)*

Charcoal pod rot disease occurs throughout the year but becomes severe during summer months. It is more in wounds caused by rodents, insects and other pests. Pods of all ages are susceptible to this disease.

Symptoms:

The symptoms initially appear as pale yellow spots originating from the stalk end or at the tip of the pod. As the disease advances, the spots turn dark brown to black colour on the pod surface. In due course, the complete pod develops a black sooty appearance and remains on the tree as mummified fruit. The internal tissues are rotten and the affected beans turn black.

Management:

- Spraying of Bordeaux mixture (1%) to the pods during summer months can manage the disease.
- Measures to control insects and rodent pests will also help in reducing the incidence.

7. Pink disease (*Pellicularia salmonicolor)*

The disease occurs during humid conditions. Fan branches and small twigs are generally affected. Humidity and temperature are critical for disease development.

Symptoms:

The first indication of the disease starts with death of the branches**.** It is characterized by the presence of a pinkish powdery coating on the stem. It causes wilting of shoots, shedding of shoots and 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.

Management:

- Proper pruning of canopy and trimming of smaller infected branches will improve the aeration of the garden and further reduce the disease incidence and intensity.
- The disease can be prevented by swabbing the cut ends with Bordeaux paste and spraying regularly with 1 per cent Bordeaux mixture.

8. White thread blight (*Marasmius scandens)*

White thread blight is prevalent in some of the gardens in Kerala and Karnataka states. It is severely under conditions of heavy rainfall and high humidity.

Symptoms:
The white mycelial threads of the fungus spread longitudinally are irregularly placed along the surface of the young stem or branches. Growth of the fungus is very rapid

under favourable condition and the infection enters leaf lamina along the petioles. The affected leaves turn dark brown. These dead leaves eventually get detached from the stem but are found suspended by the mycelial thread. The extensive death of the young branches and suspended leaves are the common field symptom.

Management:

- Removal of dead material and pruning of the affected parts can be useful in managing the disease.
- Removal of heavy shade and structural pruning of the branches may help to reduce the disease incidence to a greater extent.

B. Integrated disease management (IDM)

Diverse diseases of cocoa impart steady decline in production and a reduction in bean quality in almost all the cocoa-producing areas in the world including India. The most immediate answer to the disease problems is to follow good farming practices, biological control methods, crop sanitation to remove diseased material as a source of inoculums, and cultural practices such as shade optimization, pruning, and soil fertility management and the rational or minimal use of chemicals that could be used for IDM. IDM approaches should be strictly followed under cocoa cultivation to get economic and potential yield (Chowdappa and Rohini Iyer, 2000). In a nutshell, the IDM practices could be recommended for cocoa cultivation is given below:

- Use of disease resistant or tolerant cocoa accessions against *Phytophthora* diseases like black pod and stem canker.
- Use of disease free planting materials like seed pods, seedlings and bud wood/ scion stick collected from disease free regions and mother trees.
- Following strict quarantine measures to avoid or restrict the movement or spread of the infected germplasm from diseased to healthy areas.
- Following field sanitation practices includes regular removal and burning of the infected or dead plants and removal of diseased branches, pods to eliminate the initial source of inoculum especially in the high rainfall and humid zones.
- Providing improved drainage facilities and proper shading to the growing plants in the nursery as well as in the garden.
- Systematic annual pruning in the palm based cropping systems will considerably reduce the incidence, infection and spread of diseases.
- Use of biological control agents like *Trichoderma* coir pith cake (TCPC) against *Phytophthora* disease like stem canker.
- Use of chemical sprays like 1 per cent Bordeaux mixture or 0.2 per cent copper oxychloride against the *Phytophthora* diseases like black pod, stem canker and seedling blight; 0.05 per cent Bavistin WP (carbendazim) or 0.2 per cent Indofil M-45

(mancozeb) against *Colletotrichum* causing cherelle wilt disease; Ergosterol biosynthesis inhibitors like Propiconazole, Tebuconazole and Triadimenol against VSD disease.

References:

1. Chandramohanan, R. and Kaveriappa, K.M. 1981. Occurrence and distribution of cocoa diseases in South India. In: *Proc. 8th International Cocoa Research Conference*. 18-23, Oct., 1981. Cartagena, Columbia. pp. 445-449.
2. Chowdappa, P. 1995. *Phytophthora* causing black pod disease of cocoa in south India, PhD. Thesis. Mangalore University, Mangalore. 211 p.
3. Chowdappa, P. and Rohini Iyer. 2000. Integrated management of cocoa diseases in India. In. Proc. INCOPED 3rd International Seminar on cocoa pests and diseases, 16-17 October, 2000, Kota Kinabalu, Sabah, Malaysia (eds. Bong C.L., Lee, C.H and Shari F.S.) pp.84-104.
4. Chowdappa, P., Sharma, P., Anandaraj, M., and Khetarpal, R.K. 2014. *Diseases of Plantation crops.* Indian Phytopathological Society, IARI, New Delhi.

10. INTEGRATED PESTS MANAGEMENT IN COCOA

Shivaji Hausrao Thube and Saneera, E.K.

Recently cocoa cultivation has been facing threat due to several factors, *viz*., pests and diseases, inadequate irrigation, climate change, lack of quality planting material, improper management, etc. Among these, incidence of insect pests and diseases are key factors for low production and productivity of this crop. Integrated pest management is one of the critical components in health management of cocoa. More than 50 insect pests infesting cocoa are recorded in India (Mariamma Daniel, 1994). The major insect pests and vertebrate pests infesting cocoa are described in this chapter.

1. Tea mosquito bug (*Helopeltis* spp.)

As cocoa is introduced in the areas where cashew was the main plantation crop and gradually cashew was replaced by cocoa, tea mosquito bug (TMB) extend its host range and created havoc in cocoa. In recent past TMB is emerged as major pest with responsible for causing huge qualitative and quantitative loss in cocoa. The important species of tea mosquito bug found in the Asian region is belongs to genus *Helopeltis* (*H. antonii*, *H. theivora* and *H. bradyi*) and it is distributed in Sri Lanka, Indonesia, Malaysia and India (Thube *et al*., 2016). *Helopeltis theivora* prefers cocoa pods (Miller, 1941) but will occasionally oviposit on young shoots.

Symptoms:

Both nymphs and adults suck the cell sap from the younger shoots, cherelles and pods. The injury made by the suctorial mouth parts of the insect cause exudation of a resinous gummy substance from the feeding punctures. Sucking of cell sap from plant parts result into the formation of black necrotic lesion. Advanced stage of infestation may lead to die back of shoots and scorchy appearance of garden. Incidence of TMB is positively correlated with average monthly temperature. Cherelles and younger pods are more preferred for feeding as well as oviposition than the shoots and mature pods. Hence population of TMB is highly depended on the phonological stages of cocoa *i.e*. more the younger pods in field more the TMB population.

