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# A Decade of Growth and Achievements of CPCRI 2005 - 2014





Central Plantation Crops Research Institute
(Indian Council of Agricultural Research)
Kasaragod - 671 124, Kerala, India

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# 1. Introduction

Central Plantation Crops Research Institute (CPCRI) is the premier horticultural research Institute under the Indian Council of Agricultural Research (ICAR) mandated to conduct research on coconut, arecanut and cocoa. It has served the cause of science and society with distinction through exemplary research, generation of appropriate technologies and development of skilled human resource. Ever since its establishment as Coconut Research Station in 1916 by the Presidency of Madras and subsequently as Central Plantation Crops Research Institute (CPCRI) in 1970 as one of the agricultural research institutes under the Indian Council of Agricultural Research (ICAR) by merging Central Coconut Research Stations at Kasaragod and Kayamkulam as well as Central Arecanut Research Station, Vittal and its five substations at Palode and Kannara (Kerala), Hirehalli (Karnataka), Mohitnagar (West Bengal) and Kahikuchi (Assam), the Institute has served the country by way of development of new technologies and refinement of technologies to enhance the productivity and profitability in plantation crops. Research on cashew, oil palm and spices has been delinked from CPCRI with the establishment of separate Institutes considering the need and advancements made in the sector.

The current mandate of the Institute is to:

- Develop appropriate production, protection and processing technologies for coconut, arecanut and cocoa through basic and applied research
- Act as the national repository for the genetic resources of these crops
- Produce parental lines and breeders' stock of plantation crops
- Develop improved palm-based farming systems through more effective use of natural resources to increase productivity and income from unit area
- Collect, collate and disseminate information on the above crops to all concerned
- Co-ordinate research on these crops within the country and execute the research programmes under the All India Co-ordinated Research Project on Palms
- Transfer technologies developed at CPCRI to the farmers with the co-operation of Developmental Departments/commodity boards.

The Institute has provided an inspiring leadership in the research on plantation crops and development of technologies contributing India's emergence as the leading country in the production of coconut and arecanut. The Institute has responded well to the needs, challenges and opportunities in plantation crops sector and oriented its plans and programmes accordingly. It has played a key role in improving the productivity and livelihood of the plantation crop growers and entrepreneurs. The Institute is moving ahead with an increased thrust on strategic and basic researches to generate new scientific knowledge, technology and product development aimed at enhancing the nation's competitiveness in the present day competitive global scenario.

While improvement through conventional breeding continues to be its major mandate, marker assisted selection (MAS), identification of genes for resistance/ tolerance to biotic and abiotic stresses, molecular diagnosis of diseases like coconut root (wilt) and arecanut yellow leaf diseases received adequate focus. Mass multiplication protocols for dwarf arecanut and creation of pre-breeding stocks combining multiple resistances and other desirable attributes are some of thrust areas in recent years. Basic and strategic researches have also been strengthened in the areas of resource management, GIS, and crop modeling. Agronomic research addressing the needs and opportunities of small and marginal farmers through the development of newer cropping systems options consistent with sustainable use of land, water and other natural resources has been strengthened. Research in nutrient management, leading to the development of integrated plant-soil-water-nutrient management systems has been given high priority. The Institute has developed expertise in emerging areas such as PGPRs, climate change, nanotechnology etc. The Institute has done a commendable job in developing technologies for pre and post harvest processing, value addition and process/product diversification in mandate crops. The institute has made good progress in developing technologies and processing machineries for production of virgin coconut oil (VCO), coconut chips, coconut sap collection and its processing into sugar. Socio-economic research enabled the institute to conceptualize and validate novel approaches/delivery mechanisms to reach out to farmers and other target groups ensuring better adoption of technologies and social and economic empowerment of small and marginal farmers. Mission and centers of excellence modes are being adopted to ensure inter-disciplinary excellence and efficiency in research.

This publication brings out the major research advancements made in the last one decade from 2005 to 2014 showcasing the status of research efforts under various disciplines, development of technologies, technology dissemination, commercialization, patents obtained, efforts of strengthening research manpower, improvement in quality of publications for the benefit of farmers, researchers, developmental organizations and policy makers to effectively device future strategies and steering the ongoing research to face the challenges in coconut, arecanut and cocoa.

# 2. Research Advancements

## 2.1. Genetic resources management and breeding

### 2.1.1. Germplasm explorations for trait specific collections in coconut, arecanut and cocoa

CPCRI has been actively associated with collection and conservation of germplasm in the mandate crops, right from its inception. As a result, CPCRI hosts one of the largest assemblage of arecanut and coconut in the world and also has a large collection of cocoa genetic resources. The institute hosts the national field gene bank for the mandate crops, *viz.*, coconut, arecanut and cocoa and is recognized by the National Bureau of Plant Genetic Resources (NBPGR), New Delhi as the National Active Germplasm Site (NAGS) for Plantation Crops.

A massive exercise to collect and document the indigenous germplasm was undertaken in the country during 2002-2007, under the World Bank funded National Agricultural Technology Project on Plant Biodiversity (NATP-PB). CPCRI as a collaborating institute in this project was involved in the collection of indigenous coconut germplasm across the country. Since 2007, the focus has been on exploration in hitherto unexplored locations with greater emphasis on collection of trait-specific germplasm for enrichment of the germplasm base of the mandate crops.

**Coconut:** In the past one decade, 80 indigenous coconut accessions have been collected from Andaman and Nicobar Islands, Lakshadweep Islands, Kerala, Tamil Nadu, Andhra Pradesh, Karnataka, Maharashtra, Bihar, West Bengal, Tripura, Assam, Meghalya and Gujarat making the total coconut germplasm collection at 422. The focus has been on collection of germplasm for dwarf plant habit, cold/drought tolerance, pest/disease resistance, soft/sweet endosperm, higher copra content/copra output, tender nut water quality and fibre quality. The states of Tripura, Bihar, West Bengal, Assam and Meghalaya were surveyed for collection of cold tolerant germplasm and about 14 accessions have been collected for conservation and characterization. A subset of the collections is also planted at CPCRI Research Centre, Mohitnagar for evaluation of their performance in Sub Himalayan Terai region. Drought tolerant coconut germplasm has been collected from drought prone tracts of Tamil Nadu, while accessions with superior coconut fibre quality have been collected from Kerala. The rare soft endosperm coconut accessions (*Thairu Thengai*), similar to *Makapuno* of Philippines were collected from the Andaman & Nicobar Islands as well as Kerala. A unique, but popular coconut ecotype, *Mohacho Narel*, with less fibre and more sweetness in endosperm has been collected from Maharashtra. The popular farmer varieties of Karnataka suitable for tender nuts have been collected and conserved. The rare aromatic dwarf coconut has been collected from Andhra Pradesh and conserved. More than 15 dwarf accessions have been collected from the states of Kerala, Karnataka, Assam, Andhra Pradesh as well as the Union Territories of Andaman & Nicobar Islands and Lakshadweep group of Islands, in addition to dwarf Spicata type, with unbranched inflorescence, from Andhra Pradesh. Micro type of coconuts with more number of fruits/bunch and higher copra output have been collected from Andaman & Nicobar Islands, Lakshadweep Islands and Andhra Pradesh, while fruits with large size and higher copra content have been collected from Maharashtra, Andaman & Nicobar Islands and Lakshadweep group of Islands.

Andaman Yellow Dwarf Coconut accession

Andaman Orange Dwarf Coconut accession

*Thairu thengai* with soft endosperm

**Cocoa:** In cocoa, the focus has been on enrichment of the genetic base mainly through introduction of trait-specific germplasm from the International Cocoa Quarantine Centre, University of Reading, United Kingdom (UK) as well as the collection of trait-specific germplasm from the cocoa growing tracts within the country. During the past decade, the cocoa germplasm collection at the institute has more than doubled with the addition of 185 accessions, the vast majority being introduction of trait-specific germplasm. A total of 133 exotic accessions, including Brazilian, Jamaican, Mexican, Amazonian, Pound collections and accessions of Trinidad, Ghana, Peru, New Guinea, France, Ecuador, French Guiana from UK, two hybrids from Philippines and three hybrids from Malaysian Cocoa Board were introduced for conservation making the total cocoa germplasm collection at 321. These introductions include 20 accessions for larger bean size, 5 white bean accessions for flavor, 4 accessions for canker resistance, 25 accessions for black pod disease (BPD) resistance, 3 accessions for vascular streak disease (VSD) resistance and 2 accessions for mirid bug resistance. In addition, indigenous survey and collection was undertaken for collection of trait-specific germplasm from the states of Kerala, Karnataka and Tamil Nadu. Two Criollo types having superior flavour characteristics and 18 drought tolerant cocoa accessions from Shiradhi Ghat in the State of Karnataka have been collected and conserved.

**Arecanut:** In the case of arecanut, the emphasis was on collection of germplasm from the unexplored regions in the northeastern region of the country, with emphasis on cold tolerance, bolder fruit size and higher yield potential. During the last decade, 24 new accessions were collected mainly from northeastern region of the country and also from the arecanut growing tracts of Gujarat state, Uttara Kannada and Dakshina Kannada districts of Karnataka state increasing the total collections to 164. Among the seven accessions collected from Gujarat state, there was a semi-tall type with desirable characteristics *viz.* closer inter-nodal length, partially drooping crown, medium thick stem, heavy bearing nature, round medium sized nuts, less husk content and higher recovery of dried kernel from ripe nut. 13 cold tolerant accessions of arecanut were collected from the states of Assam, Meghalaya and northern parts of West Bengal. An alternate arecanut germplasm site, mainly for conservation and evaluation of arecanut germplasm of the North Eastern region was established at CPCRI Research Centre, Kahikuchi, Assam.

***In situ* characterization:** Work on *in situ* characterization of germplasm was initiated during this decade, starting with the morphological and molecular characterization of Chowghat Orange Dwarf (COD) and Chowghat Green Dwarf (CGD) coconut population of Guruvayoor area in Thrissur district of Kerala. Subsequently, *in situ* characterization of local coconut ecotypes was initiated to document the popular farmers' varieties and unique populations. Four coconut ecotypes from Kerala *viz.*, Bedakam of Kasaragod district, Annur of Kannur district, Kuttiadi of Kozhikode district and Puvar of Southern Kerala were characterized. In Karnataka, Mavinakuruva and Devaramutte Tall ecotypes of Honnavar taluk were studied and characterized. *In situ* characterization of local coconut populations of Minicoy Island of the Lakshadweep group of Islands was undertaken and the inherent wide variability was documented and characterized.

Diversity of Coconut in Minicoy Islands

**Coconut germplasm/ genetic stocks registered with NBPGR for unique traits**

| Sl No | Registration number | Features |
|---|---|---|
| 1 | INGR13059 | KPDT (IND001): An indigenous tall selection from IC430667 with higher copra and low husk content |
| 2 | INGR13060 | LMT (IND030): An indigenous tall selection from IC430669 with heavy bunches of micro nuts, high copra oil content |
| 3 | INGR13061 | CRD (IND092): A dwarf selection from EC121436 with orange nuts, higher copra content among dwarf accessions |
| 4 | INGR13062 | CYD (IND414): An indigenous dwarf selection from IC430664 with yellow fruits and erect frond tip |
| 5 | INGR13063 | ADHT (IND221): An indigenous tall selection producing fruits with multiple horn like structures |
| 6 | INGR13064 | LMMT (IND331): An indigenous tall selection from IC425040 with very small fruits with very low copra content |
| 7 | INGR13065 | NLAD (IND099): A dwarf coconut selection from EC415218 with breeding behaviour similar to talls and higher copra content, close leaf scars over the trunk, irregular trunk surface |

### 2.1.2. Germplasm registration

Among the conserved and evaluated coconut germplasm, seven coconut lines were registered with NBPGR for unique traits having scientific/academic/ commercial values.

### 2.1.3. Strengthening of International Coconut Gene Bank for South Asia

India hosts the International Coconut Gene Bank for South Asia (ICG-SA), one among the five multi-site genebanks established by FAO/Bioversity-COGENT to promote conservation as well as exchange of coconut germplasm for the benefit of the coconut community. Planting of coconut accessions in the ICG-SA, located at CPCRI Research Centre, Kidu, Karnataka, was initiated in 1998 and presently represents Indian accessions, accessions from member countries of the region as well as coconut ecotypes collected from member countries. In the initial years, Indian coconut germplasm was regenerated and planted in the Gene Bank. Subsequently, the genetic base of the ICG-SA was broadened with the introduction of exotic coconut germplasm. A total of 91 accessions have been planted over the years in the ICG-SA and represent coconut germplasm from the host country (India) as well as coconut ecotypes collected through COGENT-ADB from Sri Lanka, Bangladesh, Indian Ocean Islands of Mauritius, Madagascar, Seychelles, Comoros, Reunion and the Maldives.

Field gene bank under ICG-SA

During the past one decade, germplasm collected as embryos from the Indian Ocean Islands of Mauritius, Madagascar and Seychelles, Comoros and Reunion and Maldives have been planted in the gene bank. During this period, coconut germplasm collected from two member countries, four accessions from Sri Lanka and nine accessions from Bangladesh were planted. The palms in the ICG-SA are being maintained under good management with recommended dose of organic and inorganic fertilizers and drip irrigation.

The observation on growth characters, fruit component traits as well as tender nut water quality attributes and nut yield are recorded in the gene bank. In the ICG-SA, the accessions East African Tall (EAT31), Car Nicobar Tall (CART), Jamaican Sanblas Tall (PNT03), Seychelles Tall (SCT), West Coast Tall (WCT), Laccadive Micro Tall (LMT), Laccadive Ordinary Tall (LCT), Malayan Green Dwarf (MGD), Spicata Tall (WCT01), West African Tall (WAT), Philippines Ordinary Tall (PHOT), Panama Tall (PNT), Borneo Tall (BONT), Guam Tall I (GUAT), and Philippines Lono Tall (PLNT) recorded higher initial yield and showed superiority for agronomic traits. Among the Indian Ocean accessions, Sambava Green Tall (SBGT), Sambava Tall (SMBT) and Cococ Belu Tall (CBLT) continued to exhibit higher mean annual nut yield trends, while Comoros Moheli Tall (CMRT01), Hanimaadhaoo medium Round Tall (HMRT), Pemba Red Dwarf (PRD03), Pemba Green Dwarf (PEGD) were the other distinct early flowering accessions in the ICG-SA. Among the South Asian accessions, the accessions Kayamkola Tall (KYKT), BARI Narikel - I, BARI Narikel - II, Sri Lankan Yellow Dwarf (CYD01) and Sri Lankan Red Dwarf (SLRD01) recorded early flowering and higher initial yield.

Further, concerted efforts are required for improving the genetic diversity of this gene bank through targeted introduction of genetically diverse and trait-specific germplasm from different geographical regions, through exchange between gene banks as well as targeted exploration and collection of local germplasm in diversity rich hot spots, especially in the Pacific region.

### 2.1.4. Development and release of improved varieties and hybrids

The Institute has released nine coconut varieties and three hybrids suitable for different purposes at national level. The varieties were identified based on the superior performance in the experimental trials at CPCRI and multi-location trials at Centres of AICRP on palms. Besides, two Dwarf x Tall (D x T) hybrids, Laccadive

Green Dwarf (LCGD) x Laccadive Ordinary Tall (LCT) and Laccadive Orange Dwarf (LCOD) x Laccadive Ordinary Tall (LCT) for Lakshadweep Islands and three hybrids, Malayan Yellow Dwarf (MYD) x Kenya Tall (EAT 32), Chowghat Orange Dwarf (COD) x West African Tall (WAT) and COD x LCT for Kerala were identified as superior and recommended and released at Institute level by the Institute Research Committee. The Institute has also facilitated CARI, Port Blair in identifying four dwarf selections *viz.*, Annapurna, Surya, Kanchan and Chandan from the Pacific Ocean collections conserved by the Institute at World Coconut Germplasm Centre at Port Blair. The CARI selections were recommended for cultivation in Andamans.

In arecanut, four varieties *viz.*, Swarnamangala, Kahikuchi, Madhura mangala, Nalbari and two hybrids *viz.*, VTLAH1 and VTLAH2 were released during the period.

Seven varieties of cocoa including four hybrids (VTLCH-1, VTLCH-2, VTLCH-3 and VTLCH-4), one clone VTLCC-1 and two clonal selections VTLCS-1 and VTLCS-2 were released. They exhibit high pod and dry bean yields, bigger and bold beans with lesser shell content, high nib recovery, rich in fat, tolerance to water stress and suitable for growing in arecanut / coconut gardens.

**Improved coconut varieties and hybrids released during 2005 to 2014**

| Variety | Important traits | Nut yield ($ha^{-1}$ $year^{-1}$) | Copra yield (t $ha^{-1}$ $year^{-1}$) | Recommended states/regions |
|---|---|---|---|---|
| **Tall varieties** | | | | |
| Kalpa Pratibha | High nut, oil yield, dual purpose variety for copra and tender nut | 16107 | 4.12 | Kerala, Andhra Pradesh, Tamil Nadu, Maharashtra |
| Kalpa Mitra | High nut, oil yield, drought tolerant | 15222 | 3.68 | Kerala, West Bengal |
| Kalpa Dhenu | High nut, oil yield, drought tolerant | 14160 | 3.41 | Kerala, Tamil Nadu, Andaman & Nicobar Islands |
| Kalparaksha | Semi-tall, high nut and oil yield in root (wilt) disease | 13260 | 2.85 | Kerala, Root (wilt) disease prevalent tracts |

| | | | | |
|---|---|---|---|---|
| | prevalent areas; tender nut purpose | | | |
| Kalpa Haritha | Dual purpose variety for copra and tender nut; lesser eriophyid mite damage | 20886 | 3.70 | Kerala, Karnataka |
| Kalpatharu | Drought tolerant, ball copra, high yield | 20709 | 3.64 | Kerala, Karnataka, Tamil Nadu |
| **Dwarf varieties** | | | | |
| Kalpasree | Early flowering, green colour fruit, superior oil, recommended for root (wilt) disease prevalent areas | 18360 | 1.77 | Root (wilt) disease prevalent tracts |
| Kalpa Jyothi | Tender nut purpose, yellow colour fruit | 23256 | 3.30 | Kerala, Karnataka, Assam |
| Kalpa Surya | Tender nut purpose, orange colour fruit | 25092 | 4.69 | Kerala, Karnataka, Tamil Nadu |
| **Hybrids** | | | | |
| Kalpa Samrudhi (MYD x WCT) | Suitable for copra and tender nuts, Drought tolerant, higher nutrient use efficiency | 20744 | 4.35 | Kerala, Assam |
| Kalpa Sankara (CGD x WCT) | Tolerant to root (wilt) disease, high yield | 14868 | 3.20 | Root (wilt) disease prevalent tracts |
| Kalpa Sreshta (MYD x TPT) | Suitable for copra and tender nuts | 29227 | 6.28 | Kerala, Karnataka |

Kalpa Prathibha

Kalpa Mitra

Kalpa Dhenu

Kalparaksha

Kalpa Haritha

Kalpatharu

Kalpasree

Kalpa Jyothi

Kalpa Surya

Kalpa Samrudhi

Kalpa Sankara

Kalpa Sreshta

### 2.1.5. Development of DUS guidelines

Intellectual Property Rights in the domain of plant varieties was addressed by our country with the enactment of the Protection of Plant Varieties and Farmers' Rights Act, 2001 (PPVFRA). This legislation was introduced, recognizing the need for establishment of an effective system for protection of plant varieties, the farmers' rights, plant breeders' rights and to encourage development of new plant varieties in the country. To facilitate protection of any variety conforming to the criteria of Novelty, Distinctiveness, Uniformity and Stability, the DUS guidelines have to be developed for the candidate crop and then the Government has to notify the crops in order to establish the system of listing of plant varieties for the purpose.