Management:

- Shade regulation by regular pruning is one of the important cultural operations for managing TMB incidence.
- Removal and destruction of alternate host such as neem, guava, cashew etc. from immediate vicinity of cocoa.
- If pest incidence is severe then spray any of the following insecticides: Lamda cyhalothrin 5 EC (0.003%) 0.3 ml/L (or) Imidacloprid 17.8 SL 0.3 ml/L.

2. Mealy bugs (*Planococcus lilacinus, P. citri* and *Paracoccus marginatus*)

Mealy bugs are emerging insect pest of cocoa in India which is mainly confined during summer season.

Symptoms:

All the stages of this insect are covered with white mealy coatings and can be noticed in colonies. Nymphs and adult females of mealy bug suck the sap from growing shoots, terminal buds, flower stalks, foliage and pods. Flower development and pod setting can be severely affected if infestation initiated during flowering stage. Reduction in the size of pod is common in severely affected gardens. Seedlings and young plants colonized by the mealy bugs show retarded growth and excessive branching at undesired height. They also cause cushion abortion and wilting of cherelles if infestation persists in the flowering stage. Excessive feeding on different plant parts results into the secretion of honey dew. The red ant, *Oecophylla smaragdina* is usually associated with the pest due to the presence of honey dew which encourages the phoretic behaviour and shielding the pest from predators.

Management:

- Encourage the conservation of natural enemies like *Acerophagus papayae*, *Aenasius arizonensis*, *Pullus* sp. as well as *Spalgius epius* for bio-suppression of mealy bugs.
- Common management practices includes, spot application on the pest colony with 0.5% neem oil emulsion along with 5% soap solution two-times at fortnightly intervals or
- Need-based application of Imidacloprid 17.8 SL @ 0.3 ml/L of water with 5% soap solution.

3. Aphids-Citrus black aphid (*Toxoptera aurantii)*

This is one of the polyphagous insect pest attacking on tropical and sub-tropical fruit and shade trees belonging to different families including Mango, Annona, Citrus, Coffee, Ficus, Camellia etc.

Symptoms:

This dark brown to black aphid colonizes the tender leaves, shoots, flower cushions, flower buds and small cherelles. Severe feeding results in crinkling of leaves and shedding of flower buds. On flowers, they colonize the flower stalks. Aphid colonies are found throughout the year on cocoa plants, but highest infestation is noticed from July to January months. Damage caused due to this pest is very negligible.

Management:

- More number of natural enemies exists in cocoa ecosystem that exerts natural check. Spot application of Dimethoate at 1.6 ml/L of water is suggested if infestation is severe.

4. Stem Borer (*Zeuzera coffeae)*

Symptoms:

The symptoms of attack are a round hole on the stem, drying up of the upper portions of above the hole and excreta and chewed up fibres strewn out on the ground. Grubs tunnel the bark initially 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. Infestation is quite severe where cocoa is planted in forest cleared tracts or planted near forest zones.

Management:

- Mechanical collection/ destruction of grubs by using iron hook from the affected branches.
- Swab Coal tar + Kerosene @ 1:2 (basal portion of the trunk-3 feet height) after scraping the loose bark to prevent oviposition by adults.
- Dip the cotton in Chlorpyriphos 20% EC, insert it in the entry hole and plaster the hole with mud

5. Castor shoot and capsule borer (*Conogethes punctiferalis)*

Symptoms:

It was reported as a minor pest with 2% incidence during 2012-13 (Alagar, 2013) but recently gaining key pest status. Caterpillar after hatching from the eggs feeds on rind of cocoa pods later bore and feed the internal contents of the pods. Extrusion of the granular faecal pellets through the bore holes can be visible**.** If surface of the pod is rough and more than one pod touches together level of infestation will be more.

Management:

- Collection and destruction of infested pods.
- Planting preferred hosts such as castor along the border as a trap crop.
- As this pest is flare up recently no chemical/ insecticide evaluated against this pest in cocoa ecosystem. But, if infestation is severe then chlorantraniliprole 20

SC @ 0.006% or indoxacarb 14.5 SC @ 0.015% can be sprayed as this chemical is recommended against *C. punctiferalis* in caster (Patel and Borad, 2016).

6. Leaf eating caterpillar (*Lymantria* spp.)

Symptoms:

The caterpillars feed voraciously on leaves by making silken webs. The early-instar larvae feed on leaves or the surface tissues of growing pods during day and night, but later instar caterpillars are nocturnal in habit. Their population increases after the monsoon rains. Population of this caterpillar is directly proportional to green foliage of tree.

Management:

- If the damage is very severe spraying of neem oil (0.5%) is recommended.

7. Vertebrate pests

Some vertebrates had successfully adapted to cocoa trees wherever the tree is introduced and cultivated. These include rats, squirrels, palm civets and birds and they inflict direct loss of the crop by feeding on and damaging the pods. Out of these rats and squirrels are major vertebrate pests in south India.

Rodents and Squirrels:

Symptoms:

Rats (*Rattus rattus*) and squirrels (*Funambulus trisriatus* and *F. palmarum*) are the major vertebrate pests of cocoa. They cause serious damage to the pods. The rats usually gnaw the pods near the stalk portion whereas squirrels gnaw the pods in the centre. The rats are known to damage the mature as well as immature cocoa pods whereas, the squirrels damage only the mature ones. They gnaw the pods and feed on the mucilage covering of the beans. Squirrels are diurnal and rats are nocturnal in habits.

Management:

- Only the cooperative efforts of plantation owners/ small farm holdings can achieve management of rodent population. Otherwise the local trials done by individual farm owners have no impact on the population levels of rodents especially rats.
- The rats can be kept under check by keeping 10 g Bromadiolone (0.005%) wax cakes on the branches of cocoa trees twice at an interval of 10-12 days.

- Squirrels are best controlled by trapping with wooden or wire mesh single catch 'live' trap with ripe coconut kernel as the bait. The success is more if trapping is carried out during the lean periods of the crop (October-November) and when the alternate foods such as paddy, cashew apples, mangoes and jackfruits are not available.
- Timely harvest of the pods as well as maintaining proper plant density will help in increasing the efficiency of poison baiting as well as trapping.