Realizing the importance of crop variety registration, the Central Plantation Crops Research Institute has been closely working with PPV&FR Authority since 2008 to develop the DUS guidelines in the mandate crops. The first focus was on development of DUS guidelines for coconut and since, coconut does not figure in the UPOV list, the task was more daunting and CPCRI has taken the lead in facilitating registration of coconut varieties through development of coconut DUS test guidelines. The institute hosted the PPV&FRA Meeting of the Task Force for Plantation Crops to finalise the DUS guidelines for coconut on 28-29th June,

*...contd. pg. 16*

## Improved arecanut varieties and hybrids released during 2005 to 2014

| Variety | Features | Recommended states/regions |
|---|---|---|
| Swarnamangala | Improved selection, Tall palm with comparatively shorter internodes, Nuts are bold and heavier Average dry kernel yield of 3.88 kg/palm/year. | Karnataka & Kerala |
| Kahikuchi | Tall selection with medium thick stems possessing comparatively shorter inter-nodes. The average dry kernel yield is 3.70 kg palm/year | Assam & NEH Region |
| Madhuramangala | Improved selection with yield of 3.54 kg dry kernel/palm/year, suitable for tender and ripe nut processing. | Konkan area and Karnataka |
| Nalbari | Improved selection with yield of 4.15 kg dry kernel/palm/year, good processing quality ripe nuts. | Karnataka, North Bengal and NE region |
| VTLAH1 Hybrid between Hirehalli Dwarf (VTL-56) and Sumangala (VTL-11) | Dwarf palm with sturdy stem having imposed nodes, small canopy size, well spread leaves. Average dry kernel yield is 2.54 kg/palm/year. Dwarfness leads to reduced cost of cultivation in terms of harvesting and spraying. | Karnataka & Kerala |
| VTLAH2 Hybrid between Hirehalli Dwarf (VTL-56) and VTL-60 | Dwarf palms with sturdy stem having super imposed nodes, reduced canopy size, well spread leaves. Average dry kernel yield is 2.64 kg/palm/year. Dwarfness leads to reduced cost of cultivation in terms of harvesting and spraying. | Karnataka & Kerala |


Swarnamangala


Kahikuchi


Madhuramangala


Nalbari


VTLAH1


VTLAH2

**Improved cocoa varieties and hybrids released during 2005 to 2014**

| Variety/Hybrid | Features |
|---|---|
| VTLCC1 | Early and heavy bearing clone, self and cross compatible, produces green to yellow pods 75/tree/year, 36 beans/ pod, average single dry bean weight of 1.05g, 12% shelling and 52.5% fat content. The clone is capable of giving dry bean yield of 1.33 kg/tree/year ( 911 kg/ha) |
| Vittal Cocoa Selection 1 | Precocious, stable and high yielding clone, medium canopy, possesses biotic and abiotic stress tolerance with red to orange coloured pods, pod yield 54.5 / tree/ year with 42 beans/ pod, bean weight of 1.13 g, 11% shelling recovery, 52.1% fat, 2.52 kg/ tree/ year dry bean yield (1700 kg/ ha) |
| Vittal Cocoa Selection 2 | Early, stable and high yielder both under arecanut and coconut, have bold and bigger beans, less incidence of pests and diseases. Green to Yellow pods: 55/tree/year, No. of beans/ pod: 42, Single dry bean weight of 1.21 g, 15% Shelling, 53% Fat, Dry bean yield of 2.7 kg/ tree/ year (1850 kg/ha) |
| VTLCH1 | Vigorous, early and heavy bearer, green to yellow pods, pod yield 50/tree/year with 42 beans per pod, single dry bean weight of 1.00 g. 13% shelling, 53.6% fat, dry bean yield of 1.48 kg/tree/year (1014kg/ha). |
| VTLCH2 | Heavy bearer, medium canopy and tolerant to black pod rot. Green to yellow pods: 70/tree/year. No. of beans/pod: 40. Single dry bean weight: 1.15 g, 11% shelling, 54% fat, dry bean yield of 1.15 kg/tree/year ( 800 kg/ha). |
| VTLCH3 | Suitable for rainfed & irrigated areca and coconut gardens of Karnataka, Kerala, Tamil Nadu and Andhra Pradesh. Green to yellow pods, pod yield of 45/tree/year, 43 beans/ pod, single dry bean weight 1.07 g, 13% shelling, 52% fat, dry bean yield of 1.45 kg/tree/year (993 kg/ha). |
| VTLCH4 | Suitable for rainfed & irrigated areca and coconut gardens of Karnataka, Kerala, Tamil Nadu and Andhra Pradesh. Red to orange pods: 40/tree/year, 43 beans/pod, single dry bean weight of 1.01 g, 12% Shelling, 53% fat, dry bean yield of 1.25 kg/tree/year (856 kg/ha). |


VTLCH-1


VTLCC-1


VTLC-57


VTLC-1

2010 under the chairmanship of Dr. K.U.K. Nampoothiri, Director, Dr. M. S. Swaminatan Research Foundation, Koraput, Orissa and Dr H.H. Khan, ex Project Coordinator, AICRP on Palms as Member and Dr P.K Singh, Registrar, PPV & FRA as Member Secretary. The coconut DUS guidelines finalized by the PPVFRA Task Force on Plantation Crops was approved and subsequently, on the 18th August 2011, the Ministry of Agriculture (Department of Agriculture and Co-operation) notified Coconut (*Cocos nucifera* L.) for the purpose of registration of varieties under the Protection of Plant Varieties and Farmers' Rights Act 2001, in the Gazette of India: Extraordinary [Part II—Sec. 3(ii)] S.O. 11913(E). The development of DUS descriptors and subsequent notification of the crop for registration by PPVFRA has stimulated for registration of farmers' varieties as well as varieties developed by the public and private sector. The Institute is now recognized by PPVFRA as the DUS centre for coconut and undertaking Training cum Awareness programme on the Protection of Plant Varieties and Farmers' Rights Act for creating awareness among the researchers, farmers, students, developmental agencies, NGOs and general public on provisions of conservation, protection and registration of varieties. Till now, four such awareness meetings have been organized from 2011.

In addition, the Institute has prepared draft DUS guidelines for arecanut and submitted it to PPVFRA for refinement, validation and finalization of DUS test guidelines in arecanut. Similarly, the institute has also submitted proposal for development of DUS test guidelines in cocoa.

Maintenance breeding - Recording of DUS descriptor traits

### 2.1.6. Registration of extant varieties

The institute is in the process of registering the extant/released varieties of coconut developed by the institute with PPV & FR Authority. So far, 11 varietal applications have been submitted to PPVFRA from the institute, including five varieties *viz*., Kalpa Haritha, Kalpa Jyothi, Kalpa Samrudhi, Kalpa Surya and Kera Chandra, under the VCK (Varieties under Common Knowledge) category and six varieties *viz*., Kalpa Sankara, Kalparaksha, Kalpasree, Kalpa Pratibha, Kalpa Mitra and Kalpa Dhenu under the extant notified varieties category. The registration will give plant variety protection for 18 years further facilitating commercialization of these varieties.

### 2.1.7. Quality planting material production

The Institute has been producing quality planting materials in coconut, arecanut and cocoa in large number for distribution to farmers, development agencies including the breeder seeds of lines for establishment of seed gardens and multi-location trials. Seed gardens of selected tall and dwarf varieties have been

Large scale planting material production in improved varieties of coconut

established in the institute as well as in farmer's gardens to augment planting material production. Seedling standards were developed as a measure to ensure the quality and to support the certification process in coconut, arecanut and cocoa.

In the last ten years, CPCRI (RC), Kidu was strengthened to take up the role of national seed garden for coconut to supply parental material and breeder's stock for the development of seed gardens in different parts of the country. A massive community level root (wilt) disease-free material production programme has been undertaken by CPCRI (RS), Kayamkulam to meet the planting material needs of root (wilt) diseased tract. ELISA (Enzyme Linked Immuno Sorbent Assay) standardized at CPCRI is widely used to establish the identity of disease free mother palms in hot spot areas of the disease.

Considering the availability of mother gardens, maintenance of quality as per the standards and the existing resources/ expertise, CPCRI nurseries at Kasaragod, Kidu and Vittal were graded with 'four-stars' in the five-star scale by National Horticultural Board, Government of India as part of accreditation of quality nurseries in the country from 2008.

### Planting material production at the Institute (2003 - 2014)

| Year | Coconut | Arecant | Cocoa |
|---|---|---|---|
| 2013-14 | 1,09,585 | 45,6755 | 83,447 |
| 2012-13 | 1,21,993 | 2,59,000 | 69,891 |
| 2011-12 | 63,471 | 4,67,102 | 1,07,901 |
| 2010-11 | 1,21,710 | 2,98,186 | 1,12,720 |
| 2009-10 | 1,23,069 | 2,62,100 | 2,00,000 |
| 2008-09 | 1,05,829 | 2,39,613 | 1,02,091 |
| 2007-08 | 1,23,941 | 3,29,413 | 1,17,000 |
| 2006-07 | 84,146 | 2,75,541 | 1,28,270 |
| 2005-06 | 75,079 | 2,63,331 | 51,244 |
| 2004-05 | 42,244 | 2,61,261 | 48,572 |
| 2003-04 | 27,802 | 84,218 | 36,718 |

### Women scaling new heights: Transcending gender barriers for pollinating coconut

At the Institute, trained women serve as 'skilled coconut pollinators' for coconut hybrid production. Traditionally, coconut climbing and pollination was men's territory, since the practice involves considerable drudgery and the inherent risk of accidental fall. Owing to this, number of palm climbers has been on the decline and coconut communities were experiencing severe shortage of skilled climbers-cum-pollinators. The drudgery in climbing was largely reduced with the introduction of climbing machines and safety consciousness is addressed by the addition of a safety device to the climbing machine.

Artificial pollination is the most important and crucial activity in the production of quality hybrids in coconut. It demands fine-tuned scientific procedures along with skilled labour force for climbing the tree and pollinating the female flowers at the right stage. The pollinator is required to climb over the crown manoeuvring through the coconut leaves which needs power, courage and skill. Thanks to the climbing machines, the 'Friends of Coconut' programme sponsored by the Coconut Development Board (CDB) in Kerala and to a greater extent, training programmes of CPCRI have helped in overcoming the situation. Women have learnt the nuances of coconut pollination with ease and carried out the work with confidence. They are able to manage 60 tall palms for pollination work, just like their male counterparts. Success of women pollinators in coconut hybrid production will encourage more women to take up this profession as it is much remunerative and improves their social and economic status. This venture could be one of the best options as a trend setter for augmenting hybrid seed production, overcoming acute labour shortage, women empowerment, gender equality, agricultural and rural development in the coconut communities.


Trained woman doing artificial pollination of coconut

## 2.2. Biotechnological applications

### 2.2.1. Development of *in vitro* techniques for regeneration protocol and cryopreservation

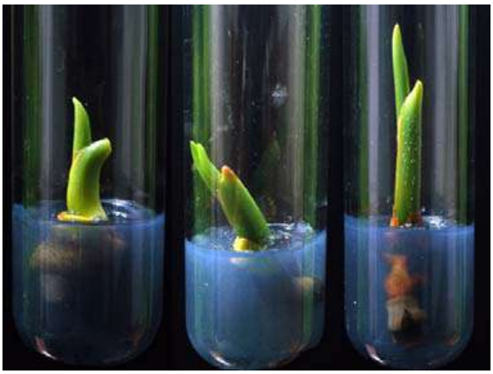
During the decade, the Institute has made rapid strides in the field of *in vitro* techniques for mass multiplication and cryopreservation. The salient achievements are as follows.

- Protocol for regeneration of coconut plantlets from plumule explants through somatic embryogenesis
- Plantlet regeneration from adult explants (inflorescence) of arecanut
- Cryopreservation techniques have been standardized for mature coconut zygotic

embryos and coconut pollen

- Droplet vitrification method developed for coconut plumule cryopreservation
- Arecanut pollen collection method and its germination media for pollen cryopreservation studies
- *In vitro* protocol for multiplication of dwarf arecanut hybrids
- Cell suspension culture studies were initiated from coconut embryogenic calli and cell multiplication

An efficient regeneration protocol for obtaining plantlets through tissue culture from inflorescence explants of adult arecanut palm has been developed. It is being used in multiplication of YLD resistant palms identified in the farmers' gardens and for mass production of plantlets in case of arecanut dwarf hybrids and dwarf parents. Forty nine tissue culture derived plantlets from YLD resistant arecanut palms were field planted. Clonal fidelity test using RAPD indicated that 98% of the progenies are similar to the mother palms.



Embryo culture in coconut

Embrogenesis in arecanut tissue explants

Plantlet regeneration from Hirehalli dwarf arecanut

### 2.2.2. Marker assisted selection for agronomically important traits in coconut

RAPD markers for the tall/dwarf trait were identified in coconut using a bulked DNA approach. Screening of tall and dwarf palm bulk DNA with 200 primers revealed that a RAPD primer OPBA3 was able to clearly differentiate both the tall and dwarf bulks. For validation, the primer was used to screen individual tall and dwarf coconut palms representing different geographic regions. The primer was also used to screen the parents and validate hybrids of Dwarf x Tall crosses. Furthermore, sequence characterized amplified region (SCAR) primers were designed from the unique RAPD amplicon. The primers produced a specific 260-bp amplicon in tall accessions, but not in dwarf accessions. The SCAR marker was utilized in assessing the purity of hybrid seedlings of D × T (Dwarf × Tall) cross, paving the way for ensuring genuineness/quality of hybrid seedlings of coconut. Also, during selection of pure dwarf progenies in nurseries, the SCAR marker would be of immense use in culling out out-crossed seedling progenies resulting from pollen contamination. Thus, the SCAR marker for distinguishing tall and dwarf coconut accessions would give headway in establishing varietal identity, achieving varietal purity within germplasm and ensuring the quality of hybrid planting material production in coconut.

A panel of SSR markers has also been identified for confirming the hybridity of Dwarf x Tall hybrids (CGD x WCT) which will ensure selection more efficient for supply of genuine hybrids to farmers.

### 2.2.3. Molecular characterization of germplasm

DNA finger printing using microsatellite markers has been carried out in 160 conserved coconut accessions representative of all the coconut growing areas around the world to document the genetic integrity and diversity. Besides, sixty indigenous and exotic arecanut accessions have been analyzed using RAPD and SSR markers. The characterization and analyses helped in identifying diverse accessions for use in breeding programmes and identifying duplicates or close relatives in germplasm pool. Besides, the molecular characterization and DNA finger printing techniques were used to test the level of homozygosity in different coconut populations for their efficient use in breeding and to finger print the desirable lines and developed varieties.

### 2.2.4. Cloning and characterisation of resistant genes for biotic and abiotic stresses

Transcripts induced during water-stress in coconut have been cloned and characterized using differential display RT-PCR. Resistant Gene Analogues (RGAs) were cloned and characterised from coconut using a degenerate-primer based PCR strategy and comparative genomics. Based on the results obtained in this study, gene-specific primers were designed to amplify genes induced during water-stress in coconut.

## 2.3. Bioinformatics

The Distributed Information Sub Centre (Sub-DIC) under the Biotechnology Information System Network (BTISnet) programme of the Department of

Biotechnology, established at CPCRI in December 2000 has greatly contributed to the creation of databases on biotechnological aspects of coconut, cocoa and arecanut and provide information retrieval services in Biotechnology. With support from the Department of Information Technology, an Agri-Bioinformatics Promotion Centre was established at the Institute. Under the Bioinformatics initiative, several comprehensive databases for the mandate crops have been developed for the benefit of plantation researchers. The Bioinformatics Centre and Library has developed the digital library using D Space software and made accessible through the library website http:// www.bioinfcpcri.org/

### 2.3.1. Application of bioinformatic tools for development of databases and tools

Under the Bioinformatics initiative, several computational tools and comprehensive databases for the mandate crops have been developed.

- MAPS (Microsatellite Analysis and Prediction Software), a bio-Java based independent (stand alone) platform to allow the identification and characterization of microsatellites in entire genomes
- Computational method based on SVM for prediction of gibberellic acid biosynthetic enzymes in palms
- Tool for prediction of the RGA motifs using Support Vector Machines (SVM), standalone BLAST and Hidden Markov Models (HMM)
- DNA barcode data of three genes of indigenous palms organized into a database
- Stand alone EST-SSR analysis pipeline (SEMAT)
- Carotenoid biosynthetic pathway was reconstructed based on cocoa whole genome sequence
- Various cocoa EST libraries (related to both abiotic and biotic) were analyzed and key genes involved in different pathways were deduced
- Database on Cocoa chloroplast specific pathway
- Identification and characterization of SSRs in date palm whole genome sequence
- Identification and characterization of SSRs and SNPs in *WRKY* genes in palms
- Development of SSR primers from whole genome sequence of date palm and confirmation of cross species amplification in other palms
- Identification of miRNA sequences in date palm whole genome
- Development of 'PMU Finder' for the identification of PMU genes from whole genome sequences of phytoplasma

- PHYTODB- a comprehensive and user-friendly web server and a knowledgebase devoted only to the phytoplasma, its taxonomic groups, associated genes and proteins

### 2.3.2. Development of algorithms for prediction of genes/promoters in plant growth promoting rhizobacteria

- 'PROMIT' tool to identify promoters in the -10 and -35 regions of sequences from the *Pseudomonas* spp.
- 'LTTRPred', a tool for identifying and predicting the LTTR genes responsible for the activation of *Plt* transcription regulators, in whole genome of various *Pseudomonas* spp.
- 'NRPS Pred', a gene prediction tool using a machine learning algorithm was developed to predict Non-Ribosomal Peptide Synthetases (NRPS) genes, which are involved in the pyoverdine biosynthetic pathway of *Pseudomonas fluorescens*
- 'BACPred' tool was developed for the identification of bacilysin synthesizing genes in whole genome of *Bacillus* spp.
- Pyoverdine gene cluster in plant growth promoting *Pseudomonas fluorescens* Pf0-1 was elucidated using comparative genome analysis.

### 2.3.3. Training programmes conducted at the Institute under Bioinformatics

- Advances in Biotechnology and Bioinformatics for Plantation Crops - 2005
- Genomics and Molecular Modeling in Plantation Crops - 2005
- *In silico* Analysis and Wet Lab Experiments in Plantation Crops - 2006
- Molecular Docking and Functional Genomics - 2006
- Applications of Bioinformatics & Biotechnology in Plantation Crops Research – 2007
- Brainstorming Session on Database for the Management of Genetic Resources of Horticultural Crops - 2008
- Bioinformatics & Biotechnology: Introduction & Applications in Plantation Crops - 2008
- Principles & Applications of Bioinformatics - 2008
- Development and Use of Bioinformatics Tools and Resources for Plant Genome Analysis - 2009
- Programming for Biological Data Analysis - 2010
- Tools for Analysis of Genetic Diversity and Mapping - 2011
- Genetic Diversity and Mapping Analysis using Molecular Marker Data - 2012
- Tools for Genetic Diversity and Mapping Analysis using Molecular Marker Data – 2013.

## 2.4. Crop Production Technologies

### 2.4.1. Coconut based integrated farming system (CBIFS) - Enterprise diversification for high returns

Mono cropping of coconut does not provide adequate returns to farm family and has several limitations like poor resource efficiency, low productivity and inadequate utilization of family labour. Coconut grooves offer excellent opportunities to adopt coconut based integrated mixed farming system to exploit the potential of inter-space in the garden for maximizing returns per unit area. Keeping this view, an experiment was carried out during 2004-2013 in Central Plantation Crops Research Institute, Kasaragod, Kerala in the existing mixed farming system model to assess the benefits of integration of coconut with intercropping of fodder grass, dairy, poultry, Japanese quails and aquaculture.

Mixed farming system with black pepper and Co-3 fodder grass

Integration of dairy in mixed farming system

Pisciculture as a component

The sustainability and profitability of coconut based farming system comprising coconut, pepper trailing on the coconut trunk, banana in the border of the plots, fodder grass (hybrid Bajra Napier Co 3) in the interspaces of coconut, dairy unit (7 cows of Holstein Friesian and one Jersey cross breed), poultry (100 broiler birds/ batch), Japanese quails (100 layers) and aquaculture (1000 finger lings) are assessed in coconut stand of 35 years old. Organic recycling in the coconut fodder grass system was achieved through cow dung and dairy shed washings, poultry and quail bird droppings, etc. and vermicomposting of coconut leaves. The dry coconut leaves and other plant wastes are converted into vermi-compost employing the earthworm *Eudrilus* sp.

To study the effect of organic recycling on fodder grass and coconut yield the experimental plot was divided into four treatments *viz*., Mono cropping of coconut with recommended fertilizer as inorganics, Coconut based integrated farming system (coconut, hybrid Bajra Napier grass, pepper, banana, dairy, poultry and aquaculture components, pepper intercropped in the basin, banana in the border of plots and hybrid Bajra Napier Grass (Co 3 and Co 4 ) in the inter space of the coconut palms) along with application of 50 per cent of the organic recycling of recyclable biomass produced from the system, Coconut based integrated farming system with application of 100 per cent of the organic recycling of biomass generated in the system and Coconut based integrated farming system with application of 100 per cent of the recommended nutrients as inorganic fertilizers.

Hybrid Bajra Napier Co 3 and Co 4 were evaluated as inter crop with different management practices. Green foliage yield of hybrid Bajra Napier - Co 3 was significantly increased with combined application of organic and inorganic fertilizers (117 tones/ha/year) and Co 4 recorded an yield of 115 tonnes/ha/year with the same treatment.

In CBIFS, coconut rerecorded higher yield compared to monocropping. The coconut palms maintained under CBIFS receiving integrated nutrient management practices i.e., combined application of organic and chemical fertilizer recorded significantly higher yield (108 to 137 nuts/ palm /year with a mean yield of 126 nuts /palm /year) which was followed by other treatments under CBIFS. From one ha of coconut based integrated farming system, 23800 coconuts, 14976 litres cow milk, 859 kg broiler chicken, 6749 quail bird eggs, 1961 kg of banana and 295 kg of pepper were obtained (Average 2006 to 2013).

Economic analysis revealed that coconut based integrated farming is an ecologically sustainable system which fetch higher income to cultivators when compared to monocropping. The total cost involved in maintaining the system under CBIFS (2005-2013) with different nutrient management practices ranged from Rs. 2,36,926 to 3,89,700, whereas, under monocropping it was Rs. 43,475/ha. The net returns were the highest in the CBIFS receiving combined application of 50 per cent organics produced from the system and 50 per cent inroganics (Rs. 1,68,196 to Rs. 2,85,512) compared to monocropping of coconut (Rs. 37,344 to 44,352). Around 98 per cent of the revenue was derived from coconut, dairy and poultry components. The coconut based integrated farming system with organic recycling positively influenced the physical, chemical and biological properties of soil and brought out significant improvement in soil health than the mono cropping with inorganic nutrient management.

### 2.4.2.1. Coconut based high density multispecies cropping system under organic and integrated nutrient management

The concept of coconut based high density multi-species cropping system (HDMSCS) was initiated during 1983 at Central Plantation Crops Research Institute, Kasaragod involving 17 different species with coconut as main crop. The HDMSCS involves growing a large number of crops at very high plant population per unit area to meet the diverse needs of the farmer such as food, fuel, timber, fodder and cash. They are ideally suited for smaller units of land and aim at maximum production per unit area of land, time and inputs with minimum or no deterioration of land.

Coconut based HDMSCS involving coconut + clove/nutmeg + pineapple + banana with application of 2/3rd of the recommended fertilizers to coconut and component crops along with orgnanic recycling proved to be sustainable as the coconut yielded about 170 nuts/palm/year. The system gave a net return of about Rs 1.5 lakh/ha/year making the system highly profitable.

Evaluation of coconut based HDMSCS under organic and integrated nutrient management was initiated during 2007. Three treatments *viz.,* 2/3rd of Rec. fert. NPK + recycling biomass (vermicompost) – $T_1$, 1/3rd of Rec. fert. NPK+recycling biomass (vermicompost) + biofertiliser + green manuring + vermiwash - $T_2$ and Fully organic with recycling biomass (vermicompost) + biofertiliser + green manuring + vermiwash + husk burial + mulching coconut basin – $T_3$ were evaluated. The crops involved in the system were coconut, black pepper, pineapple, banana, clove, annual crops like, turmeric, ginger and vegetable crops (brinjal, pumpkin, and elephant foot yam), sweet corn and baby corn. The intercrops were grown in the space available during different seasons. Coconut yield did not differ significantly among the treatments and it ranged between 145 to 155 nuts/palm/year (2007 to 2012). Black pepper yield also did not differ significantly among the treatments and ranged from 1.7 to 1.8 kg/vine, and banana (Njalipoovan variety) yield ranged from 6.0 to 7.2 kg/bunch and Grand naine variety yield also did not differ significantly among the treatments and it ranged from 13.7 kg to 15.5 kg/

Coconut based HDMSCS model at Kasaragod

bunch. The copra and oil content of coconut did not differ significantly among the treatments and it ranged from 159.5 to 164.6 g/nut and from 65.7% to 65.8%, respectively. Economics of the system indicated higher net return in T3 treatment. The cost of production was higher in Treatment 3 (Rs. 1.04 lakhs/ha during 2010-11 and Rs.1.13 lakhs/ha during 2011-12). The net return was also the highest under $T_3$ treatment (Rs.2.17 lakhs/ha during 2010-11 and Rs.1.78 lakhs/ha during 2011-12). The present study indicated that the system can be grown completely under organic management with organic matter recycling as vermicompost, biofertilizers, green manure, husk burial, mulching and vermiwash application. Improvement in soil health is noticed with the adoption of system with recycling of wastes.

#### 2.4.2.2. Screening of black pepper in coconut garden

Black pepper varieties, Panniyur-1, Panniyur-2, Panniyur-3, Panniyur-4, Panniyur-5, Sreekara, Subhakara, Panchami,Kottanadan, OPKM, Collection 1041 (Thevam) and hybrids HP-780, HP-105, HP-1411, HP-813, HP-34 were evaluated under coconut garden. Thevam and Panniyur- 5 performed better with significantly higher yield of 1.81 kg/vine and 1.12 kg/vine respectively. An improvement in coconut yield was also recorded when black pepper is introduced as intercrop.

#### 2.4.2.3. Medicinal plants as inter/ mixed crops

Different medicinal plants viz., Orila (*Desmodium gangeticum*), Moovila (*Pseudartheia viscida*) and Coleus (*Coleus aromaticum*) (8 months duration crops), Chittadalodakam (*Adhatoda beddomei*), Karimkurinji (*Nilgirianthus ciliatus*), Nagadanthi (*Baliospermum montanum*) (18 months crops) were evaluated as inter/ mixed crops in 30 years old coconut garden under organic nutrient treatments. Among the annuals, Orila recorded highest net return (Rs. 21,155/ha) in 8 months duration and among the biennials, the highest net return was obtained with *Nilgirianthes* (Rs. 1,97,260/ha) in 18 months duration.

#### 2.4.2.4. Fruit crops in coconut garden

The feasibility of growing fruit crops viz., sapota, mango, jamun, acid lime lemon, mangosteen, kokum and rambutan as mixed crops in coconut garden was evaluated. Initial results indicated the early fruit production in saopta and lemon in coconut gardens.

#### 2.4.2.5. Noni (*Morinda citrifolia* L.) as mixed crop

The Influence of different types of planting material and planting geometry on growth and yield of noni as mixed crop in coconut garden under littoral sandy soil was evaluated. The treatments consisted of different types of planting materials viz., seedling, tissue cultured plantlets and cuttings and two planting geometry viz., single hedge system and double hedge system. Plants obtained through cuttings performed better over tissue cultured plants under double hedge system.

### 2.4.3. Arecanut based cropping/ farming system

#### 2.4.3.1. Medicinal and aromatic plants as profitable intercrops

Evaluation of different medicinal and aromatic plants under arecanut was done during 2004 to 2007. All the medicinal and aromatic plants except senna, safed musli and geranium performed better. Three year pooled analysis indicated that shatavari produced fresh root yield of 10.7 t/ha of arecanut garden and contributed maximum chali equivalent yield (1524 kg $ha^{-1}$). The net return per rupee spent was the highest when brahmi was intercropped in arecanut plantation (3.64) followed by *Nilagirianthus ciliatus* (2.88). Among aromatic plants, lemon grass gave higher net returns per rupee spent (4.25) followed by basil (3.46) and davana (3.12). Medicinal and aromatic plants suppressed the plant pathogens and sustained a significantly large population of the antagonistic fungi like *T. viride* and *T. harzianum* and antagonistic bacteria *viz., P. fluorescens*, *B. subtilis* and *B. amyloliquefaciens*. Periwinkle and Vettiver harbored the maximum populations of the antagonistic fungi and bacteria. Aromatic plants were more effective in suppressing the pathogens than the medicinal plants.

#### 2.4.3.2 Arecanut based mixed farming system

The feasibility and efficiency of resource management under areca based mixed farming system was initiated in 2007 with three cows. Different components of mixed farming system included arecanut plantation, grass, dairy and fishery.

About 550-650 $m^2$ fodder area as sole crop is required to meet the year round demand of fresh fodder for each cow and about 1300-1400 $m^2$ area as intercrop in arecanut. Dairy component with 3-5 milch cows produced 19,240 l of milk yield per year and 60 t of dry cow dung that had resulted in generation of total outflows amounting to Rs. 6.18 lakhs. The 5-year data analysis indicated that the net income gradually increases from Rs.17,800 to Rs. 2.24 lakhs per year and on an average dairy unit with 3-5 milch cows generates around Rs. 6800/- net income per month. Use of arecanut leaf sheath as cattle feed with 10% supplementation reduced feed cost by Rs. 1.5 per kg mix. The cow dung from dairy was rich in nitrogen (2%) and phosphorus (0.48% P) and contained less K content (0.22%) and 60 t can meet N and P demand of four hectares of arecanut. Recycling of fish pond water and cowshed wastes to fodder (39-296 ppm N) resulted in higher fodder yields and reduced cost of fertilizers. Gross income generated from composite fish culture (rohu, katla and common carp in 4:3:3 ratio) was Rs. 14,500 /year with yield of 180 kg/250 $m^2$ pond.

### 2.4.4. Coastal sandy soil management

The coconut productivity under coastal sandy soil is 40 nuts /palm/year because of poor inherent physico-chemical properties of the coastal sandy soil (95 % is sand). One of the most important options to increase the coconut productivity is growing intercrops in the interspaces of coconut. However, growing intercrops in between the coconut palm in coastal sandy soil is not feasible under normal management practices. To raise the intercrops, waste/usufruct materials from coconut palm *viz*., husk and coir pith were used as moisture conservation materials and source of nutrient needs of crops. It was found that fodder grass, fruit crops and vegetables can be successfully grown as intercrops. The added advantage is that *in situ* availability of these materials.

Growing of fodder crops Hybrid Bajra Napier Co3 with husk burial in the planting zone recorded an average yield of 91t/ha/year and guinea grass variety Co GG3 recorded yield of 85.6t/ha/year. Pumpkin/ ash gourd can also be grown successfully as intercrops in coconut garden using husk/ coir pith as amendments with the yield ranging from 11.1 t /ha to 12.8 t/ha for pumpkin and ash gourd, respectively. Similarly banana variety, Grand Naine (23.96 t/ha) was found to suitable intercrop with coir pith and husk amendments. Pineapple recorded yield of 16.21 t/ha by adopting husk incorporation technology. For elephant foot yam, three varieties *viz*., Gajendra (18.8 t/ha), Padma( 16.1 t/ha) and local variety(17.9 t/ha) were evaluated and found to be suitable intercrop with soil moisture conservation measures. Snake gourd variety TA-19 recorded 6.95 t $ha^{-1}$

Banana intercropping with moisture conservation measures

Pineapple intercropping with moisture conservation measures compared to Co-2 (6.03 t/ha) with soil moisture conservation measures. Cow pea Jyothika recorded significantly higher yield of 1.7 t $ha^{-1}$. The main objective of the project was to incorporate husk/coir pith for raising intercrops and increase the coconut productivity. The pre-treatment yield of coconut was 40nuts/palm/year which was increased to 136 nuts/palm under coconut + vegetable intercropping system followed by coconut + pineapple (121 nuts/palm), coconut + fodder grass(102 nuts/palm) and monocropping (98 nuts/palm). The increase in productivity is mainly due to higher soil moisture content, better nutrient availability, increase in microbial population and favorable microclimate.

### 2.4.5 Drip fertigation in coastal sandy soil

Coastal littoral sandy soils are mainly skeletal soils, consisting of 99.1 per cent sand and are excessively porous with the result that their capacity to retain moisture and nutrients for the use of crop throughout the year is very poor. Frequent application of water and nutrients may help to improve crop production in such soils. The effect of fertigation on coconut yield under coastal sandy soil was studied with treatments *viz*., 25, 50, 75 and 100 per cent NPK through drip irrigation and 100 per cent NPK through soil application. The fertilizer applied through drip irrigation was given in six equal splits avoiding the monsoon period. Irrigation was given @ 66 % of open pan evaporation and the quantity of water applied through drip was 32 l $palm^{-1}$ $day^{-1}$. The conventional fertilizer application was followed as per the recommended practice. The pooled data for six years revealed that the highest coconut yield of 82 nuts/palm/year was recorded with application of 100 % NPK through drip irrigation. It was at par with 50 % NPK through drip irrigation (79 nuts/palm) and 75 % NPK through drip irrigation (80 nuts/palm). All these treatments recorded significantly higher yield over 25 % NPK through drip irrigation and 100 % NPK through soil application.

### 2.4.6. Sustainable organic farming with bio-inputs and residue recycling

The effect of organic cultivation practices on coconut productivity was studied with four organic cultivation practices (Vermicomposting in the basin, application of bio-fertilisers and cover cropping in the interspace, Vermicomposting in the trenches application of bio-fertilisers and cover cropping in the basin, Vermicomposting in the basin, application of bio-fertilisers and growing vegetables in the interspace and Vermicomposting in the trenches, application of bio-fertilisers and raising vanilla and pepper) and a control. One D x T hybrid and WCT was included in the experiment. Average six years yield data of indicated that all the organic cultivation treatments recorded significantly higher nut and copra yield when compared to control. However, the organic cultivation treatment, vermicomposting in the basin, application of bio fertilisers and cover cropping in the interspace recorded higher yield of 113 nuts/palm/year and copra yield of 3.53 t/ha/year for D x T hybrid and the treatment, vermicomposting in the basin, application of bio fertilizers and growing vegetables in the interspace recorded 96.5 nuts/palm/year and copra yield of 2.68 t/ha/year for WCT variety.

### 2.4.7. *In situ* biomass production for organic farming

Either stem cuttings or seedlings of Glyricidia can be used for planting. Seedlings can be raised in poly bags/raised beds. It is preferred that the planting season coincides with monsoon season (South West monsoon/North East monsoon) for better establishment. Spacing of 1 x 1 m can be adopted (between row to row and plant to plant). Two or three rows of Glyricidia can be planted in between two rows of coconut. Seedlings/one meter long stem cuttings should be planted in an upright position in the pits of 30 $cm^3$. For better establishment, a basal dose of 50 kg of phosphorus/ha can be applied. Pruning should always be maintained at 1 m height. Pruning can be started after one year of planting. Three rows of Glyricidia in between two rows of coconut with three prunings per year (February, June and October) resulted in higher biomass yield of 7.97 t $ha^{-1}$. The coconut growth was

Basin management with *Pueraria* in organic farming

not affected by intercropping of Glyricidia. Application of the Glyricidia prunings from interspace of one hectare of coconut garden to the coconut palms could meet a major portion of nitrogen (90 per cent), part of phosphorus (25 per cent) and potassium (15 per cent) requirement of coconut palms. The *in situ* planting of nitrogen fixing tree species like Glyricidia between the coconut rows can supply the micronutrients such as copper, zinc and boron. Further, *in situ* availability, easy decomposability and low cost of green manure are the added advantages. In addition to this, the microclimate conditions in the coconut garden is also improved.

### 2.4.8. Management practices for root (wilt) diseased gardens

#### 2.4.8.1. Integrated nutrient management

Adoption of integrated nutrient management practices for root (wilt) disease (RWD) affected coconut palms is considered essential for improving soil health and coconut yield. Improvement in coconut yield of WCT variety of coconut palms was noticed from third year onwards after applying recommended dose of chemical fertilizers along with recycling available organic biomass and its application. The performance of RWD affected coconut palms applied either with 50% recommended fertilizers + organic manure through vermicompost and incorporation of *in situ* raised green manure cowpea or 100 % recommended fertilizers alone in a coconut based high density multispecies cropping system was compared.

There was improvement in yield in the post-treatment period in both the treatments. The increase in yield in palms receiving both fertilizers and organic manures was 17 % compared to only 7 % increase in palms receiving only chemical fertilizers. The increase in nut yield of palms supplied with both fertilizers and organic manures might be due to the better nutrition the palms received under that treatment. Thus, it is evident that through an integrated nutritional management, the health of palms could be improved over the years or maintained without further deterioration, thereby bringing more palms from the disease middle category to disease early category.

In general, the copra content of coconut was higher in palms applied with both fertilizers and organic manures except in the case of Disease Middle-2 category. The overall percentage increase in copra content of palms applied with fertilizers and organic manures over fertilizers alone applied palms was 4.57. In general, an increase was noticed in available P, Mg and Ca under the fertilizer +organic manure applied plot in different disease categories than in plots applied with fertilizers alone. The reverse was the trend in most of the cases for total N and available K. Increase in available P with integrated nutrient management might have contributed to the P-solubilizing capacity of organic manure. *In situ* green manuring in basins also resulted in an increase in the level of major nutrients in soil of coconut basins.

The population level of general and function specific microbial community, in general was higher in the rhizosphere of palms applied with both fertilizers and organic manures except in the case of Actinomycetes. The population level of bacteria and fungi were higher in the rhizosphere of palms in the disease middle category, whereas, that of Actinomycetes and function-specific microbes was high in the disease early category. Presence of higher number of function-specific microbes in the rhizosphere of disease early palms could be maintaining soil health and providing better nutrient availability to palms, thereby helping them to give better yield.

The changes in disease index during the period December 2005 to May 2008 was compared between the treatments by employing the procedures for repeated measurements. While the values of index varied significantly over time, there was no significant interaction between treatment and time.

A further analysis of percentage of coconut palms falling under different root (wilt) disease intensity categories during each year (2005 and 2008) was done. Through an integrated nutritional management, the health of palms could be improved over the years or maintained without further deterioration, thereby bringing more palms from the disease middle category (2) to (1) or from category(1) to disease early category.

### 2.4.8.2. Pre-disposing factors for RWD in coconut palms

Reports are available about the occurrence of RWD in coconut growing districts adjoining the borders of Kerala. Studies were conducted to identify the soil factors acting as predisposing agents towards the expression of various symptoms of RWD in coconut. Soil samples were collected from Colachel and Cumbum (Tamil Nadu state), Kozhinjampara, Nangiarkulangara, Alappad and Edava (Kerala state) and analysed for various physico- chemical properties.

Site specific variations were observed in soil properties between localities and between the healthy and diseased gardens of the same site. Similarly, variation in symptom expression of the disease was also observed. Organic carbon, which implies the biological activity in the root zone and acts as the key buffering agent towards the exchange reactions in soil, was in the lower category in all the sites of diseased palms raging from 0.240% in Alappad to 0.474% in Cumbum. Available P content in the soil of the RWD site was very low (ranging from traces to 2.0 ppm), whereas, in the healthy area, it was to the extent up to 30 ppm. Available K in the root zone of the palms showing yellowing was extremely low and ranged from 13.35 ppm in Alappad to 41.08 ppm in Edava, whereas, it was 72.2 ppm for healthy palms in Edava. The exchangeable Mg and Ca contents in Edava and Nangiarkulangara were very low (40.05 ppm & 32.79 ppm and 186.07 ppm & 282.90 ppm, respectively). The plant available sulphur content in the soil was also very low in all the sites studied ranging from 1.76 ppm in Edava to 4.5 ppm in Kozhinjampara.

A marked variation on the particle size distribution at the two layers in both the sites was observed. In the diseased area, there was more clay and silt content in the sub surface layer as against the condition in the healthy area. Soil compaction measured in terms soil specific volume was less in the diseased sites (0.739 cc/g) compared to the healthy sites (0.854 cc/

g). A higher value indicates a lower degree of compaction.

Adoption of balanced and integrated nutrient application incorporating both organic and inorganic manures along with other agro-management practices are to be followed in the RWD affected coconut gardens for improving soil physical/ chemical conditions for better growth and sustaining crop productivity.

### 2.4.8.3. HDMSCS for root (wilt) disease tract

Evaluation of HDMSCS with WCT variety of coconut involving nutmeg, balck pepper, banana, pineapple and vegetables was taken up at the Regional Station, Kayamkulam during 2004-2008.

Inclusion of various crops in the HDMSCS helps to generate considerable quantity of recyclable biomass. The total crop residues / recyclable bio mass in the form of coconut leaves (after removing petiole portion), spathe and bunch waste; banana waste (dry leaves and pseudo stem at the time of harvest of bunch), pineapple waste (crown after harvest of fruit and whole plant while uprooting), nut meg leaves and other weed materials (collected while slash weeding) collected during different years from the HDMSCS ranged from 9.10 t during 2007-08 to 18.87 t during 2004-05. The biomass thus obtained was vermicomposted and its recovery ranged from 65% to 70%. The nutrient content of compost produced during each year was analysed and on an average it contained 1.413 % N, 0.112 % P and 0.304 % K. Thus, the total nutrient contribution from the recycling of biomass through vermicomposting ranged from 86.7 to 180.0 kg N, 6.9 to 14.3 kg P and 18.7 to 38.7 kg K during different years.

Economic analysis of coconut based HDMSCS in root (wilt) affected areas was done based on respective market prices both for input and output over the period of years. It was noticed that the total return from the HDMSCS varied from Rs.46,424 (2005-06 ) to Rs.61,565 (2007-08).

Benefit Cost Ratio was found to be 2.18 and the Net Present Worth to be Rs.2, 75, 172. Since BCR is positive and NPW is 1.18 times more than that of total investment during the period, coconut based HDMSCS is economically viable in root (wilt) affected areas, provided the disease incidence is well managed and other production and price related risks are at normal level.

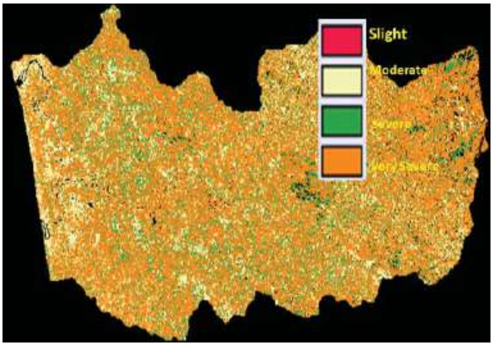
### 2.4.9. Precision farming in coconut

**Evolving site specific management practices for increasing the coconut productivity:** A Management Information System was developed in GIS and RDBMS soft wares for managing the information to develop precision farming strategies. The MIS had seven modules for storing and retrieval of information. This consists of coconut planting, monthly weather data, harvest, cultural operations, pest and disease incident and treatment of pests.

Regression tree analysis between soil nutrient status and yield indicated that in general, if soil total N is less than 0.0485% coconut yields were low. Coconut yield was high when the soil available K was greater or equal to 211 ppm and soil total N was greater than 0.0485 %.

**Regression tree analysis:** Precision farming strategies for a selected grama panchayath (Madikai, Kasaragod District) was developed. The available K was the major deficient element found under coconut based cropping system in Madikai panchayath, Kerala. The nutrient deficiency maps showing the spatial information of area under different nutrient deficiency have been created for coconut and arecanut based land use pattern in Madikai panchayath. Soil nutrient deficiency maps were also created for the land use patterns based on cashew, rubber, banana and paddy cultivation.