IPM-Package for managing Pests of Cocoa

In layman's language Integrated Pest Management (IPM) is nothing but management of any insect pest by utilizing all available pest management tactics in compatible and sustainable manner which maintains the pest population at level below that causes economic injury to plant. It includes cultural control, mechanical control, physical control, biological control, host plant resistance and if needed chemical control also. All these pest management tactics for managing pests of cocoa described below.

a) Cultural and Mechanical control:

- Maintain a healthy and balanced ecosystem to preserve natural enemies that kill/ manage pest population naturally.
- Planting/ growing of tolerant or resistant varieties which can sustain and produce well under heavy insect pest incidence.
- Plant a barrier crop that is not attractive to stem borers, such as: *Leucaena glauca*, cocoyam, sweet potato or *Pueraria* species. The barrier must be at least 15 m wide and established early for new plantings.
- Maintain a complete canopy: in young plantings, temporary shading is needed, *e.g*. with bananas and plantains. Alternative hosts of any insect pest of cocoa should not be used as shade trees on cocoa farms.
- Remove chupons regularly because mirids are attracted to the young and soft shoots that cocoa trees grow throughout the season. Chupons that emerge at the base of trees should be prune regularly, not just during the peak mirid season. Do not prune too heavily as this may stress the trees and cause the growth of new chupons, which increase TMB feeding.
- Regular and complete harvesting of pods is almost certainly the most effective cultural technique of reducing carry over stages of insects like pod borer etc.
- Removal and destruction of stem borer infested branches can reduce the incidence of this pest.
- Hand picking and destruction of pod borer infested pods is important strategy to manage cocoa pod borer (*Conogethes punctiferalis*).
- Rat traps and nooses are popular, but of little effective for lowering populations: a combination of good practices is most likely to be successful. These must be implemented over large areas as rodents reproduce and spread quickly. Areawide/

community based management of rodents will always effective than individual farm wise management.

- Squirrels are best controlled by trapping with wooden or wire mesh single catch 'live' trap with ripe coconut kernel as the bait.

b) Biological Control:

Since cocoa is not under regular sprayings of any kind of pesticides in most of the cocoa tracts of south India, it must be implied that the native natural enemies are exerting a good control of the insect fauna of the trees. The native natural enemies of cocoa pests include predators, parasites, insect pathogens and generalist predators like spiders, reduviids, some coccinellids etc. Since organic cultivation is gaining importance and to safeguard the environment biological methods to be followed.

- Mealy bug in cocoa can be managed by enhancing natural population of its natural enemies like coccinellid, *Pullus* sp. and a lycaenid, *Spalgis epeus.*
- Aphid can be managed by predators like syrphids, hemerobiid, a chrysopid, a cecidomyiid and an endoparasitic cecidomyiid. Among these two s two species of syrphids *viz; Dideopsis aegrotus* (Fab.) and *Paragus yerburiensis* Stuck. Are key predators of this aphid.
- The chrysopid, *Ankylopteryx octopunctata* is a general predator feeding also on other cocoa insects like the nymphs of *Helopeltis* spp. treehoppers etc.
- The black ant (*Dolichoderus thoracicus*) has been used in some farms for managing TMB.
- *Telenomus spp.* is one of the important egg parasitoid of TMB.

c) Chemical control:

In any IPM programme insecticide should be the last resort/ option for pest management. If all of above described management tactics fails to manage pest population below economic injury then only chemical control strategy should use. Insecticides are widely used and effective: especially when timed correctly (often early in the season). If possible, only spray those areas in the farm that are attacked by insect pest (spot application). Careful and well timed application can help farmers to save money by using less insecticide, and decrease impact on natural enemies of this pest.

- Spraying any one of following insecticides for management of sucking pests *viz*., Lamdacyhalothrin 5 EC (0.003%) 0.3 ml/L (or) Bifenthrin 10 EC (0.008%) 0.8 ml/L (or) Imidacloprid 17.8 SL (0.004%) 0.25 ml/L.
- Stem borer can be effectively managed by swabbing of Coal tar + Kerosene @ 1:2 (basal portion of the trunk- 3 feet height) after scraping the loose bark to prevent oviposition by adults.

- 0.5% neem oil emulsion + soap suspension two-times at fortnightly intervals or need-based application of Imidacloprid @ 0.3 ml/L of water or Dimethoate 30 EC @ 1.6 ml/L of water can be used to manage mealy bugs effectively.
- Rats can be kept under check by keeping 10 g Bromadiolone (0.005%) wax cakes on the branches of cocoa trees twice at an interval of 10-12 days.

References:

1. Alagar, M., Rachana, K.E., Kesava Bhat, S., Shafeeq Rahman and Rajesh, M.K. 2013. *Journal of Plantation Crops* **41(3)**: 350-356.
2. Mariamma DanieI. I994. Pests of Cocoa. In - *Advances in Horticurture* Vol. 10. Plantation and Spices Crops. part 2 (eds. Chadha, K.L and. Rethinam, P). Malhotra publishing House, New Delhi. pp 743-758.
3. Miller, N.C.E. 1941. Insects associated with cocoa (*Theobroma cacao*) in Malaya. *Bulletin of entomological Research* **32**: 1-15.
4. Patel, R.D and Borad, P.K. 2016. Bio-efficacy of insecticides against *Conogethes punctiferalis* on castor. *International Journal of Plant Protection* **9(2)**: 409-412.
5. Thube, S.H., Saneera, E.K. and Prathibha, P.S. 2016. Pests of cocoa and their management. *The Cashew and Cocoa Journal: Special Issue on Cocoa* **4**: 34-38.

11. SAFE USE OF PESTICIDES FOR PLANT HEALTH MANAGEMENT

Shivaji Hausrao Thube and R. Thavaprakasa Pandian

Farmers have the challenge to produce food for an estimated 9.1 billion people expected to inhabit the earth by 2050. Crop losses due to pests and diseases are the major threats to incomes of rural families and to food security worldwide (Savary, 2014). About 20-30 per cent agricultural produce is lost annually due to insect-pests, diseases, weeds and rodents, which in monetary term equals to Rs. 1,00,000 crore (Oerke, 2006).

Pesticide usage is an immediate and effective way for reducing losses caused by different pests like insect, diseases, nematodes, weeds etc. A pesticide is any chemical substance or mixture produced with the intent of eliminating, preventing, repelling or decreasing the population of one or more pests. The consumption of chemical pesticides in the country has increased over the past few years, from 55,540 tonnes in 2010-11 to 57,353 tonnes in 2014-15 (http://agricoop.nic.in/imagedefault/state_agri_1516.pdf). Crop-wise pesticides consumption in India showed that cotton contributes maximum with 50% followed by paddy with 18% (Fig. 1). Among pesticides category, insecticides alone contributes 65% usage followed by fungicides with 15% (Fig. 2). Over this period, the imports of pesticides also increased from 53,996 tonnes to 77,376 tonnes. Issues pertaining with the use of pesticides include use of low-quality pesticides and lack of awareness about pesticide use.