Land cover map of the Kadalundi and Tirur river basins were developed using remote sensing and GIS techniques for the spatial information needed to measure and formulate appropriate site specific management techniques for soil erosion and run off management. These river basins were having soil erosion potential ranging from moderate to very severe and most of the areas were coming under very severe soil erosion prone category. To prepare action plan for soil conservation measures in the slope lands, the soil erosion map was created.




Soil erosion map for Kadalundi and Tirur river basins

Multiple Regression analysis of soil available nutrient and coconut nut yield in red sandy loam soil at CPCRI Kasaragod revealed that there was a linear increase in the nut yield with increasing level of available K when the total N level is high, suggesting N and K have co-limiting role in coconut productivity.

### 2.4.10. Remote sensing and GIS application

**Identification of root (wilt) diseased palms:** Linear spectral reflectance model was developed for the identification and mapping of RWD affected coconut land cover by implementing the NCLS (Non-negative Constrained Least Square) algorithm for the sub pixel classification of RWD affected coconut palm in IRS P-6 satellite data.

**Coconut root (wilt) affected fraction of pixel – Alapuzha district**

Coconut land cover and coconut RWD affected area maps were developed for Alappuzha, Thrissur, Ernakulam, Idukki, Pathanamthitta, Kollam, Kottayam, Thiruvananthapuram, Palakkad, Malappuram, Kozhikode, Wayanad, Kannur and Kasaragod districts of Kerala state and erstwhile Madurai and Coimbatore districts of Tamil Nadu state.

## 2.5. Applications of agriculturally important micro organisms in palms and cocoa

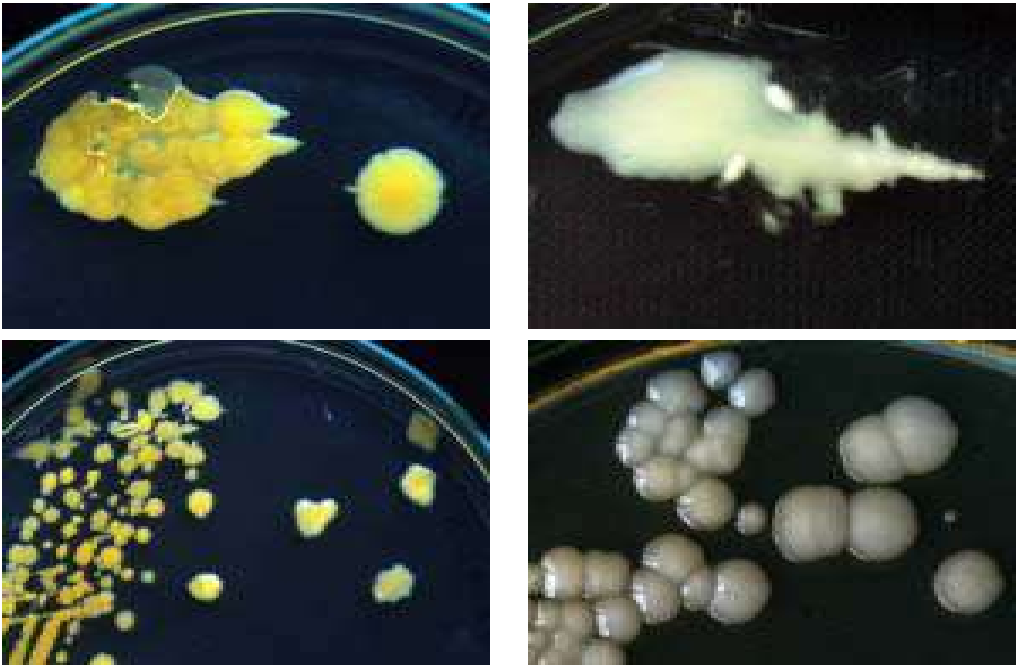
### 2.5.1. Modern tools in microbial taxonomy/research

Identification and taxonomic placement of microorganisms are important for better understanding and use of bacteria, fungi and actinomycetes. Several modern tools are now available for identification and phylogenetic analysis of the microorganisms. Molecular sequencing of the 16S rRNA gene fragment of bacteria followed by BLAST analysis for bacterial identity is considered as Gold Standard in the microbial taxonomy. Using 16S rRNA protocol, identification of 125 bacteria that include plant growth promoting rhizobacteria, arbuscular mycorrhizae spore associated bacteria isolated from coconut and arecanut based cropping systems, cocoa gardens and acid tolerant bacteria isolated from extreme acid soils of Kerala were carried out and submitted to NCBI and Gen Bank Number for 123 of them have been obtained.

BIOLOG, which identifies bacteria, fungi and actinomycetes based on their ability to use different carbon and amino acids, is a proprietary cell-based phenotypic assay technology widely used for identification of microbes. About 500 bacteria isolated have been identified using GenIII plates through BIOLOG. The BIOLOG system was procured under a NAIP funded network scheme by ICAR.

### 2.5.2. Advances in PGPR research/ PGPR formulations

Plant growth promoting rhizobacteria (PGPR) are now being considered as new microbial resources for developing bioinoculants. They are known to possess multiple plant growth promotion properties. About 1031 aerobic heterotrophic and endophytic plant growth promoting rhizobacteria were isolated from rhizosperes of coconut, arecanut and cocoa cultivated in different agro-ecological zones of Kerala, Karnataka, Tamil Nadu, Andhra Pradesh and Maharashtra in an ICAR funded network project on AMAAS. All of them were screened for plant growth promoting properties from which the best were assayed in *in vitro*, growth chamber and



PGPR diversity in coconut based system

green house for ability to improve plant growth parameters of rice and cowpea. The identities of the PGPRs were ascertained by 16S rRNA and BIOLOG protocol. Finally forty three isolates (22 from coconut and 21 from cocoa) were tested for their ability to promote robust growth of coconut and cocoa seedlings. Based on the whole dry matter weight index of seedlings, four coconut and four cocoa isolates were shortlisted for bioincoulant development. The most effective bacterium from each crop was selected and developed into talc based bioformulation. *Bacillus megaterium* isolated from coconut rhizosphere was branded as 'Kera Probio' while *Pseudomonas putida* of cocoa as 'Cocoa Probio'. Both these PGPRs, which were also found to be effective for vegetable crops such as tomato, brinjal and chilli, are available to the farmers through ATIC of the Institute. Efficient PGPR isolates have been submitted to National Agriculturally Important Microbial Culture Collection (NAIMCC), NBAIM, Mau.


Plant growth promoting bio-agent formulations

### 2.5.3. Whole genome sequencing of PGPR

In-depth knowledge on the whole genome sequence of plant-beneficial bacteria and its genes and functions helps in developing a better bioinoculant technology. Whole genome sequencing of three PGPRs, one each from coconut, cocoa and arecanut, was carried out by shotgun multiplexing using the next generation 454-sequencing platform. The sequences were then analyzed using bioinformatics tools for genome size and GC content; various genes involved in plant growth promoting properties and other important metabolic functions were predicted and annotated. The sequences have been deposited with EBI. This was an outcome of public-private partnership between CPCRI and SciGenom Lab Pvt. Ltd. Kochi.

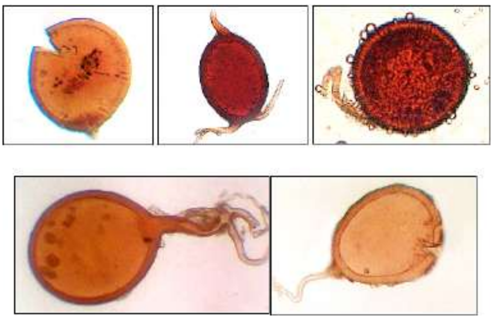
### 2.5.4. NGS-transcriptome analysis of acid tolerant *Bacillus* spp.

While whole genome sequencing gives information on the presence or absence of genes and their possible functions, the transcriptome analysis actually yields information on the functions carried out by the genes present in an organism. To analyse the molecular mechanisms employed by *Bacillus* to mitigate acid stress, transcriptome level studies were initiated. Next-generation sequencing (NGS) has provided a new method for mapping and quantifying transcriptomes. The transcriptome profile of acid tolerant *Bacillus,* when exposed to pH 2.5, was generated using Solexa/Illumina RNA-seq based NGS technologies as these technologies facilitate investigations into the functional complexity of transcriptomes.

For transcriptome sequencing, more than 6.76 million paired end sequencing reads were produced. These reads were assembled into 11,326 non-redundant transcripts which were annotated with their gene description. Differential Gene Expression (DGE) analysis was performed using DESeq software. The normalization was done using DESeq in-built normalisation method using Negative Binomial (NB) distribution. A total of 182 transcripts were differentially regulated, out of which 83 were up- and 99 were significantly down-regulated under acid stress in the *Bacillus* transcriptome. 152 transcripts were found to be exclusively acid induced.

### 2.5.5. Diversity of AMF in coconut/ arecanut based cropping systems

Arbuscular mycorrhizae fungi (AMF) form a critical component of soil biota that help in sustainable function of plantation crop ecosystem through improved nutrient and water absorption. AM diversity was studied in coconut and arecanut based cropping systems in an ICAR Netwrok Project under AMAAS. Forty five AMF species belonging to the family *Glomaceae*, *Acaulosporaceae*, *Gigasporaceae*, *Clarideoglomaceae* and *Diversisporaceae* were identified in both the palm based cropping systems. Eighteen new records in coconut rhizosphere in crop mixed agroecosystem are also reported. Twenty three cultivable spore associated bacteria (SAB) were isolated from *Glomus* and *Gigaspora* spp. (from coconut and arecanut based cropping), the maximum germination effect on *Glomus* spores was observed by *Bacillus cereus* and *Citrobacter amalonaticus* with 40 % increase in spore germination over uninoculated control. Thirty two AMF pure cultures of *Glomaceae* (18) and *Clarideoglomaceae* (14) were obtained and *Clarideoglomus etunicatum* GLA1CK was found to give the best growth promotion in coconut seedlings, while *Glomus macrocarpum* GLNc showed the best performance in arecanut seedlings. The AM diversity, species richness and evenness were found to be influenced by the type of intercrops cultivated in the palm based cropping system as well as the physico-chemical parameters of the soils.



Arbuscular mycorrhizal diversity in coconut based system

### 2.5.6. Biochars from coconut wastes

Biochar is a soil amendment produced by charring plant based biomass in an oxygen limited environment. Application of this recycled material improves C sequestration in soil, promotes microbial activity and soil nutrients and physical properties aiding in better crop production. Biomass residues having high lignin contents are ideal substrates for production of biochars. Coconut and arecanut residues such as coir pith, tender coconut husk, coconut leaf petioles and arecanut husk were converted to biochars using a simple charring kiln. The physico-chemical properties of these biochars, their impact on soil nutrient, enzyme and microbiological properties and effects on coconut leaf degrading earthworm have been assessed. Biochars had medium levels of organic carbon (< 25%), 1-1.2% N with arecanut husk biochar having the highest potash content. Addition of biochars produced from coconut wastes improved the soil organic carbon, total N, available P and K and pH and soil microbial populations with graded dose compared to recommended fertilizer dose and control. No detrimental effect of mixing tender nut husk biochar (at graded doses)

Biochar made from Coconut and Arecanut wastes in soil was observed on earthworms (*Eudrilus* sp.) through this assay.

### 2.5.7. Microbial diversity analysis in coconut leaf vermicomposting using pyrosequencing

Vermicomposting depends greatly on the microorganisms present in the substrates, earthworm gut and composting environment. The microbial community dynamics during the different vermicomposting stages employing pyrosequencing was carried out using NGS based pyrosequencing technology. The bacterial 16S rRNA was amplified with bar-coded primers and sequenced using 454-Gs-FLX Genome sequencer of the genomic DNA extracted from different stages of coconut leaf vermicomposting. The data output was analyzed using QIIME and mothur software. The analysis generated 68,438 unique sequences and 18,637 OTUs (Operational Taxonomic Units). The results indicated that the diversity of the bacteria increased as the substrates were converted to vermicompost by the earthworms and then decreased in the finished product to stabilize on par with the initial stage. The $\alpha$-proteobacteria and Bacteroidetes were the dominant phyla present in the samples followed by $\gamma$-proteobacteria and Actinobacteria. Unlike Verrucomicrobia, a significant increase in the Firmicutes numbers was recorded from the first to fourth stage of the vermicompost production.

### 2.5.8. Impact of coconut leaf vermicompost on soil microbial community structure

A PCR based T-RFLP studies were carried out to understand changes undergoing in the microbial community structure of the soil upon addition of vermicomposts produced from different palm wastes. The T-RFLP analysis showed that there was significantly different microbial community structures in the soil and vermicomposts. The incubation samples showed that microbial community structure moved closer to that of the vermicompost upon mixing with the soil indicating that the addition of vermicompost altered the microbial structure of the soil and pulled it more close to its own structure. However, by the 100$^{th}$ day of the incubation, it was observed that the microbial community structure in soil + coconut leaf vermicompost mixture slowly returned to that present in soil alone. This study clearly indicated that vermicompost addition significantly altered the microbial community structure of the soil in the initial period. It points to the fact that there is addition of the microbial communities from the vermicompost into to soil which precisely proves that vermicomposts are foci for dissemination microorganism, more so of the plant-beneficial nature that leads to spurt of activities in soil that could improve the mineralization and nutrient availability to the plants, prevent build-up of soil pest/pathogens, allow stronger plant establishments besides several other functions that improve the soil fitness for sustainable crop productivity.

### 2.5.9. DNA bar coding of *Eudrilus* sp.

Barcoding is a concept that uses identifying organisms using short gene sequence that is standard portion of the organism's genome. A dedicated website for such barcodes named 'Barcode of Life' functions as repository for such DNA sequences. The coconut leaf vermicomposting earthworm *Eudrilus* sp. was 'barcoded' using the short 658-bp locus (Folmer region) of the mitochondrial cytochrome c oxidase subunit I (*COI*) gene which provides a large variation between species, yet a relatively small amount of variation within a species. The partial mitochondrial CDS of *COI* gene of *Eudrilus* was deposited in the Barcode of Life Datasystems (BOLD) database and the DNA barcode was received.

### 2.5.10. Coir-pith composting using poultry manure amendment

A simple short-duration composting technology of the highly recalcitrant coir pith without using urea was developed. The technology involved co-composting coir pith with solid poultry manure along with lime and rock phosphate amendments. Poultry manure addition hastened the composting of coir pith to a final product in 45 days period that possessed physico-chemical characteristics required for quality organic manure. The C:N ratio, which is considered as a maturity index of composting process, reduced during the composting process to 21.42. The quality of coir-pith compost was found suitable for plant growth promotion as indicated by a bioassay carried out on cow pea. The coir-pith compost can, thus, form an important recycled soil input for crop production.

### 2.5.11. Vermiwash production technology

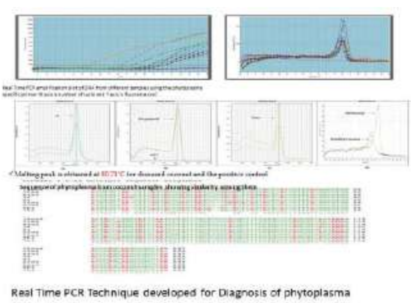
Production of vermiwash from coconut leaf vermicompost was standardized. It has an alkaline pH; contains major and minor nutrients, growth hormones, humic acid and plant beneficial bacteria. Field trials with cowpea, maize and bhendi in CPCRI farm showed its capacity to increase biomass and yield of the crops accompanied by enhanced soil microbial activities. Application of the CLV in red sandy loam soil produced an increase of 36% of fresh biomass weight, nodule numbers and 43% nodule fresh weight in cowpea at 1:10 dilution compared to control. In maize, increase in cob yield by 5-10%, fresh cob weight increase of 29-64% and in bhendi (okra) 22 to 33% increase in yield were recorded when CLV was applied at 1:5 dilution. To validate these results, field trials were taken up in farmers' plots at Majal and Edneer area in Kasaragod. Bitter gourd and cowpea crops were taken up at Majal while amaranthus, cowpea and green chillies at Edneer. In both the places, observations indicated that application of vermiwash resulted in yield of crops on par or slightly lower than the plots that received regular fertilizer inputs as per farmers' practice. However, the farmers listed many other important benefits like, healthy plant and root hair growth, lesser pest and disease damage, larger leaf size and deep leaf colour, ability of plants to stay longer without wilting in field as well as longer time of remaining fresh in case of amaranthus after harvesting etc.

### 2.5.12. Allelopathic interaction in coconut based cropping system

Allelopathy is a kind of ecological interaction wherein beneficial and detrimental chemical interactions among plant organisms and microorganisms take place in the soil environment which impacts the growth and yield of the crops. Allelopathic studies in coconut based cropping system was conducted through an ICAR funded AP Cess Project. Leachates from coconut and its intercrops are rich in allelochemicals, particularly phenolic types. The allelochemical flux (volume and concentration) in the coconut based cropping system was influenced by amounts of precipitation, intervals between precipitation and the stages of plant growth in the plot. The plant beneficial microorganisms like the free-living nitrogen fixers were sensitive to the coconut leachates, whereas, the phosphate solubilizers and plant growth promoters were stimulated in numbers in their presence. The rhizosphere soil of coconut as well the bulk soil had microorganisms that could catabolise the allelochemicals that possibly nullify the negative allelopathic effect of the allelochemicals on intercrops. Among the different intercrops studied using soil microcosm trials, black pepper was found to have intrinsic capacity to grow well in coconut basin, whereas, nutmeg, clove, vanilla and Bhendi required the support of bulk soil microflora to overcome the suppressive effect of allelochemicals.

### 2.5.13. Production and supply of bioresources

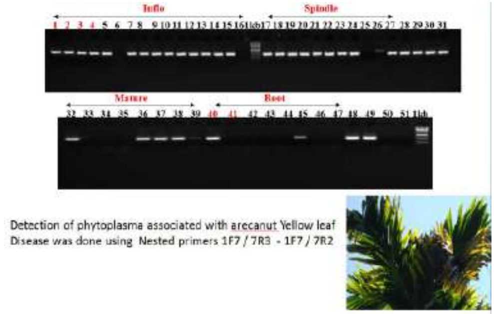
In the period 2005 to 2014, more than 24 lakh coconut leaf degrading




Diagnosis of root (wilt) phytoplasma through real-time PCR

Leaf rot management in root (wilt) affected coconut

Bioprimed vigourous coconut seedlings




Molecular diagnosis of phytoplasma associated with areca YLD

earthworms, 160 t of coconut leaf vermicompost, 2000 l of coconut leaf vermiwash and 900 kg of *Pleurotus florida* mushroom spawn were produced. The vermicompost was mainly used for research purpose in several projects of Agronomy and Soil Science, Plant Pathology, Plant Breeding and Genetics, Plant Physiology and Biochemistry, Biotechnology sections. Surplus compost was sold to farmers and to those who produced vegetable seedlings under the SHM programmes. About 5 lakhs earthworms and 45 t of vermicompost and 700 kg of mushroom spawn were sold to farmers, unemployed youth, self help group and others.

## 2.6. Integrated disease management in palms and cocoa

### 2.6.1. Root (wilt) disease of coconut and yellow leaf disease of arecanut

Root (wilt) disease (RWD) of coconut is still a major threat to coconut cultivation in India. Association of phytoplasma was established way back in 1980s and 1990s through electron microscopy and vector transmission studies. However, the rapid spreading of the disease in Tamil Nadu in the recent years is a major concern. After the establishment of phytoplasmal etiology, strategies were developed for management of the RWD through management of leaf rot, integrated nutrient management and breeding for resistance using the disease free mother palms. Attempts were made to produce polyclonal antiserum against RWD phytoplasma. Direct antigen coated indirect ELISA( DAC-ELISA) technique using polyclonal antiserum for detection of coconut RWD was standardized and the same was employed successfully to diagnose the RWD affected palms in new emerging areas as well as to select disease free mother palms of coconut for breeding and multiplication of disease free planting materials. Attempts made during 2000-2005 to detect a phytoplasma associated with RWD through PCR using universal primers had given inconsistent results.

#### 2.6.1.1. Molecular detection of Phytoplasma

Later, phytoplasma associated with RWD of coconut was detected and characterized by semi-nested PCR. Two primer sets (1F7/7R3) and seminested primer pair 1F7/7R2 were designed from sequencing of a 1.8-kb fragment (GenBank No. FJ794816) amplified by primers P1/P7 from a diseased sample. Since the DNA isolated by normal CTAB method was not able to detect the phytoplasma by PCR because of low concentration, a phytoplasma enriched DNA isolation protocol was developed. Sequence comparisons of the 16S rRNA genes showed that the phytoplasma associated with RWD of coconut in 99 % identity with sugarcane white leaf phytoplasma and belongs to 16SrXI group of phytoplasma. Further, a real time PCR based detection for RWD phytoplasma was developed using double-stranded DNA intercalating dye SYBR green. Primers were designed to specifically amplify a 218 bp fragment from the 16S ribosomal DNA region.

### 2.6.2. Managing *Phytophthora* diseases

Bud rot of coconut; fruit rot, crown rot and bud rot in arecanut and black pod and stem canker of cocoa are the major *Phytophthora* diseases affecting plantation crops.

#### 2.6.2.1. Bud rot of coconut

Field trials conducted in an area of 23.12 ha in disease endemic areas of Kasaragod district for the management of bud rot disease, indicated that placing 2 perforated sachets each containing 5g of mancozeb 50WP (Indofil M-45) in the innermost leaf axils of coconut just before the onset of monsoon (May end) and thereafter at two months interval is effective as a prophylactic measure. Complete removal of infected tissue in bud rot disease affected palms and pouring of mancozeb solution by dissolving 5 g in 300 ml of water as a curative treatment is found to be effective for controlling bud rot disease of coconut.

Studies conducted on epidemiology indicated that inoculum present in the crown of bud rot affected palms was found to be a potential source for disease spread. *Phytophthora* propagules were isolated from crown debris of dead coconut palms even after one year. *Phytophthora* was also isolated from coconut roots and soil at the base of affected palms. Rain water was also found to be a carrier for *Phytophthora* propagules. The common slug, *Deroceras* sp. is abundant in coconut and cocoa gardens during rainy season. Sporangia were observed in the faeces of 10% of slugs collected from the trunk of coconut palms during June-July when there was no incidence of bud rot in the garden and more than 90% of slugs collected from the cocoa plants with black pod incidence. Sporangia survived and remained very infective after passing through the alimentary canal of the slugs.

### 2.6.2.2. Deciphering *Phytophthora* diversity

Over 136 *Phytophthora* isolates causing bud rot and fruit rot diseases of coconut were collected from major cococnut growing areas and characterized for their morphological, cultural and pathogenic traits. Out of 136 *Phytophthora* isolates, 131 isolates were identified as *P. palmivora*, four isolates as *P. nicotiane* and one isolate as *P. capsci*.

A total of 369 *Phytophthora* isolates infecting cocoa were collected from 328 locations in 13 districts of Kerala, 7 districts of Karnataka and 2 districts each of Tamil Nadu and Andhra Pradesh. Variability in symptoms of black pod diseases was also recorded.

The molecular level identification of the five species of *Phytophthora* was done by PCR detection using ITS1/ITS4 primers and sequence analysis. The identification of *P.palmivora* and other *Phytophthora* species was further confirmed based on nucleotide homology and phylogenetic analysis. RAPD analysis of selected isolates of *Phytophthora* species was conducted to find out the molecular diversity. RAPD analysis revealed the inter and intraspecific diversity in *Phytophthora* spp./ *P. palmivora* isolates.

### 2.6.2.3. Climatic variables with *Phytopthora* disease

Monthly mean, minimum and maximum temperature and relative humidity, no. of rainy days total rainfall and *Phytophthora* disease incidence per month were recorded. Bud rot incidence started in the month of June, reached a peak during September and became the lowest during November. Black pod disease incidence initiated two weeks after the onset of south-west monsoon, reached a peak in August and the lowest incidence was recorded in the month of October. Dried cankers, mummified fruits (pods infected during the end of rainy season of previous year), soil, foliar infection, infected seedlings (self sown) and rain water were found to be the major sources of inoculum for *Phytophthora* diseases of cocoa.

### 2.6.2.4. Black pod and stem canker disease of cocoa

The black pod management field trial on cocoa indicated that spraying of all pods, main stem and branches with copper oxychloride (Blitox 50 WP 0.5%) or metalaxyl + mancozeb (Ridomil gold 0.5%) or potassium phosphonate (Akomin 0.5 %) just before the rainy season (May end or June 1st week) and thereafter at monthly intervals till September and cultural practices (removal of infected pods and proper pruning) are effective in control of the *Phytophthora* diseases in cocoa.

#### 2.6.2.5. Fruit rot of arecanut

Based on the earlier studies before 2004, spraying of 1% Bordeaux mixture just before the onset of south west monsoon and one more spray after 40-45 days to the bunches was recommended for the management of fruit rot (koleroga or mahali) of arecanut. Covering the bunches before monsoon with polythene bags was also found to protect the arecanut from fruit rot. Though these methods are highly effective, due to paucity of skilled climbers, farmers are unable to adopt the timely prophylactic control measures. Apart from this, continuous heavy rainfall during certain years (like 2013) will hamper the management activities, thereby resulting in heavy incidence of fruit rot. In recent years, other chemicals like potassium phosphonate, ridomil and few other new fungicides were screened against *Phytophthora meadii,* the causal agent of fruit rot and the effective ones are being evaluated to find out the more efficient and effective method for management of this disease.

### 2.6.3. Integrated disease management (IDM) for major diseases

Integrated disease management developed for major diseases were further improved, evaluated and demonstrated in the farmer's fields. Apart from the chemicals and cultural methods of control, the biocontrol using *Trichoderma harzianum, Pseudomonas fluorescence* and *Bacillus subtilis* were developed for the diseases like bud rot of coconut, leaf rot of coconut, stem bleeding and basal stem rot diseases of coconut and arecanut, stem canker disease of cocoa. Application of consortium of biocontrol agents (*Pseudomonas fluorescens* and *Bacillus subtilis*) along with phytosanitation was found to be effective in the management of leaf rot disease. The performance of bioagents was on par with the fungicide treatment as revealed in the leaf rot management demonstration trial conducted in 25 ha area of Pathiyoor Panchayat (Muthukulam Block) in Alappuzha District of Kerala.

From field trials, the following treatments were found very effective in managing coconut bud rot disease when integrated with cultural practices.

i. Pouring mancozeb solution (5 g in 300 ml/palm) + placing pesticide slow release cake/(PSRC) pieces (each containing 5 g mancozeb/palm) in the innermost leaf axils.

ii. Pouring Akomin 0.5% solution to the leaf axil pit around the base of the spindle leaf: 300 ml/palm.

Keeping two pieces of *Trichoderma* enriched coir pith cake ( TCPC) containing *T.viride* in the innermost leaf axils of each palm at bimonthly interval starting from last week of May. Similarly the TCPC was found effective for management of stem canker disease of cocoa caused by *Phytophthora*.

### 2.6.4. Low-cost technologies/ products for plant protection

A coir pith formulation for effective delivery of *Trichoderma* which is named as *Trichoderma* enriched coir pith cake (TCPC) was developed. Compared to the shelf life of about 5 to 6 months of talc formulation of *Trichoderma*, shelf life of TCPC was found to be up to one year.

Considering the convenience in handling of this coir pith cake formulation, a pesticide slow release cake (PSRC) was also developed. The PSRC incorporated with 5 g mancozeb could be placed easily in the inner most leaf axils of coconut and can replace polythene sachets.

Pesticide slow release product containing mancozeb

Clearing affected area of cocoa plant for TCPC application

Application of TCPC

Wound packing with TCPC

## 2.7. IPM technologies for key pests of coconut

The IPM technologies developed for the management of key pests of coconut are well-defined, perfectly fine-tuned and found effective in the changing pest scenario of palm ecosystem. Adoptionm of these technologies would significantly enhance sustained production, ensuring good palm health which is very crucial to export oriented enterprises in value addition and diversification in highly competitive, quality conscious global markets.

### 2.7.1. Rhinoceros beetle

Two major biocontrol components *viz.*, *Oryctes rhinoceros* nudivirus (OrNV) @ 12 infected beetles/ha, and green muscardine fungus (*Metarhizium anisopliae)* @ $5x10^{11}$ spores/$m^3$ were integrated with pheromone trapping technology (one trap/ha) and successfully validated in area-wide community approaches.

Leaf axil filling of neem cake, marotti cake or *Pongamia* cake (250 g) admixed with equal volume of river sand was found effective in the prophylactic management of rhinoceros beetle. The highest reduction (45.2%) in leaf damage by rhinoceros beetle was observed in palms treated with *Pongamia* cake admixed with sand.

A wedge-shaped cake with botanical extracts of *Clerodendron infortunatum* and *Chromolaena odorata* was developed for the prophylactic leaf axil filling against rhinoceros beetle infesting coconut. Placement of two botanical cakes on the top most leaf axils reduced 30-40% leaf damage.

Perforated sachet containing 3-5 g chlorantraniliprole (Ferterra) granules safeguarded juvenile palms up to 5 months. Initial establishment of coconut seedlings with this treatment was very successful and devoid of rhinoceros beetle attack.

A unique concept of coconut-based crop-habitat diversification for regressing

Dispensing GMF on rhinoceros beetle breeding grounds

Metarhizium infected grubs of rhinoceros beetle

OrNV Infected and healthy grubs of rhinoceros beetle

Chlorantriniprole Sachet for leaf axil filling

rhinoceros beetle attack was initiated to diminish the host-specific volatiles of coconut under multiple-cropping system warding off rhinoceros beetle attack in juvenile gardens.

The conventional bucket trap used for trapping adult rhinoceros beetle was refined with a PVC pipe trap with height 2 m and diameter of 11 cm. Bottom of the PVC pipe was closed with an end plug. Two windows were cut (10 x 7 cm) at a distance of 26 cm and 60 cm from top on opposite sides. An average of 20-30 beetles per trap per month was recorded. Beetle catch was found to be three-folds higher than the conventional bucket traps.

Farm level production of entomopathogenic fungus, *Metarhizium anisopliae* involving rural educated women by refining the low-cost multiplication process was established. Field delivery of this Green murcardine fungus on breeding grounds reduced the incidence of rhinoceros beetle attack (45%) significantly.

Installation of PVC pheromone trap

### 2.7.2. Red palm weevil

Cigna (Lufenuron 5.4% W/W EC) @ 0.01%, a chitin-synthesis inhibitor induced 55-65% larval-pupal intermediates in RPW grubs with retention of larval structures, blister formation on grubs, softening of cuticle, precocious pupation, unfastened fibrous cocoons and malformed adults. Application of Lufenuron 0.01% would be an effective technology for the biorational management of the pest since RPW grubs undergo ten larval instars.

A prototype of RPW detector based on acoustic system was developed in association with Centre for Development of Advanced Computing (CDAC), Thiruvananthapuram and the electronic gadget is being standardized for effective field detection of RPW infestation on coconut. This gadget could be linked to mobile phone for timely and instantaneous alert based on the bite signals of feeding grubs.

Curative treatment with imidacloprid (0.02%) or spinosad (0.013%) was found effective in the management of red palm weevil (RPW) infestation. The highest


RPW detector prototype

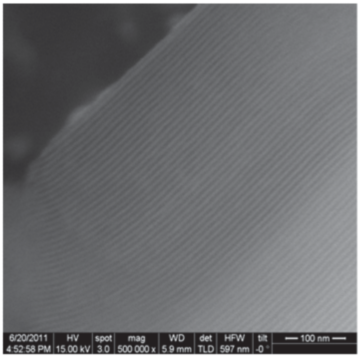
recovery (79.1%) of RPW infestation was registered in imidacloprid (0.02%) treated palms. Higher virulence of local entomopathogenic nematode (EPN) strain of *Heterorhabditis indica* (LC 50 355.5 IJ) in the suppression of *Rhynchophorus ferrugineus* grubs as well as greater susceptibility (82.5%) of pre-pupal stage than that of grubs was significant. Synergistic interaction of *H. indica* (1500 IJ) with imidacloprid (0.002%) against grubs holds promise in the field level management.

Serine protease inhibitors *viz.*, aprotinin (50 μg), soybean trypsin inhibitor (50 μg) and phenyl methyl sulphonyl fluoride (1700 μg) inhibited the gut proteinases of *R. ferrugineus* such as trypsin, elastase-like chymotrypsin and leucine amino peptidase affecting the digestion and nutrient uptake of the insect leading to impaired growth and development.


*Hirsutella thompsoni* isolate collected from Hassan district Karnataka and *H. indica* infected RPW pre-pupae

### 2.7.2.1. Development of nanomatrix for delivery of red palm weevil pheromone

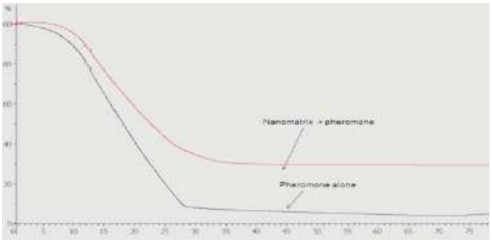
In India, aggregation pheromone (4 methyl 5 nonanol +4 methyl 5 nonanone 9:1) is used in tandem with food baits to attract the weevils. Though effective, the lures need to be replaced once in 3 – 4 months interval. Nanoporous materials are a novel carrier/ dispenser for the volatile signaling molecules with controlled spatiotemporal release rates. A nano dispenser made with ordered pore channels was used for loading the pheromone and kairomone of red palm weevil. Characterization by Field Scanning Electron Microscopy (FESEM) and X - ray Diffraction (XRD) confirmed the ordered structure of the pores.



FESEM image of ordered pores in the nanomatrix

**Thermal gravity analysis of nanomatrix loaded with pheromone**

Pheromone when loaded in nanomatrix showed delayed dissipation as compared to pheromone alone when assayed by thermal gravity analysis (TGA). Fourier transform infrared (FT-IR) measurements confirmed the presence of pheromone in the mesoporous silica. Further, studies on release rate of the entrapped pheromone in the nanomatrix using the Gas Chromatography revealed lower release rate of volatile compounds as compared to the commercial lures. The release rate from the nanomatrix was sufficient to cause physiological response that was ascertained by electrophysiological techniques (electroantennogram) and their flight dynamics to pheromone from nanomatrix was confirmed by imaging with high speed videography. Field test of pheromone loaded in nanomatirx captured more weevils as compared to commercial lure.




Thermal gravity analysis curve of nanomatrix loaded pheromone

**2.7.2.2. Pheromone synergists from host volotiles**

Placing of food baits (banana/ pine apple) with pheromone lure in the bucket trap had synergistic effect in attracting the red palm weevils. Identifying the volatiles released from food bait facilitated in developing kairomonal blends that could be used in tandem with pheromone rather than depending on fresh food baits. The physiologically relevant volatiles from food baits (fermenting banana, pineapple and neera) causing the antennal response in red palm weevil were identified by combing the chemical detector and biological detector (Gas chromatograph – Mass spec. coupled with electroantennography - GC

MS-EAD). Of the 48 compounds released from food bait, the antennae of the weevil responded to ethyl acetate, isobutyl butyrate, phenol, n butyl butyrate and guiacol.

The kairomonal blends (A, B and C mix) were prepared based on the proportion in the host volatiles and electrophysiological response. Among the blends, 'A mix' had major and minor compounds, 'B mix' had minor compounds and 'C mix' had ethyl acetate alone.The compounds causing physiological response in the weevil antennae need not be behaviourally active. In wind tunnel behavioural assay, pheromone (4 methyl 5 nonanol + 4 methyl 5 nonanone 9:1) along with 'blend A' (having major and minor components) caused maximum activation.

Pheromone and kairomone blends were evaluated for field efficacy at Aliyarnagar, Vepankulam in Tamil Nadu, Ambajipetta in Andhra Pradesh and Ratnagiri in Maharashtra. Across the centres, the pheromone loaded in nanomatrix combined with 'A blend mix' trapped higher number of weevils than the reference commercial lure.

### 2.7.2.3. Integrated management of red palm weevil

Closer planting of coconut and deliberate palm injuries are key factors for flare-up of the pest in this region. Farmers in these tracts were sensitized about the pest by correct identification of damage symptoms and perform timely management practices. Scouting of palms at regular intervals for the characteristic damage symptoms was explained and trained through field schools. Complete destruction of crown toppled palms so as to eliminate the residual population was also included. Front-line demonstration studies on IPM of RPW conducted at Cheppad, South Kerala revealed reduction in incidence from 6.07% to 1.59% in a period of two years which further reduced to 1.14% during third year.

### 2.7.3. Coconut eriophyid mite

Three sprayings of palm oil (200 ml) and sulphur (5g) emulsion on the terminal five pollinated coconut bunches during January-February, April-May and October-November evinced significant reduction (67.4% to 69.8%) of mite incidence. Mite population in treated palms was also reduced drastically.

Studies on natural enemies of coconut eriophyid mite could identify eight species of predatory mites, a species each of coccinellid, thrips and syrphid (insects). Predators were present in 80% of the nuts with predominance of *Neoseiulus baraki*. The most potential acaropathogenic fungus, *Hirsutella thompsonii* was isolated from various locations of Kerala, Karnataka and Orissa. A total of 42 isolates of *H.*

*thompsonii* were collected from nut samples from various locations and were screened for pathogenicity on coconut mite.

Management trial of coconut eriophyid mite conducted in farmers' field using talc based formulation of *H. thompsonii* @ 20 g/l/ palm containing 1.6 x $10^8$ cfu with a frequency of three sprayings per year resulted in 63%-81% reduction in mite population. Multi-location trials were initiated in three centers of AICRP Palms in Ambajipeta (Andhra Pradesh), Ratnagiri (Maharashtra) and Aliyarnagar (Tamil Nadu) for evaluating effectiveness of *H. thompsonii* in management of coconut mite.

Coconut water was found to be an ideal medium for mass production of *H. thompsonii*, as evidenced by comparable growth rate (1.91 cm/20 days), spore production (12.9x $10^4$/$cm^3$) and yield of dry mycelium mat (1.017 g/100 ml) to that of standard fungal growth media.

### 2.7.4. Bio-suppression of coconut leaf eating caterpillar

Black headed caterpillar *Opisina arenosella* is a major pest of coconut. Caterpillars feed on the chlorophyll containing parenchymatous leaf tissues resulting in massive leaf drying specially in coastal and backwater areas. Coconut palms with severe infestation of leaf eating caterpillar recorded a reduction in a nut yield loss of 45.38%. Sporadic outbreaks of coconut leaf eating caterpillar, *Opisina arenosella* was observed in different parts of Kerala (Vechoor, Kottayam, Valiathura, Trivandrum) and Karnataka (Arsikare).

The biocontrol technology for the management of *Opisina arenosella* using augmentative release of stage-specific parasitoids *viz*., *Goniozus nephantidis* and *Bracon brevicornis* @ 20 parasitoids palm$^{-1}$ release$^{-1}$ was successfully field validated in Vechoor (Kottayam district, Kerala), Bhimapalli (Thiruvananthapuram district, Kerala) and Arisikare, Karnataka. Full-fledged recovery of infested palms was recorded in a period of one year and the recovered palms yielded substantially.

Moderate level of *O. arenosella* infestation was observed in Trivandrum district in 62.5% coconut palms (WCT variety) with 61% leaf infestation during 2011-12. Monitoring and release of stage specific parasitoids could reduce leaf damage to the tune of 63% and population of *O. arenosella* to the tune of 91.3% in a period of eight months and complete recovery of palms from *O. arenosella* incidence in the parasitoid released plot in a period of two years. In a period of 12 months at Vechoor, South Kerala, the pest population declined to 94.7% (304 per 100 leaflets to 27 per 100 leaflets) and complete recovery of palms was recorded in a period of 18 months.

Rejuvenation of palms through balanced nutrition and need-based irrigation improved the overall health status of the palms and the infested palms started bearing nuts. Scorched appearance during the advanced stage of the pest incidence disappeared and new leaves emerged were devoid of any pest attack. Local famers in these regions were so convinced on the complete recovery of palms and started adopting the technology for the successful management of leaf eating caterpillar and yield enhancement.

### 2.7.5. White grub

Emergence of adult *Leucopholis coneophora* initiated at 195.5 lux and terminated at 0.33 lux and mechanical collection of emerging adults during this period was found superior to light trapping. More than 90% reduction in grub population was recorded in plots treated with bifenthrin (4 kg a.i per ha) and chlorpyriphos (4 kg a.i per ha). Dissipation studies of bifenthrin indicated residue level of 2.59 ppm in soil in 30 days after treatment whereas it was found negligible for chlorpyriphos. Soil application of *Steinernema carpocapsae* @ 1.2 crore IJ palm$^{-1}$ in combination with imidacloprid (0.004%) reduced root grub population to an extent of 54%.

### 2.7.6. Surveillance for emerging pests

An effective vigil is being kept over all the coconut growing regions of the country including island territories of Lakshadweep and Andaman to identify and report the possible invasion of the invasive pest, *Brontispa longissima*. The pest has been reported to cause economic setbacks in neighboring countries including Maldives, China and Union of Myanmar. This invasive pest is fortunately not recorded so far from any of the areas surveyed in India including Lakshadweep and Andaman Islands.

Surveillance on outbreak of coconut leaf eating black headed caterpillar (*Opisina arenosella*) indicated very low to medium incidence in Kerala during 2008-13 and high incidence in parts of Karnataka during 2012-13.

## 2.8. Physiology and Biochemistry

### 2.8.1. Modeling impacts and adaptations to climate change and field response of coconut and cocoa to increased temperatures and $CO_2$

The impact of climate change on coconut production was studied using a generic model Infocrop-coconut which was calibrated and validated to simulate the coconut production of different agro-climatic zones. The validated model was further used to simulate the coconut production under future climate.

The climate change scenarios A2, B2 and A1B for coconut growing regions were extracted from PRECIS RCM, which has HADCM3 as its GCM. The model was run using these scenarios and the projected elevated $CO_2$ to simulate the coconut production under future climate. Of all the scenarios, A1B is the most optimum wherein coconut productivity on all India basis is likely to go up by up to 4%, 10% and 20% during 2020, 2050 and 2080 respectively. In the West Coast, yields are projected to increase by up to 10%, 16% and 39%, while in the East Coast, yields are projected to decline by up to 2%, 8% and 31% in 2020, 2050, and 2080 respectively. Thus, on all-India basis, climate change is projected to increase coconut production by 4.3 % in A1B-2030 scenario. In places where positive impacts are projected, current poor management will become a limiting factor in reaping the benefits of $CO_2$ fertilization. While in adverse impact regions, adaptation strategies can reduce the negative impacts. Hence, better irrigation and fertilizer management is expected to further increase the yields.