The Economic Survey (2015-16) noted that the use of pesticides without proper guidelines has led to an increase in the pesticide residues being found in food products in India. No doubt pesticides are reliable source to keep the pest population below economic threshold but if used injudiciously, they may pose serious health hazards to human beings, domestic animals, natural enemies of crop pests and other forms of life through unwanted contamination of food, feed, water bodies and environment. Development of resistance in insect-pests against pesticides, pest resurgence, secondary pest out-break and increase in cost of production due to high cost of pesticides are other disadvantages associated with injudicious use of pesticides.

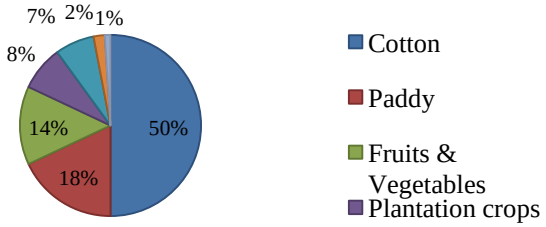

Fig.1. Crop-wise pesticide consumption in India
(Source: Industry reports, Analysis by Tata Strategic)

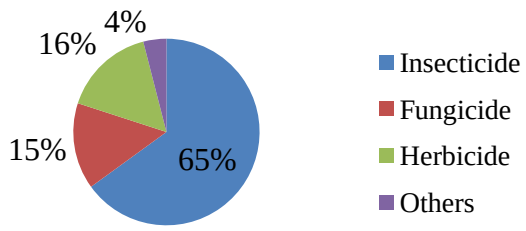

Fig.2. Share of different pesticides in India
(Source: Industry reports, Analysis by Tata Strategic)

Pesticides classification:

Based on their intended use or targeted pest organism, pesticides are classified as follows:

- Insecticides : Controlling insects
- Algicides : Control algae in lakes, canals, etc.
- Ovicides : Kill eggs of insects and mites
- Acaricides : Controlling mites
- Nematicides : Controlling plant parasitic nematodes
- Molluscicides : Controlling snails and slugs
- Rodenticides : Controlling rodents
- Fungicides : Controlling phytopathogenic fungi
- Bactericides : Controlling phytopathogenic bacteria
- Herbicides : Controlling weeds

Pesticide Toxicity

The toxicity of a pesticide is a measure of its capacity or ability to cause injury or illness. Toxicity is usually divided into following two types.

1. Acute Toxicity

Acute toxicity of a pesticide refers to the chemical's ability to cause injury to a person or animal from a single exposure, generally of short duration. The harmful effects that occur from a single exposure by any route of entry are termed acute effects. Acute toxicity is measured as the amount or concentration of a toxicant required to kill 50 percent of the animals in a test population. This measure is usually expressed as the LD50 (lethal dose 50) or the LC50. The lower the LD50 or LC50 value of a pesticide product, the greater its toxicity to humans and animals. Pesticides with a high LD50 are the least toxic to humans if used according to the directions on the product label.

2. Chronic Toxicity

The chronic toxicity of a pesticide is determined by subjecting test animals to long-term exposure to the active ingredient. Any harmful effects that occur from small doses repeated over a period of time are termed chronic effects. Suspected chronic effects from exposure to certain pesticides include birth defects, toxicity to a foetus, production of benign or malignant tumors, genetic changes, blood disorders, nerve disorders, endocrine disruption and reproduction effects. The chronic toxicity of a pesticide is more difficult than acute toxicity to determine through laboratory analysis.

Pesticide Signal Words

Signal words indicate product toxicity from a single exposure. Pesticides are either toxic by being corrosive or irritating or by causing improper bodily function. Signal words and colour of label with respect to different category are mentioned in following table.

Toxicity Category	Signal word	Colour of identification band
Category I- Extremely toxic	"POISON" with symbol of a skull with cross-bones	Bright Red 
Category II- Highly toxic	"POISON" with statement "Keep Out of The Reach of Children"	Bright Yellow 
Category III- Moderately toxic	"WARNING" with statement "Keep Out of The Reach of Children"	Bright Blue 
Category IV- Slightly toxic	CAUTION	Bright Green 

Precautionary procedures:

Precautions suggested by Directorate of Plant Protection, Quarantine & Storage, Faridabad while handling the pesticide during different activities.

A. Precaution to be taken while PURCHASING chemicals from market

1. Purchase pesticides/ bio-pesticides only from registered pesticide dealers having valid license.
2. Purchase only the required quantity of pesticides for single operation in a specified area.
3. See approved labels on the containers/ packets of pesticides.
4. See batch no., registration number, date of manufacture/ expiry on the labels.
5. Purchase pesticides well packed in containers.

B. Precaution to be taken while HANDLING the pesticides

1. Keep pesticides separate during transportation.
2. Bulk pesticides should be carried tactfully to the site of application.

C. Precaution to be taken while PREPARING SPRAY SOLUTION

1. Always use clean water.
2. Use protective clothings *viz*., hand gloves, face masks, cap, apron, full trouser, etc. to cover whole body.
3. Always protect your nose, eyes, ears, hands etc. from spill of spray solution.
4. Read instructions on pesticide container label carefully before use.
5. Prepare the solution as per requirement.
6. Granular pesticides should be used as such.
7. Avoid spilling of pesticides solutions while filling the spray tank.
8. Always use recommended dosage of pesticide.
9. No activities should be carried out which may affect your health.

D. Precaution to be taken while SELECTION OF EQUIPMENTS

1. Select right kind of equipments.
2. Select right sized nozzles.
3. Use separate sprayer for insecticides and weedicides.

E. Precaution to be taken while APPLYING SPRAY SOLUTIONS

1. Apply only recommended dose and dilution.
2. Spray operation should be conducted on cool and calm day.
3. Spray operation should be conducted on sunny day in general.
4. Use recommended sprayer for each spray.
5. Spray operation should be conducted in the wind direction.
6. After spray operation, sprayer and buckets should be washed with clean water using detergent/ soap.
7. Avoid the entry of animals/ workers in the field immediately after spray.

F. Precaution to be taken while AFTER SPRAY OPERATION

1. Left over spray solutions should be disposed off at safer place *viz*. barren isolated area.
2. The used/ empty containers should be crushed with stone/stick and buried deep in soil away from water sources.
3. Wash hands and face with clean water and soap before eating/ smoking.

4. On observing poisoning symptoms give the first aid and show the patient to doctor. Also show the empty container to doctor.

References:

1. Savary, S. and Willocquet, L. 2014. Simulation Modeling in Botanical Epidemiology and Crop Loss Analysis. *The Plant Health Instructor* 173 p.
2. Oerke, E.C. 2006. Crop losses to pests. *Journal of Agricultural Science* **144**: 31–43.
3. http://agricoop.nic.in/imagedefault/state_agri_1516.pdf
4. Farm Inputs and Management, State of Indian Agriculture 2015-16, Ministry of Agriculture and Farmers Welfare, May 2016.