### 2.8.1.2. Response of coconut and cocoa to climate change

The interaction effect of climate change variables $CO_2$ and elevated temperature (ET) with drought and nutrients on growth and development of coconut seedlings was studied in an Open Top Chamber (OTC) at CPCRI, Kasaragod. Seedlings were exposed to elevated $CO_2$ ($ECO_2$ 550 and 700 ppm), ET (3°C above ambient) and elevated ET+$ECO_2$ (550 ppm $CO_2$ + 3°C). In each OTC, a set of plants were grown under normal condition and another set was subjected to drought (50% FC) and a third set was maintained at 150% recommended dose of fertilizer (RDF).

Coconut seedlings under elevated $CO_2$ treatments accumulated significantly higher biomass. It was 1.13 and 1.98 kg palm$^{-1}$ with 550 and 700 ppm $CO_2$ respectively as against 1.10 in ambient treatment and least in ET treatment (0.91). Plants grown at elevated $CO_2$ had lower stomatal conductance, which did not have significant effect on photosynthesis, but reduced the transpiration significantly. As a consequence, the $ECO_2$ treatment had higher WUE, 2.53 and 2.93 g litre$^{-1}$ at 550 and 700 ppm, respectively as against 2.10, 1.79 of ambient and ET treatments, respectively. Thus, the water requirement to produce unit biomass in $ECO_2$ treatment is less. This indicated that, at the present level of moisture available, coconut would produce more biomass under future climate. However, under water limited condition, photosynthesis per unit water transpired is less, as a consequence the WUE was low in stressed plants.

Cocoa plants jorquette (branch) after attaining certain height. Jorquetting was seen early, in those plants grown at higher temperature compared to ambient grown plants. On the other hand, jorquetting was inordinately delayed in plants grown under $ECO_2$. These plants exhibited apical dominance and grew straight without branches.

Plants under $ECO_2$ exhibited significantly high photosynthesis (Pn) both in water stressed and high temperature treatments. Growth data suggests that, the high Pn under elevated $CO_2$ compensates for water stress and high temperature induced reduction in growth. The ratio of Ci/Ca remained constant for ambient and elevated $CO_2$ condition, such that at high Ci, the gs (stomatal conductance) reduced. It is an adaptive response of cocoa plants to water stress, that the reduced gs is not decreasing photosynthesis but significantly reduced the transpiration loss of water as a consequence they had higher water use efficiency. This is in contrast to coconut, where the whole plant water use efficiency decreased under water deficit stress.

#### 2.8.1.3 Genotype dependent proteases and oxidative isozyme response of coconut under elevated $CO_2$ and temperature

Quantitative assay of total protein/HSP (Heat Shock Proteins) in five cultivars has shown significant differences among the treatments and cultivars. The highest percentage of HSP was observed in WCT (66.75) followed by LCT (56.61) under elevated temperature. Under elevated $CO_2$, percentage HSP was low irrespective of cultivars. Oxidative isozyme profile for SOD (Superoxide dismutase) and PPO (Poly phenol oxidase) was done in WCT and COD plants exposed to $ECO_2$ and temperature. Significant difference in SOD and PPO activity as well as PPO isoforms was observed. Very less PPO activity was observed in assay as well as in native gel under chamber control and elevated temperature in both the cultivars. The expression of two higher molecular weight isoforms of SOD was less in chamber control and at higher temperature. Identification of SOD isoforms and their stability to higher temperature was investigated. Out of the 13 isoforms of SOD, five were Cu/Zn- SODs, four Mn-SODs, two Fe-SODs and two unknown isoforms with very high molecular weight. Under sequential heat treatments, nine of these isoforms lost their activity at 80°C and only four isoforms (two each for Cu/Zn-SOD and Mn-SOD) were stable up to 80°C, and at 100°C, only two existing isoforms of Cu/Zn-SOD were stable; but two new isoforms of Cu/Zn-SODs also developed afresh.

### 2.8.2. Carbon sequestration potential of palms and cocoa

Plantation crops has significant potential for offsetting and reducing the projected increases in green house gas (GHG) emissions and regarded as an important option for greenhouse gases mitigation. Above ground biomass in coconut varied from 15 CERs to 35 CERs depending on cultivar, agroclimatic zone, soil type and management. Annually sequestered carbon stocked in the stem is in the range of 0. 3 CER to 2.3 CER. Standing C stocks in 16 year old coconut cultivars in different agro-climatic zones varied from 15 CERs to 60 CERs. Annual C sequestration by coconut plantation is higher in red sandy loam soils and the lowest in littoral sandy soils. Simulation results indicated that the carbon sequestered and stored in stem in coconut plantation in four southern states (Kerala, Karnataka, Tamil Nadu, and Andhra Pradesh) is to the tune of 0.732 million tonnes of carbon every year. The biomass, carbon stock and carbon sequestration in cocoa varied in relation to age with increasing trend. Cocoa-arecanut is a good system for carbon sequestration with a potential to sequester 7.16 to 13.99 t $CO_2$ $ha^{-1}$ $year^{-1}$.

## 2.9. Post-harvest technologies for product diversification

### 2.9.1. Kalparasa: A nutritious health drink from coconut inflorescence

Kalparasa is the phloem sap rich in sugars, protein, minerals, anti-oxidants and vitamins utilized by the plant for the growth and development of tender or mature coconut. It is more nutritious healthy drink than any other juice. The Institute has developed a simple ice box technology to collect farm fresh, hygienic, unfermented sap from coconut palm. In this device, the sap oozed out from the cut surface easily flows through an adaptor into a collection container which is housed in an ice box. Further, the commercial ice box has been replaced by an improved

Kalparasa collection box (Cocosap chiller) exclusively for coconut or palm trees. This new box is lighter, water proof, easy to connect to the spadix, requires less ice and retains low temperature for longer period. (patent application is under process)

The sap, thus, collected under cold condition remains fresh and unfermented. In the traditional method, even though lime is coated to the collection pot to prevent fermentation, the sap collected is partially fermented, unhygienic due to fallen insects and leaves a harsh odour. In the revised CPCRI technique of collecting sap, as the whole device from the cut surface till the collection container is completely closed, there is no chance for contamination from insect, ants, pollen and dust particles. Moreover, the freshly collected sap by the CPCRI method can be stored for any length of time under refrigerated conditions. The sap, thus, obtained can straight away be consumed as ready to serve drink or can be used for the preparation of natural sugar, jaggery, honey or other value added products without the addition of any chemicals.

CPCRI Chiller for collection of kalparasa

The fresh sap has a very good colour like honey and it is sweet and delicious. Chemically it is rich in sugars, minerals, proteins, vitamins and anti-oxidants. Some of the notable minerals are iron, zinc, calcium, magnesium, phosphorus and potassium. It is high in amino acids like glutamic acid and threonin and vitamins like thiamine (vitamin B1), pyridoxine (vitamin B6) and inositol. Moreover, the glycemic index (rate at which sugar is absorbed in blood) is found to be low in Kalparasa. This Technology has already been transferred to entrepreneurs from Karnataka, Kerala and Tamil Nadu.

### 2.9.2. Value added products from coconut sap: coconut sugar, jaggery and honey

Coconut sugar, jaggery and honey are obtained by boiling unfermented sap in moderate heat to evaporate the water at 115° C. The viscous fairly thick heated syrup is cooled to get coconut honey or syrup. More viscous and still thicker consistency syrup is poured to moulds of either coconut leaf or steel to obtain jaggery. Sugar forms from thick syrup, when it is continuously stirred to avoid burning and to form granulation. At this stage, the liquid will change into solid form and it is immediately cooled.The sugar obtained is sieved to get uniform particle size and to produce quality product. Coconut sugar is also known as coconut palm sugar, coco sugar or coco sap sugar. Coconut sugar supplies calories and nutrients. It has high mineral content and is a rich source of potassium, magnesium, zinc and iron. When compared to brown sugar (prepared from sugar cane molasses), coconut sugar has twice the iron, four times the magnesium and over 10 times the amount of zinc. More importantly, the glycemic index of coconut sugar is only 35 as against 60 of cane sugar.

Coconut sugar from kalparasa

### 2.9.3. Coconut haustorium: a rich source of biochemical and mineral nutrients

Haustorium is the spongy tissue developed in coconut during germination. It is pale yellow on the outside and creamy white inside. The yellow portion contains more oil while the inner white portion has carbohydrates and proteins. The total sugar, reducing sugar and protein content in the white portion range from 42 to 44%, 26 to 27% and 6.8 to 7.9%, respectively. Phosphorus (P), potassium (K), sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe) and zinc (Zn) content in white portions of coconut haustorium were found to be in the range of 0.32-0.35 g, 1.76-2.89 g, 1.79- 2.46 g, 91.4-132.6 mg, 14.6-34.8 mg, 2.6-2.9 mg, 1.1-1.2 mg, respectively. Contribution of coconut haustorium towards recommended dietary allowance (RDA) for mineral was calculated and found that 100 g dry haustorium powder can supply 53.3 – 58.3 % P, 47.5 - 90.0 % K, 85.2 - 117.1 % Na, 15.2 – 22.1% Ca, 4.3 – 10.2% Mg, 15.2 – 17% Fe and 8.9 – 10.0% Zn.

### 2.9.4. Development of cassava and coconut based food extrudates

Technology for producing food extrudates by blending cassava flour and defatted coconut meal coconut was standardized. The work was taken up in collaboration with CTCRI, Trivandrum to examine the feasibility of making extruded products from VCO meal, the defatted coconut gratings obtained as a by-product during VCO processing. Cassava flour and coconut powder were blended in three different proportions (95:5, 90:10 and 85:15) and extruded using single screw food extruder. It was found that ideal extrudate with maximum porosity and expansion ratio could be formed with cassava flour and defatted coconut powder blended at a ratio of 95:5.

### 2.9.5. Processing Virgin Coconut Oil

Virgin coconut oil (VCO) can be extracted directly from the fresh coconut meat or from coconut milk. The different processes involved in VCO production are hot-processing method, natural fermentation method, centrifugation process and extraction from dried grating (EDG) method. The choice of the technology to be adopted depends to a great extent on the scale of operation, the degree of mechanization, the amount of investment available and the market demand.

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

Virgin coconut oil production by fermentation method

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

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

**Biochemical profile and anti oxidant capacity of VCO:** Various chemical parameters such as free fatty acid content, saponification value, peroxide value and total polyphenols content were determined in hot processed VCO and traditional coconut oil (TCO). Free fatty acid content of VCO (0.23 ± 0.18 mg KOH $g^{-1}$) was found to be very low compared to TCO (1.066 ± 0.079 mg KOH $g^{-1}$). The saponification value of both VCO and TCO are almost the same, with 271.80 for VCO and 253.57 for TCO. The peroxide value of two weeks old VCO and TCO was found to be 0.54 and 0.823 meq oxygen $kg^{-1}$ respectively. The peroxide values were negligible in fresh sample. Total polyphenols content was high in VCO in terms of Catechol (18mg $100g^{-1}$oil) equivalent and Gallic acid equivalent (9.57 mg $100g^{-1}$oil) compared to TCO (below 2mg $100g^{-1}$). The antioxidant activity of the methanol extracts of the VCO and TCO was investigated using the DPPH radical scavenging assay. The methanol extract of the VCO and TCO exhibited a significant dose-dependent inhibition of DPPH activity, (with a 50% inhibition (IC 50) at a concentration of 44.15±1.02g $g^{-1}$ BHT; 36.12±0.84g $g^{-1}$ Vitamin C for VCO and 342.68±2.12g/g BHT; 355±3.42g $g^{-1}$ Vit. C for TCO) indicating that the antioxidant activity of VCO is almost nine times greater than TCO.

## 2.10. Agro-Processing Centre

The Agro-Processing Centre was established in 2005. Prototypes of machineries / gadgets developed by the institute are showcased at the centre. This includes mainly machineries for the production of VCO and coconut chips. Coconut testa removing machine, coconut grating machines, pulverizer, coconut milk expellers of different types and various capacities, VCO cookers having different heat sources, fermentation tanks and fermentation chamber are the machineries developed for the production of VCO by hot processing and fermentation techniques. Manual and electrical slicing machines, blanching unit and coconut chips dryers (electrical and agricultural waste fired) makes coconut chips production competitive. Apart from these machineries, the tender coconut punch and cutter and the portable Snow Ball Tender Nut Machine also are in good demand. The operation of these prototypes is regularly demonstrated to the visiting farmers and other dignitaries. The Agro-Processing Centre has been effectively utilized to impart hands on training to entrepreneurs availing technologies of VCO, coconut chips and Snow Ball Tender Nut through Institute Technology Management Unit


A view of the Agro-Processing Centre

(ITMU) as part of commercialization initiatives.

### 2.10.1. Snowball Tender nut Machine

Snow ball tender nut (SBTN) is the white kernel scooped out from the tendernut without shell with the water inside intact. This is served in an ice cream cup. The user can drink the tender nut water by piercing the kernel with a straw. After drinking water, the kernel can be consumed using a fork. The machine consists of a circular blade that rotates by a 0.5 HP single phase electric motor. Tender coconut of 7-8 months maturity is most suitable for making snow ball tender nut. Tender coconut of this age is harvested and its husk removed without damaging the shell. The main unit operation in the snow ball tender nut making is to take a groove around the shell on its middle. This operation is done by the snow ball tender nut machine. The machine is switched on and the dehusked tender nut is placed above the circular teeth by firmly holding the nut at two sides by both the hands. The groove is extended through out the circumference of the nut by rotating the nut above the circular teeth using both hands. The depth of cut can be adjusted as per the thickness of the shell by adjusting the stop cutter box. Care should be taken to cut the entire thickness of the shell without damaging the kernel inside. A flexible knife known as scooping tool also has been developed for scooping out the tender nut kernel from the shell. The scooping tool is made of nylon and is flexible at one end. The scooping tool is inserted in between the kernel and shell through the groove and is rotated slowly to detach the entire kernel from the shell. The action is repeated to the other half of the tender nut. Remove the detached shell and wash the snow ball tender nut in clean water and keep it in an ice cream cup with the eye portion facing up. The snow ball tender nut is ready for serving. By using the snow ball machine, any unskilled person can make a SBTN in 5 minutes, which could be brought down to 2 minutes by practice.

### 2.10.2. Shell fired Copra Dryer

The shell fired copra dryer is to dry coconut in 24 hours which works on indirect heating and natural convection principles using coconut shell as fuel. The drying air temperature in the drying chamber was 80 $^0$C. The unique burner designed generated heat for 5 hours without tending and the heat is retained for one more hour. No electrical energy is used in this dryer making it farmer friendly. Once the fuel is charged it produces heat for 6 hours thereby allowing the farmer to do other useful work as compared to other dryers where in fuel is loaded once in 15-20 minutes. Smoke does not come into contact with the copra; and hence, the copra produced is of good quality. About 100 g of shell charcoal is also produced during the final phase of heating. Capacity of the dryer is 1000 nuts per batch and another dryer having half the capacity, 500 nuts per batch, also was developed.

### 2.10.3. Coconut de-shelling machine

Traditionally after partial drying of split coconut, the kernel and copra is separated using a traditional wooden mallet by taking the individual cups in hand. The batch type coconut de-shelling machine is to separate shell and copra after partial drying mechanically. Capacity of the machine is 400 half cups per batch. The optimum average moisture content for maximum de-shelling efficiency (92.16 %) was 35 % d.b. The optimum speed of the de-shelling machine is 10 rpm and the time taken for de-shelling was 4 minutes per batch.

### 2.10.4. Coconut Testa Removing Machine

The machine consists of a circular wheel covered with an emery cloth or water paper. This friction wheel is rotated using an electric motor. Coconut kernel is pressed to the surface of the rotating friction wheel either by hand or using a fork. Removed testa is collected at the bottom. The emery cloth/ water paper needs to be replaced periodically when the surface gets smoothened. One person can remove testa of about 75 coconuts per hour.

Coconut Testa Removing Machine

### 2.10.5. Coconut slicing machine (Electrical)

The machine consists of two stainless steel slicing blades fixed on a circular blade supporting disc, a feeder to insert coconut endosperm for slicing, an exit guide to guide the sliced coconut chips towards the outlet and an electric motor as a prime mover. The electric motor rotates the blade supporting disc using a V-belt. Coconut endosperm is pressed to the surface of the rotating wheel through the slot provided on the feeder at the top of the machine. When it comes into contact with the blades, the coconut endosperm gets sliced and chips produced. The sliced coconut chips are then guided towards the outlet by the exit guide and are collected in a container. Coconut chips of uniform and required thickness could be produced using this machine. Capacity of the machine is 50 coconuts per hour.

### 2.10.6. Manual coconut slicing machine

The machine consists of a stainless steel slicing blade fixed on a circular blade supporting disc, a specially designed curved feeder to insert coconut endosperm for slicing, an exit guide to guide the sliced coconut chips towards the outlet and a pedal operated mechanism similar to that of a sewing machine to operate the slicing machine. Power is transferred from the pedal to the blade by belt and pulley. The operator, sitting on a chair in front of the machine operates the machine by pedalling. The blade supporting disc gets rotated along with the blade because of this. Coconut endosperm, the kernel obtained after the removal of husk and shell, is fed to the surface of the blade supporting disc through the slot provided in the feeder by the operator. When the blade supporting disc rotates the kernel pieces are pressed towards its surface. When it comes into contact with the slicing blade, coconut kernel gets sliced. The sliced kernel, coconut chips, is guided towards the outlet by the guide. Coconut chips coming out through the outlet is collected in a tray. Coconut chips of required thickness could be made by adjusting the clearance between the slicing blade and the blade supporting disc. Approximately 25 coconuts can be sliced in one hour using this machine.


Manual coconut slicing machine

### 2.10.7. Blanching unit

Thoroughly washed coconut slices are put in the muslin cloth and dipped in hot water at 90-95°C for two minutes. This facilitates the removal of some amount of oil and milk so that the final product will have more crispiness and taste. A blanching unit has been developed to make the process hygienic and efficient. The unit is fabricated using stainless steel and provision is made to heat the water inside to required temperature.

### 2.10.8. Electrical coconut chips dryer

The electrical dryer consists of a set of 10 trays with wire mesh screens for loading coconut slices. This batch type dryer uses four electric heaters and the heat is uniformly distributed using a blower. Temperature in the dryer is controlled automatically by a sensor and electronic control unit. Though the dryer is designed for 50 coconuts, the size could be enhanced to any desired capacity.

### 2.10.9. Agricultural waste fired coconut chips dryer

The dryer is a batch type indirect heating one where only hot air comes in to contact with the coconut chips. It consists of a heating chamber that is kept indoor and a burning chamber, a furnace kept out door for convenience. The rectangular shaped heating chamber is made of MS sheet lined with fire bricks inside. Though any agricultural waste may be used as fuel, coconut shell is preferred. A chimney is provided for smoke to escape. Hot air from the heating chamber is conveyed to the drying chamber through insulated pipes using a blower. The drying chamber consists of a set of 10 trays with wire mesh screens for loading coconut slices. Temperature in the dryer is monitored by a sensor and is displayed outside. Though the dryer is designed for 50 coconuts, the size could be enhanced to any desired capacity.

### 2.10.10. Batch type coconut flaking machine

The batch type flaking machine consists of two cutting blades rotating in a vertical plane. Coconut kernel pieces are kept in a circular bowl and rotate in a clock wise direction. Prime mover of the flaking machine is a 220V A/C induction motor with a power rating of 0.37kW. The motor and the cutting blades rotate at a speed of 1440 rpm. Power is taken to the cutting blade and bowl using a V-belt. The bowl rotates at a speed of 24 rpm with the help of a reduction gear. A lid is provided to the bowl for safety and to contain the coconut flakes within the bowl.

Coconut kernel pieces are kept in the bowl. The cutting blades rotating in the vertical direction cut the kernel in to small pieces. The rotating bowl brings the fresh kernel to be cut, to position. The machine can make 10kg coconut flakes in one hour.

Two coconut flaking machines are

Batch type coconut flaking machine

available to make coconut flakes of uniform thickness. Prime mover of one machine is an electric motor and that of the other one (pneumatic coconut flaking machine) is an air compressor. The machines are provided with two sets of cutting blades that could make coconut flakes of 5 mm and 10 mm thickness. All the contact parts including cutting blades are made of food grade stainless steel.

### 2.10.11. Coconut grating machines

The two motorized coconut gratings machines are simple machines to reduce the drudgery involved in coconut grating and also to enhance the grating efficiency. First one is of single user and the second one is of multi user (four grating blades) type. The coconut grating machines scrapes off the coconut flesh into fine gratings with the help of a specially designed stainless steel blade. An operator feeds the coconut half into the grating machine during the grating process. The single user machine has a capacity of 60 nuts/hr and the multi user has a capacity four times of the first one.

Multi-user coconut grating machine

### 2.10.12. Coconut pulveriser

The coconut pulveriser consists of power operated rotary blade. The coconut kernel pieces are fed into the hopper manually. Due to the impact of the rotary blade and the rubbing on the stationary blade, the coconut kernel turns into fine powder. The machine has a capacity of 250 nuts per hour.