12. COCOA DEVELOPMENT STRATEGIES

Nagaraja, N.R. and C.T. Jose

Cocoa is grown as a mixed crop under coconut, arecanut and oil palm gardens in India. Nearly 21.13 lakh ha of coconut, 4.53 lakh ha of arecanut and 2.00 lakh ha of oil palm gardens are available in India of which 35% is under irrigation and can be utilized for cocoa planting (Malhotra and Hubballi, 2016). Production of cocoa is about 18,920 MT (DCCD, 2016-17) which is low as against the demand of 30,000-45,000 MT of dry beans in Indian chocolate industry, which necessitating large scale imports to meet the national requirements and contributes about Rs.2000 million annually to the GDP of the Nation (Thomas *et. al*. 2013). During 2016-17, 25,700 MT of cocoa worth of Rs.1089.987 Crores was exported and 63,613 MT of cocoa worth of Rs.1542.307 Crores was imported (DCCD).

Considering the market growth in the chocolate segment in India, which is about 20 percent per annum, cocoa has a great potential to develop in future years. The projected demand of cocoa during 2050 is 212.27 thousand tonnes against the estimated supply of 121.35 thousand tonnes. With the projected supply there would be a demand-supply gap of 90.92 thousand tonnes of cocoa beans in 2050 and to achieve this target the production should grow at an annual growth rate of 7.68 per cent (Thomas *et al.,* 2013). The Mission for Integrated Development of Horticulture (MIDH) has identified cocoa as a potential plantation crop and encouraging area expansion through Directorate of Cashewnut and Cocoa Development (DCCD), Kochi, Kerala.

Agencies involved in cocoa technologies transfer

Various agencies like, ICAR-Central Plantation Crops Research Institute (CPCRI), State Agricultural Universities (SAUs) of Kerala, Karnataka, Andhra Pradesh and Tamil Nadu, Directorate of Cashewnut and Cocoa Development (DCCD), Central Arecanut and Cocoa Marketing and Processing Cooperative Ltd. (CAMPCO), Mondelez International, Departments of Horticulture, Farmers Organizations, Self Help Groups (SHG's) etc. are involved in technology development and transfer for cocoa development. Technology is defined as application of scientific knowledge for solving problems in particular field. The technology should have practical purpose, economical, efficient, environment friendly and easy to use. The term technology transfer is defined as the process of movement of technology from one entity to another. Technologies related to cocoa improvement, production, protection and processing have been developed and released by research institutes. However, still there exists a gap between the technologies generated and their utilization by the growers. Timely and sustainable transfer of technologies and extent of adoption play a critical role in improving the productivity and profitability. Transfer of technology programmes of institutes/ universities/ organisations are given below.

1. ICAR-Central Plantation Crops Research Institute (CPCRI)

Present ICAR-Central Plantation Crops Research Institute, Regional Station, Vittal has a history of more than 60 years of arecanut research and nearly 50 years of cocoa research with the development of high yielding varieties/ hybrids, package of practices, post harvest technologies etc. The demand for CPCRI technologies of cocoa like high yielding hybrids and clones of cocoa from biclonal/ polyclonal orchards, soft wood grafting in cocoa, pruning and training technology for seedlings and grafts, vermicomposting using arecanut and cocoa wastes, integrated nutrient management with judicial, balanced and split application of organic and inorganic fertilizers, natural enemies/ predators in areca-cocoa ecosystem and bio-control agents and integrated pests and diseases management practices has been very high among the farming community and other clientele. Research and extension activities are changed as per the demands of clients *viz.*, farmers, agricultural/ horticultural officers, agro processors, self help groups, college/ school students etc. Assessment and refinement of technologies is done through co-operation of Developmental Departments/ Boards by organizing various programmes with the active participation of farmers. Important technology transfer programmes of CPCRI are given below.

Training Programmes: The term training refers to the acquisition of knowledge, skills, and competencies as a result of the teaching of vocational or practical skills related to agriculture. Training is conducted either at the institute or at the farmers' field. Training programmes for the farmers are conducted with the financial assistance from Directorate of Arecanut and Spices Development (DASD), Calicut, Directorate of Cashewnut and Cocoa Development (DCCD), Cochin, Ministry of Agriculture and Farmers Welfare, Government of India and others. Trainings are conducted for scientists, technical staff, agricultural/ horticultural officers, farmers, self help groups etc. based on the need and request.

Front Line Demonstrations: Front Line Demonstrations conducted by researchers in the farmers' fields to show how production can be increased per unit of area and per unit of time. These demonstrations usually include the system of multiple cropping and the use of high-yielding varieties, along with the best package of practices. CPCRI had established 96 Front Line Demonstrations plots on cocoa in farmers' gardens of 1 ha each in 8 taluks during 2003-04 with the financial assistance from DCCD, Kochi to convince the farmers about the technical feasibility and economic viability of the technologies. Grafts of high yielding cocoa clones were distributed and the farmers were trained on scientific cultivation practices including pruning, training and balanced application of manures and fertilizers. Six plots on 'Arecanut based multi species cropping system' were established in Bantwal taluk during 2008-09, ten demonstration plots were established in the farmers' gardens in Belthangady and Puttur taluks of Dakshina Kannada district and Kasaragod taluk of Kasaragod district during 2011-12 with the funding of Directorate of Arecanut and Spices Development (DASD), Calicut. From

2016-17, establishing eight more participatory demonstration plots on ‘Arecanut based multi species cropping system’ in farmers' gardens of five taluks of Dakshina Kannada district with the financial support from DASD. These plots serve as model plots for other farmers to follow this system.

Farm Advisory Visit: A multi-disciplinary team of scientists visit farmers’ fields and will give expert or professional advice for solving problems related to cocoa farming.

Method Demonstration: Organized to show the technique of doing things or carrying out new practices, e.g. Bordeaux mixture preparation, grafting technique, pruning technique, *Trichoderma* preparation etc.

Group Discussion: It is used to encourage and stimulate the people to learn more about the problems that concern the community through discussion. It is a good method of involving the local people in developing local leadership and in deciding on a plan of action in a democratic way.

Meetings: These are usually held for passing on certain information to the people for future action. Scientists give lectures to the people on certain pre-selected items of work, such as organizing farm training, field day etc.

Agricultural Information Centre: Established to provide the required technology information, diagnostic and advisory services.

Exhibition: Systematic display of information, specimens, models, posters, photographs, charts etc. in a logical sequence which is organized for arousing the interest of large number of people. It is one of the best media for reaching a large number of people, especially illiterate and semi-illiterate people. Exhibitions are used for a wide range of topics, such as displaying improved practices, showing high-yielding varieties, fermentation techniques etc.

Seminar: Arranged for formal presentation, discussion and exchange of technologies, ideas, information.

Field Day: Arranged to convince the farmers and to provide them an opportunity of seeing the results of new practices, techniques, new implements etc. regarding the suitability and application of technologies in their own area.

Kisan Mela: Organized to disseminate the technological advances and encourage the farmers to adopt new technologies in agriculture and allied areas for boosting agricultural production and their export.

Publications: Technical bulletins, folders, CD ROMs, Video Cassettes etc. are also prepared for effective dissemination and popularization of the cultivation technologies in cocoa among the farmers and extension personnel.

Mass Media: Effective utilization of mass media like Radio, TV, Newspapers and Farm Magazines is made to create awareness among farmers about various production technologies.

CPCRI Web Site: CPCRI web site, www.cpcri.gov.in and other services provided by CPCRI for the benefit of farmers form a part of the cyber extension activities. Arrangements are made for answering queries from farmers, extension personnel and entrepreneurs on different aspects of production, protection and processing of cocoa through e-mail.

2. Kerala Agricultural University, Thrissur

Cocoa breeding programme was initiated in Kerala Agricultural University (KAU) in 1979 and terminated in 1984. The cocoa research gained further momentum from April 1987 with the implementation of Cadbury-KAU Cooperative Cocoa Research Project (CCRP), with financial assistance from Cadbury India Ltd. This project has resulted in number of varieties/ technologies *viz.*, seven superior clones and three hybrids showing ample resistance to vascular streak die back disease, nutrient management, pest and disease management and post harvest processing technologies. Some of the important transfer of technology programmes of KAU are, training programmes, farm advisory visits, interface programmes, group discussions, exhibitions, publications etc.

3. Dr. Y.S.R. Horticultural University and Indian Institute of Oil palm Research, Andhra Pradesh

In Andhra Pradesh cocoa area is expanding. Horticultural Research Station, Ambajipeta, Indian Institute of Oil palm Research, Pedavegi, Developmental Departments, Mondelez International etc. are involving in cocoa promotion activities through demonstrations, training programmes, farm advisory visits, interface programmes, group discussions, seminars, publications etc. Both bi-clonal and poly-clonal orchards are established in YSR Horticultural University.

4. Tamil Nadu Agricultural University (TNAU), Coimbatore

Cocoa breeding programme was initiated recently in Tamil Nadu Agricultural University for releasing cocoa hybrids/ clones suitable for Tamil Nadu conditions. During May 2008, Cadbury India Ltd. joined hands with them to promote cocoa cultivation in Tamil Nadu. Some of the important transfer of technology programmes of TNAU are, training

programmes, farm advisory visits, interface programmes, group discussions, TV programmes, publications etc.

Developmental programmes

Developmental organizations like Directorate of Cashewnut and Cocoa Development (DCCD), Central Arecanut and Cocoa Marketing and Processing Cooperative Ltd. (CAMPCO), Mondelez International Pvt. Ltd., Departments of Horticulture, Farmers Organizations and Self Help Groups (SHG's) borrow technologies from research institutes/ universities for transferring them to farmers. They play a vital role in taking the technologies to farmers' door steps through various schemes/ programmes. Developmental programmes of various organizations are given below.

Directorate of Cashewnut and cocoa Development (DCCD), Cochin

Directorate of Cashewnut and Cocoa Development is a National Level Agency primarily involved in the overall development of Cashewnut and Cocoa in the country from the year 1966 onwards under Ministry of Agriculture and Farmers Welfare. The Directorate completed 50 years of its glorious service to the nation in the year 2016. The Directorate of Cashewnut Development which was handling only cashew got the mandate for development of cocoa in the year 1997. Though cashew and cocoa enjoys different parameters, both are economical cash crops of the country and in 1997-98, the Directorate of Cashewnut and Cocoa Development started driving both the crops on similar tracks.

Directorate of Cashewnut and Cocoa Development, from 8^{th} Plan onwards has been supporting technology dissemination through farmer participatory demonstrations of cocoa. With this background the Directorate has been involving in area expansion of cocoa by providing subsidy schemes and intensive publicity measures through trainings, workshops, field days, seminars, publications etc. to convince the farmers about the benefits of various scientific production technologies. It also provides certification of recognition to nurseries for quality planting material production and help in establishment of model nurseries.

Mandates of DCCD

- Formulation and implementation of development programmes for Cashewnut and Cocoa.
- Promote new planting and replanting of Cashewnut and Cocoa in potential areas.
- Co-ordinate the activities for the promotion of Cashewnut and Cocoa between central and state institutes with the Ministry of Agriculture and Farmers Welfare.

- Monitoring Cashewnut and Cocoa development programmes under National Horticulture Mission (NHM) and Mission for Integrated Development of Horticulture (MIDH).
- Advisory body to recommend, watch and monitor the various aspects of crops development, marketing and by product utilization.
- Function as data bank on crop area, production, price trends, marketing and trade performance.
- Take up intensive publicity measures for dissemination of technologies among farmers.
- Impart technical advice to farmers, entrepreneurs on all aspects of cultivation and processing.

Central Arecanut and Cocoa Marketing and Processing Co-operative Limited (CAMPCO)

'CAMPCO' was started on 11th July 1973 as a multi state co-operative, a joint venture of the states of Karnataka and Kerala. Starting with its Head Office at Mangalore in coastal Karnataka, the CAMPCO began with a handful of procurement centers in Karnataka and Kerala. CAMPCO adopted a safe policy for purchasing and marketing the commodity and maintaining standards in quality with the dedicated cooperation of a network of diligent officers and workers.

The co-operative encouraged growers to take-up cocoa cultivation as an inter crop in the latter half of the 70's as a supplemental crop. This grew up to become a large scale operation with good results. A sudden withdrawal by the buyers of cocoa from the procurement operations due to crash in the international market came as a shock to cultivators. Karnataka and Kerala governments enthused at this stage the CAMPCO to enter on the scene to rescue the farmers from distress. CAMPCO willingly took up the responsibility to enter the cocoa market and performed a savior's role. It procured cocoa pods from growers, by adopting scientific processing methods released dry cocoa beans matching in quality in the world market to that of Ghana, Brazil and other leading cocoa cultivating nations. With a view to create a permanent demand and a steady market for the beans, CAMPCO established a Chocolate Manufacturing factory at Kemminje village in Puttur Taluk of Dakshina Kannada adopting foreign technical collaboration in chocolate making. The factory was set up in 1986 at an initial investment of Rs.116.7 million and a licensing capacity to produce 8800 metric tonnes. It has been producing a variety of products-semi finished items like cocoa mass, cocoa butter, cocoa powder and finished products in moulded line, count line, chocolate drink etc. The main activities of CAMPCO for cocoa promotion are given below.