Coconut pulveriser

### 2.10.13. Manually operated coconut milk extracting machines

Two manually operated coconut milk extracting machines are available to extract milk from coconut gratings. Both the machines are similar to a hand operated vertical screw press. The grated coconuts are kept in a perforated cylinder and by rotating the handle provided at the top of the screw the gratings are pressed. An outer cover to the perforated cylinder is provided to avoid possible milk splash during the process. In the first machine the whole pressing process is done manually by rotating the handle. In the second machine an additional hydraulic jack is provided at the bottom. After exerting maximum pressure using the handle, the bottom hydraulic jack is operated, again manually. By doing this, the platform holding the cylinder moves up thereby pressing the gratings. Using this hydraulic jack, a pressure of eight ton could be easily applied enhancing the extraction efficiency considerably.

### 2.10.14. Hydro pneumatic coconut milk extractors

Two hydro pneumatic coconut milk extractors of different capacities were also developed for large scale extraction of coconut milk. The operation of both the machines is completely automated using a programmable logical controller. The user can programme the operation of these machines, i.e. extraction pressure, frequency and duration of pressing etc. using the programmable logical controller as per the requirement. They are useful for large scale extraction of coconut milk in coconut milk processing industries and virgin coconut oil (VCO) production centres. The smaller machine is having a capacity of handling 250 nuts/hr whereas the bigger machine can handle 500 nuts/h.

### 2.10.15. Double screw coconut milk expeller

Coconut milk expelling is an important process in the production of high value products like VCO, coconut milk powder, cream etc. Prototype of a double screw coconut milk expeller has been designed and fabricated to extract milk from coconut kernel. Prime mover of the expeller is an induction motor having a power rating of 1.1 kW and run at 1415 rpm. Power from the motor is transmitted to the screws first through a belt driven pulley and then through a reduction gear. The screws rotate at 14 rpm. Screws of the expeller are custom made in stainless steel to get maximum extraction efficiency. Clearances in the strainers are so designed that each one expands outward. This reduces the chance of these apertures getting clogged to a very minimum. All the contact parts of the machine are fabricated using food grade stainless steel. The expeller has a capacity to extract milk from 1000 coconuts in one hour. Maximum milk could be extracted in two runs itself. Milk extraction efficiency remains the same when the coconut kernel is fed with or without pulverization. The machine would be of great help to all processing units involved in coconut milk extraction.

Double screw coconut milk expeller

### 2.10.16. Coconut milk expeller with cooling mechanism

Milk expellers of various types are available to extract coconut milk from kernel. Among the expellers screw type expellers are the preferred ones since they have high milk extraction efficiency. In order to dissipate the heat generated during the extraction process, prototype of a coconut milk expeller has been fabricated with an in built cooling mechanism. The expeller is basically a single screw type expeller. The cooling is done by providing a cavity at the outlet side of the screw because maximum pressure is exerted and hence heat is generated towards the outlet side of the screw. Provision is made to circulate water through this cavity. Heat energy generated due to compression of coconut is dissipated by circulating cold water. By controlling the water circulation rate temperature could be maintained within the safe/ required limit.

### 2.10.17. Virgin Coconut Oil Cooker

The VCO cooker developed is used to extract VCO from coconut milk. It consists of a double jacketed vessel filled with thermic fluid. The thermic fluid ensures efficient and uniform heat transfer to coconut milk kept in the cooker. Four Teflon tipped stirrers are provided to stir coconut milk. This helps the cooker to distribute heat energy uniformly within the coconut milk kept in the cooker. The stirrers are powered by an electric motor with a reduction gear. An outlet with a door attached to a lever is provided at the bottom of the cooker to take out the extracted oil. The cooker is supported by three legs with sufficient clearance from ground for easy collection of extracted oil. A thermometer is provided to measure the temperature of the thermic fluid so that it can be kept from 100$^0$C -120$^0$C. Biogas or LPG could be used as fuel. Virgin Coconut Oil Cookers of any capacity could be fabricated.

### 2.10.18. Agricultural Waste Fired Virgin Coconut Oil Cooker

The agricultural waste fired VCO cooker also is used to extract VCO from coconut milk. The cooker is heated by burning any agricultural waste, preferably coconut shell, in the burning chamber. An

Agricultural Waste Fired Virgin Coconut Oil Cooker

opening is provided at the front to feed the fuel. An exhaust to remove smoke is provided at the opposite side and is connected to a chimney kept out-door for easy combustion of fuel. Virgin Coconut Oil Cooker of this type can be fabricated as per the capacity required by the user.

### 2.10.19. Fermentation tank

Virgin coconut oil can be extracted directly from fresh coconut milk by natural fermentation. Coconut milk extracted is allowed to stand for 20-24 hr. Under favourable conditions, the oil naturally separates from the water and the protein. The air borne lactic acid bacteria has the capability to break the protein bonds, acts on the coconut milk mixture causing the VCO separation. The fermentation container is made of food grade, transparent plastic or stainless steel, cylindrical in shape with a conical bottom with outlet tap and a sight glass to see the different layers as the oil separates. Oil can be withdrawn from the outlet tap based on the levels shown in the sight glass.

If proper operating conditions and sanitary precautions are strictly followed, four distinct layers can be seen in the fermenting container after settling for 16 hr. The bottom layer is made up of gummy sediment. The next layer is the watery, fermented skim milk that is no longer fit for human consumption. The next layer is the separated oil for recovery as VCO. The top layer is floating fermented curd. The fermented curd also contains a considerable amount of trapped oil. By carefully separating the distinct layers, the oil can be separated.

### 2.10.20. Coconut vinegar filter

The coconut vinegar filter is used for the filtration of coconut vinegar by passing through a layer of sand and activated carbon. The capacity of the filter is 5 l/ batch/ 2hr.

### 2.10.21. Coconut/ Arecanut palm climbing device

Timely harvesting and other plant protection measures of coconut and arecanut palms become very difficult because of the difficulty in climbing the tree. This remains the biggest problem among the coconut and arecanut farmers. In an effort to address the problem a simple coconut and arecanut palm climbing device has been developed. The main parts of the coconut and arecanut palm climbing device are two U shaped frames slightly larger than the tree trunk so that it can move up and down along the tree trunk freely. The frames are laminated using vulcanized rubber to provide good grip with the tree trunk.

The climbing device can be carried by hand or may be taken by hanging the frames on the user's shoulder, in the same way the coir rope rings or bamboo ladders carried by traditional coconut and arecanut palm climbers.

**Safety attachment to the Joseph model of Paddle type coconut climbing device:** Various types of climbing devices like tractor operated, self propelled, manually operated and some robotic type (electronic) devices have been developed and tested for harvesting of coconut by both the government and private sectors. Among the manual devices, paddling type model developed by an innovative farmer (Joseph model) is the only machine commercially available and used by professional climbers. However, safety of the climber still was a major constraint and it prevents many, especially newcomers from using the climbing machine. To make the Joseph model user friendly and safe, a safety attachment was developed, and its performance was evaluated under field condition.

The safety attachment is independent of the climbing machine and gives fool proof safety to the climber from falling. This could provide much needed confidence, especially for beginners to attempt climbing coconut using the Joseph model climbing machine. The same safety device can also give protection to the traditional climbers who climb the coconut tree using a pair of coir rings, one for leg and the other for hand.

Safety attachment to the Joseph model of Paddle type coconut climbing device

## 2.11. Value Chain in coconut

With the objective of strengthening the value chain involving production, community level processing and marketing, a consortium of three research institutions *viz.*, CPCRI, Kerala Forest Research Institute (KFRI), Peechi and Defence Food Research Laboratory (DFRL), Mysore was formulated to take up research under the NAIP on "Value Chain in Coconut". During the period, coconut production technologies were demonstrated in 250 ha area covering 534 farmers organized under 10 community based organizations (CBOs). Integrated nutrient management, vermicomposting of coconut leaves, intercropping and soil and water conservation measures were popularized among the coconut farmers.

A Self Help Group (SHG) unit established in the Ajanur cluster has taken up the mass production of *Trichoderma* and marketing with the brand name 'Ethiran'. Machineries *viz.*, coconut testa remover, coconut milk extractor, VCO cooker and fermentation tank were developed for the cost effective production of virgin coconut oil. The protocol for the production of VCO by fermentation and hot process methods were popularized.

Technology and a pollution-free plant for community level production of coconut shell charcoal and activated carbon was developed. The existing method for charcoal production, the earth pit method has got the disadvantages of ground level smoke spreading, thereby, polluting the environment. Product quality from the traditional earth pit method is poor due to soil contamination and there is no control over the quality of charcoal such as volatile content and fixed carbon content. The new technology developed, being a continuous process and employing a chimney, is free from ground level smoke pollution. Also, the system provides control over the volatile content and fixed carbon content of charcoal, helping in production of charcoal of desired quality for industrial use. The design of the plant permits an input of 1 tonne coconut shell with an output of about 0.34 tonne charcoal per day. The technology developed is appropriate for community level operation for CBOs.

The existing method of activated granular coconut shell charcoal is limited to large scale commercial enterprises employing continuous rotary kilns. Factors like the large size of the kiln, high input capacity and high cost limit its application to community level operations by CBOs. Fluidized bed reactor technology offers better contact of the reactants and reduced retention time. The newly developed system RFBR (rotary fluidised bed reactor) combines the advantage of rotary and fluidized reactor bed and requires only reduced retention time and can handle small to medium quantity of shell charcoal. In the RFBR, it was possible to reduce the manufacturing cost of the activation kiln, due to its limited size. The design of the RFBR permits an input capacity of 1 tonne shell charcoal with an output capacity of 0.3 to 0.5 tonne activated granular charcoal per day, appropriate to community level operation by CBOs. The plant is ready for commercialization.

## 2.12. Technology transfer, social and economic paradigms and analytical process

### 2.12.1. Transfer of technology programmes in palms and cocoa

Assessment and refinement of technologies are done through co-operation of Developmental Departments/ Boards by organizing various programmes with the active participation of farmers. The demand for CPCRI technologies has been very high among the farming community and other clientele. Research and extension activities were fine tuned considering the demand of the stakeholders.

### Technologies transferred are

- High yielding varieties and dwarf hybrids of coconut and arecanut
- High yielding hybrids and clones of cocoa
- Soft wood grafting in cocoa
- Pruning and training technology for seedlings and grafts of cocoa
- Vermicomposting using coconut, arecanut and cocoa wastes
- Integrated nutrient management with judicious, balanced and split application of organic and inorganic fertilizers
- Natural enemies/ predators in coconut, areca-cocoa ecosystem and biocontrol agents
- Integrated pests and diseases management practices for coconut, arecanut and cocoa
- Coconut/Arecanut based multispecies cropping system
- Value addition in coconut, arecanut and cocoa

### Details of the TOT programmes organized

During the decade, 47 residential training programmes, 330 institutional training programmes and 291 off-campus training programmes were organized. 63 research-farmer extension, 40 cyber extension programmes and 133 frontline demonstrations were conducted by the Institute. 11 kisan melas, four farm innovators meet and 240 exhibitions were organized at various centres of the Institute

Shri Oommen Chandy, Hon'ble Chief Minister, Kerala handing over techinical bulletin on coconut to a farmer

Interface programme organised in collaboration with Doordarshan Thiruvananthapuram

Interface programme with coconut producer organisation

Inauguration of Kisan mela at Kahikuchi

Dr. S. Ayyappan, Hon'ble Director General, ICAR visiting Krishi Vasant exhibition at Nagpur

Smt. Shakuntala Shetty, MLA, Puttur inaugurating Kisan Mela at Kidu

MLA, Puttur and other dignitaries visiting CPCRI exhibition stall during Kisan Mela

Demonstration of coconut pest control at Hassan and also at different states showcasing the technologies. More than 2800 farm advisory visits were made and 43000 farm advisory services attended during the decade. About 97000 farmers and officials were benefited by the exposure visits during the period. About 650 extension literature/popular articles, 158 radio programmes and 65 television programmes delivered from the Institute.

Women participatory seedling production at Kasaragod

### 2.12.2. Extension research: Empirical reflections

- Evolved technology delivery mechanism for Area Wide Community Adoption of IPM of rhinoceros beetle and red palm weevil. GIS tools were employed for studying the pattern of pest infestation.
- Developed and standardized tools for measurement of group performance and group capacity of community based organization in coconut sector.
- Extent of discontinuance of drip irrigation technology among the farmers in Kannur and Kasaragod districts was observed to be more than 70%, mainly due to lack of awareness on its maintenance.
- Soil and water conservation technologies were demonstrated in 225 farmers' gardens. Analysis of impact of technological interventions under FPARP in farmers' field revealed the efficacy of soil and water conservation and low cost water harvest technologies for water saving/water use efficiency, yield enhancement in crops and enhancing cropping intensity in farmers' gardens.

### 2.12.3. Policy research on mandate crops

Analysis of coconut sector in India in the light of recent policy issues, especially the ASEAN free trade agreement was attempted. It was observed that the likely impact of free trade agreement couldn't be undermined for three reasons. Firstly, the present context should be seen as a continuation of other free trade agreements signed and the worsening effects of the agreements on coconut prices. Secondly, although coconut and coconut oil is put under the negative list, the tariff reduction in palm kernel oil, which is a close substitute of coconut, would turn up detrimental in the near future. Thirdly, the agreement is an evolving one and the tariff rates fixed are ceiling rates (the maximum level to which tariff can be fixed), thus the fixation of tariff is flexible all through the period. Although coconut and coconut oil is in negative (exclusion) list of ASEAN agreement, the price wedge between domestic and international coconut oil is very high (though of late it tends to integrate) which may facilitate the cheap imports in the long run (as negative list is liable to revision).

Studies on house hold level consumption of coconut for culinary purpose among the major states of India has been carried out. The study was based on data extracted from three rounds of NSSO surveys during 1993-94, 1999-00 and 2004-05. A general decline in consumption has been observed. This was invariably true among the major states as well as all India level. The results hold significant policy level implication as far as demand of coconut is concerned.

A Sectoral System of Innovation (SSI) methodology was developed and applied to analyse the tender coconut market scenario of Kasaragod district. The consumption of tender coconuts in the district was estimated to be 10,066 per day. The results underscore the paramount importance to restructure the chain governance from middleman-driven to producer-driven, thereby improving the value share of the producer in the chain.

In the case of coconut, the results on rate of adoption of the selected technology showed that about 12 per cent of farmers in Kerala adopted hybrid palms and improved varieties in their gardens. The Tobit regression analysis showed that education level of the farmer and his extension contact with government departments are significant in influencing the use of hybrids and improved varieties in cultivation of coconut in their garden. This indicates the strength of extension system in disseminating a technology.

The impact study of improved arecanut varieties based on a field survey of 320 arecanut farmers in Dakshina Kannada revealed that 13.6% of total area in southern Karnataka is under released arecanut varieties. The economic impact of released arecanut varieties in monetary terms was found to be Rs. 221 million per year (according to the year 2011).

The impact assessment of arecanut based cropping systems in Dakshina Kannada region revealed that, total economic impact in monetary terms due to adoption of cropping systems in the region was found to be Rs.819 million per year.

### 2.12.4. Marketing, price analysis and trade of mandate crops

Domestic value chain study in coconut shows that the producers share in consumer rupee is just around 64% and the market chain consumes as much as 36 per cent share in the total value chain which reflects the low marketing efficiency of the market channel.

Four different marketing channels were observed in the case of arecanut trade in Dakshina Kannada. Regarding the consumer's share in the final price, cooperative marketing channel was found to be the most efficient which could provide the farmer with 68.1 per cent of the final price.

The per capita consumption of cocoa in the country was estimated using Production-Trade balance and Stock-Grind Ratio of cocoa beans. Although the per capita consumption in India (0.021 kg/ head) is meagre in comparison with major cocoa consumers, the consumption is continuously increasing over the last 10 years, reflecting a bright prospect for the cocoa sector.

The price analysis indicates that the price fluctuations in the case of coconut and coconut oil are very much associated with the trade movements and supply of other edible oils. In nut shell, five major reasons could be attributed to the price instability, which are i) the supply deficits, ii) price rise in substitute oils, iii) surging industrial demand, iv) high volume of exports and v) a global shortfall in edible oil supply.

### 2.12.5. Statistical applications in improving research methodology

The fundamental objective of an agricultural experiment is to obtain data systematically and to make inferences or appropriate decisions based on the data. The most important principle of experimentation technique is to plan the experiment in such a way that the unexplained variation or the experimental error is minimized. Though the statistical techniques followed in experimentation with annual and perennial crops are essentially the same, the problems faced while experimenting with perennial crops are sometimes different from those of annual crops. Perennial crops live longer and are therefore more susceptible to mishaps. Also they are in general, larger than annuals and are of greater interest as individuals. It requires special attention due to the long duration of the crop, repeated measurements, large plant to plant variation, requirement of large experimental area, high variation in annual yield, missing plants etc. The institute has developed many specific methodologies for experiments with perennial/plantation crops. The summary of the research achievements during the last ten years is given below.

#### 2.12.5.1. Spatial smoothing technique in field experiments

Spatial (bivariate) smoothing technique is developed to estimate/ eliminate the positional effect in field experiments nonparametrically. The method is very much useful when the direction of soil fertility or other location effects influencing the parameter under study to make homogeneous blocks is not known in advance. The semiparametic regression model considered is of the form

$$Y = \mu + X\beta + f(U, V) + \varepsilon$$

where, $Y = [y_1\ y_2 \ldots y_n]^T$ is the observation vector, $m$ is the general mean, $X = [x_1\ x_2 \ldots x_n]^T$ is the design matrix, $\beta = [\beta_1\ \beta_2 \ldots \beta_p]^T$ is the treatment effect vector, $f(U,V) = [f(u_1,v_1) \ldots f(u_n,v_n)]^T$ is the nonparametric spatial function representing the positional effect and $\varepsilon$ is the iid random error vector with mean zero and constant variance. The back fitting algorithm is used to compute the estimates for the parameters of semiparametric regression model.

### 2.12.5.2. Nonparametric covariance analysis in field experiments

Analysis of covariance technique in field experiments is made more robust/ flexible by taking the relationship between the response variable and covariate as nonparametric instead of linear. The simple nonparametric *ANCOVA* model considered for the field experiments is given by

$$Y = X\beta + \phi(u) + \varepsilon$$

Where, $Y$ is the observation vector, $X$ is the design matrix, $\beta$ is vector of treatment effect + general mean, $\phi(u)$ is the nonparametric function representing the relationship between the response variable $Y$ and the covariate $U$ and $\varepsilon$ is the error term. The above method is successfully applied to the Yellow Leaf Disease (YLD) management trial data at 5 locations. The comparative study showed that in all the five locations Nonparametric ANCOVA technique performed better than the traditional covariance technique and also has the added advantage that it is more robust against assumptions.

### 2.12.5.3. Semiparametric additive model for positional effect

Semiparametric additive regression model is proposed to estimate/ eliminate the positional effect in field experiments, when the number of experimental units is comparatively small. The semiparametric additive model considered is of the form

$$Y = \mu + X\beta + f_1(U) + f_2(V) + \varepsilon$$

where, $f_1$ and $f_2$ are the univariate nonparametric functions representing the positional effect in the $U$ and $V$ directions. The backfitting algorithm will provide an explicit solution to the above semiparametric regression model. The proposed spatial technique is applied to the data of irrigation cum fertilizer trial of cocoa+areca mixed cropping system at CPCRI Regional Station, Vittal and it has been compared with the traditional method of eliminating the positional effect by blocking the experimental area. It was observed that the proposed method performed better than the traditional method for comparing the treatment effects.

### 2.12.5.4. Nonparametric additive modeling technique for input response analysis in arecanut

Nonparametric additive regression model is proposed to explain input-output relationship in arecanut. The additive model considered is of the form

$$Y = \alpha + \sum_{i=1}^{p} f_i(X_i) + \varepsilon$$

Where $\alpha$ is the intercept, $\varepsilon$ is iid error term with mean 0 and constant variance. The estimated values of the component functions provided the mean response of input variables on the yield of arecanut. The optimum values of the input variables were obtained from the graphical representation of the component functions.

### 2.12.5.5. Crop production model in arecanut

Crop production model in arecanut is developed based on semiparametric regression technique. Both qualitative (discrete) and quantitative (continuous) input variables are included in the crop production model. The relationship between quantitative input variable and yield is taken as nonparametric function. The semiparametric regression model considered for the study is of the form

$$Y = \alpha + \sum_{i=1}^{p} f_i(X_i) + \sum_{j=1}^{q} Z_j \beta_j + \varepsilon$$

where, Y is the response variable, $\alpha$ is the general mean, p is the number of quantitative variables, $X_i$'s are the quantitative variables, q is the number of qualitative variables $Z_i$'s are the dummy variables having values 1 or 0 denoting the presence or absence of qualitative variables, $\varepsilon$ is iid error term with mean 0 and constant variance. The functions $f_i$ (i = 1,..., p) are assumed to be smooth and $\beta_i$'s are the regression coefficients corresponding to the qualitative variables. The estimators for the semiparametric additive regression are obtained by using the backfitting algorithm.

### 2.12.5.6. Data driven technique for trend and growth rate analysis

A data driven technique is developed to estimate the trend and relative growth rate of time series data. The method is based on the local linear regression smoother and the only assumption about the form of the trend and growth rate function is that they are smooth functions of time. It is useful to study local changes in the function. The method is extended for handling sudden shifts or changes in the trend or growth rate functions by adding dummy variables for the jumps. It is applied to estimate trend and growth rate of area, production and yield of major crops in India.