- Procuring arecanut and cocoa grown by member cultivators and if necessary, from other growers on an agency basis or on outright purchase basis.

- Sale of arecanut and cocoa and their products to the best advantage of members and also to advance loans to members on the pledge of goods.
- To promote and develop arecanut and cocoa cultivation, marketing and processing.

Mondelez International Pvt. Ltd.

Cadbury India Limited, a subsidiary of Mondelēz International Inc., has changed its name to Mondelez India Foods Limited. Cadbury India Ltd was incorporated in the year 1948 as a private limited company with the name Cadbury Fry (India) Pvt. Ltd. The company began their operations in India by importing chocolates. In the year 1950s, the company started the manufacture of chocolate and Bournvita. In the year 1960s, the company set up a Cocoa Research Centre in Kerala. In May 2008, the company joined hands with Tamil Nadu Agricultural University to promote cocoa cultivation in Tamil Nadu. Cadbury India Ltd. also plays an important role in area expansion programme of cocoa through various schemes. The company has its field offices/ branches in four southern states *viz.*, Kerala, Karnataka, Tamil Nadu and Andhra Pradesh where cocoa is grown. Major activities of Cadbury for cocoa development are given below.

- Supply of cocoa seedlings
- Supply of critical inputs
- Arranging interaction between scientists and farmers
- Technical guidance on crop production, protection and processing
- Buy back arrangements
- Procuring cocoa beans from growers (wet/ dry beans)

Strategies for cocoa development

- Intercropping of cocoa in irrigated coconut/arecanut/oil palm gardens.
- Replanting of old plantations with good quality planting materials of high yielding varieties, increasing the productivity of existing gardens by the adoption of crop management and plant protection technologies.
- Make superior quality planting materials and other inputs available to small and marginal farmers in sufficient quantities at reasonable price.
- Use of mass media to highlight the advantages of cocoa as mixed crop/intercrop in arecanut/coconut garden is essential to create awareness among farmers.
- Organizing a series of seminars, workshops, symposium etc. for better interaction of the farmers with the scientists, extension workers and government officials for further upgradation of the technologies.
- Organizing plantation growers network to exchange ideas, technologies etc.
- Need based training programmes with appropriate methodologies are to be organised for farmers on various aspects of production, protection and post harvest processing technologies.

- Training programmes are also required for the extension personnel engaged in the development of this crop to keep abreast with the latest technological advances.
- Training of rural women for home scale processing of cocoa and chocolate preparation.
- Farmers' participatory research should be encouraged for developing feasible technologies for better adoption.
- Substantial financial support by state and central governments is necessary to promote cocoa cultivation.
- Providing subsidies and other financial support to help the farmers to cover the initial expenses of growing cocoa.
- Establishment of public warehouse for storage of produce.
- Offering continuous market information and direct contact to buyers.
- Developing strong linkage between growers and factories with minimum influence of middlemen.
- Coordination of various research/extension agencies is essential for the successful implementation of such strategies.

APPENDIX - I

Training Programme on 'Cocoa Production Technology'

(15.02.18 to 24.02.18)

List of resource persons

Sl. No.	Name and Address	Specialization	E-mail
1	Dr. P. Chowdappa Director, ICAR-CPCRI, Kasaragod, Kerala	Plant Pathology,	pallem22@gmail.com
2	Dr. K.S. Ananda Principal Scientist and Acting Head, ICAR-CPCRI, RS, Vittal	Genetics & Plant Breeding	ksananda_cpcri@yahoo.co.in
3	Dr. C.T. Jose Principal Scientist, ICAR-CPCRI, RS, Vittal	Agricultural Statistics	ctjos@yahoo.com
4	Dr. S. Elain Apshara Principal Scientist, ICAR-CPCRI, RS, Vittal	Horticulture	elain_apshara@yahoo.co.in
5	Dr. M. Senthil Amudhan Senior Scientist, ICAR-CPCRI, RS, Vittal	Biochemistry	senjp@yahoo.com
6	Dr. Nagaraja, N.R. Scientist-Sr. Scale, ICAR-CPCRI, RS, Vittal	Plant Breeding	naga_gene@yahoo.com
7	Mr. Najeeb Naduthody Scientist, ICAR-CPCRI, RS, Vittal	Fruit Science	naduthodinajeeb@gmail.com
8	Mr. Shivaji Hausrao Thube Scientist, ICAR-CPCRI, RS, Vittal	Agricultural Entomology	shivajithube@gmail.com
9	Dr. R. Thavaprakasa Pandian Scientist, ICAR-CPCRI, RS, Vittal	Plant Pathology	r.thavaprakash@gmail.com
10	Ms. Suchithra, M. Scientist, ICAR-CPCRI, RS, Vittal	Spices, Plantations, Medicinal and Aromatic Crops	suchithramss@gmail.com
11	Dr. C. Thamban Principal Scientist, ICAR-CPCRI, Kasaragod	Agricultural Extension	c.thamban@gmail.com
12	Dr. K. P. Chandran Principal Scientist, ICAR-CPCRI, Kasaragod	Agricultural Statistics	chandran.kp@gmail.com
13	Dr. S. Jayasekhar Scientist (Sr. Scale), ICAR-CPCRI, Kasaragod	Agricultural Economics	jaysekhars@yahoo.co.in
14	Dr. N. Balasubramani Deputy Director (OSPM), MANAGE Hyderabad		balasubramani@manage.gov.in

APPENDIX - II

Training Programme on 'Cocoa Production Technology'

(15.02.18 to 24.02.18)

List of trainees

Sl. No.	Name and Address	Contact No. and E-mail ID
1	Mr. G. Perumalsamy Assistant Director of Agriculture Anaimalai, Coimbatore Dt., Tamil Nadu	9894715157 Adaami646@gmail.com
2	Mr. M. Shaffe Ahamed Assistant Director of Agriculture Sulur, Coimbatore Dt., Tamil Nadu	9442563666 adasulur@gmail.com
3	Dr. G. Sathish Subject Matter Specialist (Horticulture) ICAR-KVK, Tirur, Tiruvallur Dt., Tamil Nadu	9790643877 gskspice@gmail.com
4	Mr. Surjoo Lal Ivane Assistant Director of Agriculture Office of Joint Director, Marmdapuram Division Hoshangabad, Madhya Pradesh	9406524342 sivanesgr@gmail.com
5	Mr. Dennis George Agricultural Officer Magalpady, Kasaragod Dt., Kerala	8086881989 vvdennis@gmail.com
6	Mr. Kiran Kumar, N. Assistant Professor (Post Harvest Technology) College of Horticulture, Hiriyur, Chithradurga Dt., Karnataka	9916424881 Kiran69@gmail.com
7	Ms. Kayashree, M. C. Assistant Professor (Plant Pathology) ZAHRS, Brahmavar, Udupi Dt., Karnataka	9743817216 kavyabanadar@gmail.com
8	Dr. Vikram, H. C. Assistant Professor (Horticulture) ZAHRS, Brahmavar, Udupi Dt., Karnataka	9744791608 vikram.hc@gmail.com
9	V. Hari Narayana Nuzvid, Krishna Dt., Andra Pradesh	9347919219
10	V. L. N. Raghava Rao Nuzvid, Krishna Dt., Andra Pradesh	9494512197 vraghava789@gmail.com
11	Mr. M. Narayana Naik Senior Technical Assistant ICAR-CPCRI, Research Center, Kidu, Nettana Dakshina Kannada Dt., Karnataka	8105989747 cpcrirckidu@gmail.com

12	Mr. M. V. Sreedharan Senior Technical Assistant ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9446777894 mvsreedharan@gmail.com
13	Mr. A. R. Padmanabha Naik Senior Technical Assistant ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9400431218
14	Mr. B. Ananda Gowda Technical Assistant ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9449448926
15	Mrs. Pankaja, B. D. Senior Research Fellow ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9482176832 Pankajagirish03@gmail.com
16	Mr. Shivaprakash Senior Research Fellow ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	8762540173 shivanedle@gmail.com
17	Mr. Sandesh, M. S. Senior Research Fellow ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9483923567 sandeshmullia@gmail.com
18	Ms. Shaili, M. S. Field Assistant ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9945913750 shailisharma@gmail.com
19	Ms. Deepashri, Y. Junior Research Fellow ICAR-CPCRI, Regional Station, Vittal Dakshina Kannada Dt., Karnataka	9901570295 Deepanaik126@gmail.com

APPENDIX - III

Training Programme on 'Cocoa Production Technology'

(15.02.18 to 24.02.18)

Training Programme Schedule

Date & Time	Topic	Resource persons
15.02.2018	**Thursday**	
10.00 AM	Registration	
11.00 AM	Inaugural Session	
11.30 AM	Tea break	
12.00 AM	Overview on ICAR-CPCRI, Regional Station, Vittal	Dr. K. S. Ananda
01.00 PM	Lunch	
02.00 PM	Cocoa genetic resources management and improvement	Dr. S. Elain Apshara
03.00 PM	Tea break	
03.15 PM	Planting material production in cocoa	Ms. Suchithra, M.
04.15 PM	Hybridization technique in cocoa - Practical session	Dr. Nagaraja, N. R.
16.02.2018	**Friday**	
09.30 AM	Cocoa production technology	Mr. Najeeb Naduthody
10.30 AM	Tea break	
10.45 AM	Cocoa processing technology	Dr. S. Elain Apshara Mr. Najeeb Naduthody Ms. Suchithra, M.
01.00 PM	Lunch	
02.00 PM	Nursery visit/ Primary processing demo	Dr. S. Elain Apshara Mr. M. Ananda
03.15 PM	Tea break	
03.30 PM	Visit to mixed farming unit	Mr. Abdul Azeez Mr. Dharmapala
17.02.2018	**Saturday**	
09.30 AM	Visit to ICAR-DCR, Puttur	Dr. Nagaraja, N. R.
12.00 PM	Visit to Mondelez International processing unit, Puttur	
01.00 PM	Lunch	
02.00 PM	Visit to CAMPCO Chocolate factory, Puttur	Dr. Nagaraja, N. R.
18.02.2018	**Sunday**	
09.30 AM	Field visit - Puttur and Belthangady Taluks	Mr. C. Purandhara

19.02.2018	**Monday**	
09.30 AM	Integrated pests management in cocoa	Mr. Shivaji Hausrao Thube
10.30 AM	Tea break	
10.45 AM	Integrated diseases management in cocoa	Dr. R. Thavaprakasa Pandian
01.00 PM	Lunch	
02.00 PM	Demo on Bordeaux mixture preparation	Mr. C. Purandhara Mr. P. Santhosh Kumar Mr. K. Vinod
03.00 PM	Tea break	
03.15 PM	Mass multiplication of Trichoderma	Mr. C. Purandhara Dr. H. Moosa Mr. P. Santhosh Kumar
04.30 PM	Lab visit	All Scientists
20.02.2018	**Tuesday**	
09.00 AM	Visit to ICAR-CPCRI, Research Centre, Kidu	Dr. Nagaraja, N. R.
21.02.2018	**Wednesday**	
09.30 AM	Biochemical components and health benefits of cocoa	Dr. M. Senthil Amudhan
10.30 AM	Tea break	
10.45 AM	Cocoa scenario	Dr. C. T. Jose
12.00 PM	Visit to meteorological observatory	Mr. Santhosh Kumar, P. Mr. Vinod, K.
01.00 PM	Lunch	
02.00 PM	Visit to ICAR-CPCRI, Vittal Farm Demonstration on pruning and training	Horti. Section Mr. C. Purandhara
22.02.2018	**Thursday**	
09.00 AM	Visit to KVK, Mangaluru ICAR-CMFRI, Regional Station, Mangaluru Agricultural and Horticultural Research Station, Ullal	Dr. Nagaraja, N. R. Mr. C. Purandhara
23.02.2018	**Friday**	
09.00 AM	Visit to ICAR-CPCRI, Kasaragod	Dr. Nagaraja, N. R.
10.30 AM	Interaction with Director, ICAR-CPCRI, Kasaragod	Dr. P. Chowdappa, Director
11.00 AM	Participatory Rural Appraisal (PRA) techniques for identification and prioritization of problems to formulate extension/development programmes for plantation crops	Dr. C. Thamban
01.00 PM	Lunch	
02.00 PM	Sustainable plantation crops sector for inclusive growth: Scenario, issues and challenges	Dr. K. P. Chandran Dr. S. Jayasekhar
03.30 PM	Visit to experimental gardens, Labs of ICAR-CPCRI	All Scientists

24.02.2018	**Saturday**	
09.30 AM	Cocoa development strategies	Dr. Nagaraja, N. R.
10.30 AM	Tea break	
10.45 AM	Cost of production of cocoa	Dr. C. T. Jose
12.00 PM	Overview about MANAGE, Hyderabad	Dr. N. Balasubramani
01.00 PM	Lunch	
02.00 PM	Valedictory function and certificate distribution	

Course Director : Dr. K. S. Ananda
Course Co-Director : Dr. S. Elain Apshara
Course Co-ordinator : Dr. Nagaraja, N. R.

HEAD