### 2.12.5.7. Yield loss estimation due to diseases

A quick field survey was conducted during the last week of September in the year 2007 in Dakshina Kannada, Udupi, Chikmagalur, Shimoga and Uttara

Kannada districts of Karnataka to assess the yield loss in arecanut due to *mahali*. To cover large number of gardens with limited time and resources, purposive sampling method has been used in the selected taluks of each district. To take observations, the gardens were selected systematically in each taluk. From each selected garden, 20 palms were selected at random and observations taken on total number of bunches present, number of bunches affected due to *mahali* and the percentage loss of nuts expected per bunch. Taluk wise percentage incidence of *mahali* and the average yield loss were worked out by taking average of the selected gardens in each taluk.

### 2.12.5.8. Yielding pattern in arecanut

Locally weighted robust regression models are used to explain the yielding pattern in arecanut. Both annual and cumulative yield data of 594 palms for 17 years were considered for the study. Total number of palms is divided into four equal groups based on the cumulative yield. A significant difference in yield stabilization period for different yield groups is observed. High yielding palms stabilize faster than the low yielders. The yield stabilization period varied from 9 years in high yielding group to 14 years in low yielding group. It is found that the cumulative yield is a better indicator to model the yielding pattern than the annual yield. Similar estimation surveys were conducted during 2012 for the yield loss assessment due to mahali in arecanut and bud rot in coconut.

### 2.12.5.9. Robust spatial smoothing technique in field experiments

Robust spatial smoothing technique is developed to estimate the spatial effect of a field in the presence of outliers or extreme observations. It is based on fitting M-type robust nonparametric spatial regression following iterative kernel weighted local regression surface technique. The proposed method is useful to estimate the spatial effect and to identify the high potential trees in an orchard. The performance of the proposed method is verified through simulation study. The cross validation technique to estimate the optimum bandwidth behaves very badly in the presence of outliers in the data or when the errors are heavy-tailed. A robust M-type cross validation technique is proposed to estimate the optimum bandwidth for estimating the regression surface in the presence of outliers. The method performed very well in the simulation study. The proposed method is applied to the annual yield data of Laccadive Ordinary Coconut field at CPCRI RS, Vittal to estimate the spatial effect and to identify the outliers.

### 2.12.5.10. Production forecast

Coconut production forecast was carried out during 2007-08 surveying 18 major coconut growing districts in the country. A stratified three stage randomized sampling design was used with six strata. Sample size was fixed depending upon the area under the crop in a district. By taking forecasted production of coconut for the previous year as reference value, ratio estimators were constructed and used for forecasting at state and national level.

A model was developed predicting cocoa yield based on partial harvest data. Observations on number of pods present at different growth stages of cocoa were recorded twice from 100 trees one before the beginning of the major harvest season and other after six months. Harvest data of individual trees were recorded to obtain total harvest as well as partial harvest data to work out a suitable model to predict the yield/tree/year. It was observed that about 80 percentage of the pods were harvested during May to October and only the remaining 20 percentage were harvested during November to April. The initial analysis showed that the annual yield of cocoa can be predicted based on the number of pods available on the tree during the month of April (before the peak harvest season) and during the month of October with a coefficient of determination 0.97. The fitted regression model for predicting the annual yield of cocoa is given by

$$Y = -0.83 + 0.95X_1 + 1.066\ X_2 \quad (R^2=0.97)$$

where, Y is the number of pods per tree, $X_1$ and $X_2$ are the number of pods present in the tree during April and October, respectively.

Cocoa yield estimation survey was conducted in Kasaragod and Kozhikode districts of Kerala, Dakshina Kannada district of Karnataka, Coimbatore district in Tamil Nadu and West Godavari in Andhra Pradesh in two phases. Three villages from each district were selected randomly and 30 cocoa farmers were interviewed per village. No. of pods available on the tree were observed from 15 trees per plot in the districts. The average yield/ tree/ year (no. of pods) was estimated as 38, 50, 39, 38 and 56 for Kasaragod, Kozhikode, Dakshin Kannada, Coimbatore and west Godavari districts, respectively. Variation in pod yield at village level were analysed and between villages variance was modeled using Hierarchical Linear model (HLM).

### 2.12.5.11. Computational Resources

The institute was a nodal centre of NAIP project on 'Strengthening statistical computing for NARS' wherein training programmes were organized on applications of statistical techniques in SAS software. Various macros were developed in SAS for analysis of designed experiments, time series analysis, multivariate techniques like cluster analysis, Principal Component Analysis (PCA) and Factor analysis. In addition, applications for soft computing techniques like Support

Vector Machines (SVM) and Artificial Neural network (ANN) were developed in SAS and R software. Arc GIS 10.0 software is also employed for generating thematic map and other GIS applications. Statistical package for social sciences (SPSS19.0) is also widely used for the analysis of survey and experimental data. The institute has conducted various training programmes and work shops with hands on trainings in different statistical software for the benefit of researchers, academicians and students in the area of biological research

### 2.12.6. Latest developments in ICT

CPCRI has started utilizing Information and Communication Technology (ICT) effectively in the field of Web-based systems, interactive software and cyber extension. To place CPCRI in the arena of Internet to communicate research results to the end users, a website of CPCRI was developed (http://www.cpcri.gov.in). Some of the interactive softwares like "Nalikeram" on coconut cultivation practices, software on arecanut cultivation, e-manual on cocoa cultivation, integrated pest management (IPM) and Integrated Disease management (IDM) are popular among the farmers. A Video programme "About CPCRI" was produced in English, Hindi, Kannada, Malayalam, Tamil and Telugu. It exhaustively describes different scientific activities and achievements of the institute. Similarly, a video in Malayalam was developed on package of practices on different farming activities and crop production. A kiosk with a touch screen application installed at ATIC of the institute for the benefit of farmers visiting the institute helps in self learning on CPCRI technologies and services. CPCRI is the front runner in utilizing the group videoconferencing facility in extension activities with mobile units used at farmers' end. A videoconferencing facility was established and for the first time in ICAR, it was used for conducting research-farmer-extension interface programme during 2007 which was further augmented with mobile Kodak capable of conducting programmes from the field itself using 3G services or BSNL Wimax connectivity. To strengthen the cyber extension activities of the Institute, collaborative programmes were conducted with the Kerala IT mission and Coconut Development Board (CDB) covering major coconut growing states of the country.

Institute functions in fully computerized and web enabled work environment with

Research-extension interface programme facilitated through videoconferencing an efficient Manage Information system (MIS) for the routine administrative activities. Reporting and monitoring of research programmes are carried out on centralized web applications like HYPM, PermisNet and PIMSNET. Different databases on germplasm, Coconut Artificial Pollination Management Database, pest and disease surveillance database, Coconut pest and disease management database and information Management systems like Coconut Germplasm Management System (CGMS), Coconut Harvest Information System (CHIS) were also developed at the institute for easy and efficient management of information. A Decision Support System (DSS) for enhancing soil based input use efficiency has also been developed. Application of Image processing for texture analysis of coconut exocarp was utilized in assessing maturity of nut at different stages. High bandwidth networks like National Knowledge Network (NKN) at the institute facilitate sharing of resources live, like online data analysis by IASRI. In order to showcase the information and technologies and facilitate the mandate of being the leader in information on coconut, a portal on coconut was developed. Similarly, CPCRI Agropedia also serves in providing updates to those in the field of coconut, arecanut and cocoa research.

Shri Mohammed Sagir, IAS, District collector of Kasaragod inaugurating the Business Planning and Development Unit

### 2.12.7. Business Planning and Development Unit

The Business Planning and Development (BPD) Unit at CPCRI, Kasaragod was established as a sub-project of National Agricultural Innovation Project with the objectives of promoting entrepreneurship in coconut value added products, promote commercialization of selected technologies, and providing training and consultancy in the area of coconut production and processing technologies. Within a short span of time the BPD Unit could attract over 76 walks-in interested in coconut-based technologies of which 24 registered as incubatees. Important services provided to the incubatees include (i) DPR on coconut shell powder, which was approved by DIC, Kasaragod for land grant and funding and (ii) facilitate the export of packaged tender coconut water (worth Rs.9.5 lakhs) to Italy in liaison with Indian Consulate, Milan. For providing solutions to various problems faced by the startup entrepreneurs, effective linkages were established with various organizations and institutions like

NABARD, District Industries Centre, Coconut Development Board, Coir Board, MSME, SFAC, VIA, Goa Chamber of Commerce, Goa Bagayatdar Sahakari Kharedi Vikri Saunstha Maryadit etc.

### 2.12.8. Area Wide Community Management of Bio control of Rhinoceros beetle

A participatory community based initiative was taken up by Central Plantation Crops Research Institute, Regional Station, Kayamkulam. The IPM practices recommended by CPCRI consist of mechanical, chemical, cultural and biological methods. A participatory analysis indicated that the farmers prefer low cost, safer, environment friendly and bio control practices to manage the pest.

**I stage** – Implementing participatory programme involving rural women farmers- introducing them to the technologies on IPM of rhinoceros beetle by field based off campus programmes– Convincing them the visibility of technology impact.

**II stage** – Farm level *Metarhizium anisopliae* production – involving rural educated women – refining low cost multiplication procedure of CPCRI through participatory analysis.

**III stage** – Production /multiplication of Green Muscardine Fungus (GMF) under the facilitation and supervision of CPCRI scientists –community based adoption of the technology at panchayath level.

Bio control methods are preferred by farming community as environment friendly, safe, cost effective and efficient as well. CPCRI, Regional Station, Kayamkulam has evolved effective bio control techniques for management of rhinoceros beetle, using GMF, *Metarhizium anisopliae*. Rhinoceros beetle lays eggs in cow dung pits, vermicompost units, coirpith, degraded coconut logs etc. Treatment of such breeding sites with GMF effectively brings down the population of the pest. The fungus will not affect the earthworms in vermicompost in any way. Different stages of grubs and adults will be infested by the fungus within a week of its application. Incorporation of *Clerodendron infortunatum,* a common weed seen in coconut gardens, in the breeding sites also inhibits the growth stages of the black beetle.

The non-availability of sufficient quantities of GMF coupled with low level of awareness of the technology among the farming community were the major obstacles in the adoption of the environment friendly and effective bio management technologies. CPCRI intervened and facilitated Area Wide Community Adoption (AWCA) strategies in augmenting the technology utilization by refining the technology delivery mechanisms.

As per the CPCRI technology, the fungus could be multiplied at farm level by simple and cheap methodology in rice grains, tapioca chips and coconut water. The Metarhizium fungus production was decentralized through farm level GMF multiplication units operationalized by trained farm women groups. The capacity building and skill up gradation of the units were done by the CPCRI scientists, as a continuous process of confidence building. Another strategy was effective building up of network and linkage with relevant stakeholders like Department of Agriculture, coconut farmers' groups, Veterinary Department, Milk co -operative societies, farmers ,Mass media especially All India Radio, local panchayath etc. for rapid spread of technology and multiple level of interventions. This model project was implemented in Edava grama panchayath during 2010-13 which proved to be very effective in field situations and enabled rapid spread and utilization of technology in other areas.

Approximately 2000 ha of area in three panchayaths were brought under the process in Thekkekara, Devikulangara and Edava panchayaths of Alappuzha and Trivandrum districts. 2-3 women groups of 12-15 members in each ward were involved in technology transfer activities and treatment of breeding sites. Thus, a total of 150-200 women were mobilized to represent the panchayaths in popularizing and adopting the technologies. This indicated that these technologies were very much women friendly and doable.

While planning for panchayath wise community adoption programmes, initially all the potential breeding sites of rhinoceros beetles in each ward of the panchayath may be mapped and treated with GMF as a one week campaign with the active involvement of various stake holders. It requires only Rs.20, 000 – 25,000/- per panchayath for this progarmme. The impact analysis of this programme at Edava indicated 70% to 80% reachability to the potential adopters and 75% reduction in fresh incidence of rhinoceros beetle especially in the bearing palms, thus reducing the yield loss to farmers. Participation and functional linkages at grass root level could influence the technology utilization in a positive and effective manner and that is the message of the activities of Edava panchayath facilitated by CPCRI, Regional Station Kayamkulam.

### 2.12.9. Clustering coconut farmers – innovative extension approach for enhancing adoption and income from small and marginal holdings in root (wilt) affected areas

Coconut cultivation continues to be the one of the major livelihood options of lakhs of farm families either directly or indirectly.

Some of the important challenges of coconut farming are the incidence of debilitating phytoplasmal disease of root (wilt), infestation of pests like rhinoceros beetle, red palm weevil, eriophyid mite etc. low productivity, low level of adoption of recommended cultivation practices and fluctuating and low price of coconut. Even though no therapeutic control measures are available for coconut root (wilt) disease, research efforts of CPCRI resulted in evolving viable integrated management practices for enhancing the health and productivity of the affected palms. The effectiveness and the feasibility of the package of technologies were demonstrated in a contiguous area with the participation of 210 farmers in the farmers' fields around the research institute with convincing results.

The participatory demonstration resulted in 92 percent yield improvement over the pre-demonstration yield and observable reduction in disease intensity. The B: C ratio improved from 1.07 to 1.77. The feedback of the programme as perceived by the farming community was documented through an interface/dialogue process. The points were the relatively high cost of adoption of the entire package of technologies, sustainability should be ensured through appropriate strategy and that the income realized from the small or marginal land holdings (100% of the farmers belonged to marginal farmer category) was adequate to meet neither the family requirement nor the investment in coconut farming. Hence an alternate strategy for improving the productivity as well as income from coconut cultivation was evolved by CPCRI and implemented as farmer participatory programme of "Coconut Clusters" by extension agencies.

The programme was implemented on a pilot basis at Nambaruvikala area of Karunagappally block, Kollam district, Kerala with severe incidence of root (wilt) disease. A contiguous area of 25 ha of coconut holdings were selected, wherein 106 farm families were clustered together through participatory efforts.

#### 2.12.9.1. Impact of the technical interventions

The average yield of coconut in the root (wilt) affected area improved from 24 nuts/palm/year to 50 nuts/palm/year.

As given in the table on the facing page, the IPM practices including prophylactic measures reduced the pest incidence considerably, thus leading to improved yield. Incidence of red palm weevil was rated as a major felt problem among the coconut farmers. Through collective efforts facilitated by CPCRI in implementing IPM components none of

### Impact of recommended technologies in managing coconut root (wilt) disease

| Diseases/pests | Before implementation | After implementation |
|---|---|---|
| Root (wilt) disease | Apparently Healthy (AH) -12%<br>Disease Early(DE)-32%<br>Disease Middle (DM) - 34%<br>Disease advanced (DA) -22% | Apparently Healthy (AH) -10%<br>Disease Early(DE)-34%<br>Disease Middle (DM) - 36%<br>Disease advanced (DA) -20% |
| Leaf rot disease | 13.1% | 1.35 % |
| Rhinoceros beetle | 56.2% | 5.10% |
| Red palm weevil | 10.2% | No fresh incidence |
| Eriophyid mite | M0 - Nil - 50.5%<br>M1 - Low - 16.82 %<br>M2 - Medium - 24.24%<br>M3 - High - 8.21% | M0 - Nil - 75%<br>M1 - Low - 17 %<br>M2 - Medium - 8%<br>M3 - High - 0% |
| Yield | 24.22 nuts/palm/year | 50 nuts/palm/year |

the palms were affected by the pest.

Further analysis of the results clearly indicated the effect of management levels in terms of increased yield and reduced incidence of pests and diseases.

Intercropping intensity enhanced to 4-5 folds compared to the pre-project area. The improvement in intercropped area among the farmers with holding size less than 0.1 ha was 120% and 0.2-0.3 ha was 430%. The diversification in homestead also improved significantly i.e., coconut+intercrops+backyard poultry/duck improved from 12.5% of homesteads to 70% after the project implementation. Group activity on farm level coconut value addition was also adopted. The products were virgin coconut oil, coconut based food products and chutney powder. They could realize four fold income from these activities.

Vermicomposting technique was made popular in the project area as well as in the adjacent area through farmer to farmer dissemination of skill and exchange of earthworms. 40% of the households adopted either small or medium level of vermicomposting pits/tanks.

Knowledge and adoption of the technologies significantly improved through extension interventions and training programmes. The knowledge scores improved to 62.5% (organic manure), 81% (vermicomposting), 81.25% (basin management with cowpea), 55.5% (identification of root (wilt) disease symptoms), 60.5% (boron deficiency symptoms), and 57% (processing techniques). A total of 27 training programmes were organized in the field with a training intensity of 3.2 per individual farmer.

### 2.12.9.2. Improvement in income

The income from coconut based homestead farming system improved due to improved productivity and adoption of allied activities either individually or group basis.

**Improvement in average income from coconut based homesteads per annum**

| Sl.No | Land holding size | Average income from coconut | | | Average income from intercrops/ poultry in coconut holdings | | |
|---|---|---|---|---|---|---|---|
| | | Before (Rs.) | After (Rs.) | Improvement (%) | Before (Rs.) | After (Rs.) | Improvement (%) |
| 1 | 0.1ha (up to 25 cents) | 687 | 1117 | 71.30 | 728 | 1737 | 138.60 |
| 2 | 0.11-0.2 ha (26-50 cents) | 3272 | 4998 | 52.75 | 4319 | 6584 | 51.74 |
| 3 | Above 0.2ha (above 50 cents) | 9043 | 14317 | 58 | 10519 | 22247 | 112 |

The project outcome benefitted approximately more than one lakh coconut farmers through the up scaled project of Coconut Clusters by Coconut Development Board, Kochi in major coconut growing states. Besides the model process was inculcated in the Kerasree progamme implemented by the State Department of Agriculture, Kerala.

The Coconut Development Board implemented the "Coconut Cluster programme" with appropriate changes based on the pilot programme process evolved by CPCRI to neutralize the disadvantages of small and fragmented holdings where coconut is largely cultivated. Total of 329 clusters were formed in 12,038 ha area in seven coconut growing states of the country directly benefitting 47,802 farmers.

## 2.13. Coconut based cropping systems for Island conditions of Lakshadweep

The Centre of CPCRI at Minicoy Island, Lakshadweep was established as 'ICAR Research Complex for Lakshadweep' during 1976 and consequent up on the formation of the Island Zone under the ICAR system, the station was merged with the Central Agricultural Research Institute (CARI), Port Blair, Andamans during 1989. Subsequently the centre was brought under the administrative control of CPCRI again during 1994 and operated as one of the Regional Stations of CPCRI till 2011. The centre presently functions as a demonstration - cum - production centre for enhancing the production and availability of fruits and vegetables in the island. Significant achievements made during the last decade are given below.

### 2.13.1. Coconut varieties and hybrids for Lakshadweep

Evaluation of performance of various hybrids produced by crossing the locally available Laccadive Ordinary Tall (LCT) and three dwarf cultivars *viz.*, Laccadive Green Dwarf (LCGD), Laccadive Orange Dwarf (LCOD) and Laccadive Yellow Dwarf (LCYD) was initiated at the Research Centre at Minicoy, Lakshadweep during 1989-1990. All the hybrid progenies started flowering and yielding earlier than the local Tall variety. First flowering was observed in LCOD x LCOT at 30 months after planting. The result indicates that all the hybrids are performing better (with a mean yield of 166 nuts/palm/year) than their parents. Based on the nut yield and copra out turn, two hybrids viz., LCGD x LCT, LCOD x LCT were identified and released at Institute level by the Institute Research Committee of CPCRI and recommended for commercial exploitation under Lakshadweep conditions. It would be rewarding to cultivate these hybrids to further enhance the productivity of coconut palms in Lakshadweep Islands as they have potential for better adaptability and higher yield.


Laccadive Orange Dwarf coconut accession

A dwarf selection from Laccadive Orange Dwarf (LCOD) was identified for tender coconut purpose with early bearing palms, orange fruits with water content of over 300ml. Compact blocks of the dwarf variety was established at Minicoy as well as at CPCRI, Kasaragod.

A collaborative research effort to study the flora of Minicoy Island was carried out by CPCRI and NBPGR-RS Thrissur during 2009 under which, 24 accessions of Noni (*Morinda citrifolia*) was collected. Besides, sixty six important germplasm accessions of different plant species were recorded during the survey. Among them, 29 plants were of importance from the agri-horti, medicinal and tree crops point of view for the local inhabitants.

## 2. 13. 2. Introduction of vegetables /fruit crops

High yielding varieties of various vegetables/fruit crops were introduced and evaluated as intercrop in coconut garden. It was found that inclusion of such crops in the coconut based cropping system could ensure regular supply of good quality fruits and vegetables in Island and also increase the income per unit area. Screening of improved varieties from National Agricultural Research System and scaling up production through the Tribal Sub Plan Project of ICAR contributed to the increased availability of fruits and vegetables.

Intensified efforts taken up by CPCRI in the recent years have facilitated identifying the most suitable varieties of fruit crops *viz.*, banana, papaya, sapota and vegetables crops *viz.*, tomato, brinjal, chilli, bhendi, amaranth, cabbage, cauliflower, cucurbits, moringa for Island conditions of Minicoy. Large scale production of vegetables and fruits has become the most important activity of the CPCRI centre at Minicoy Island to cater to the needs of Island community in meeting the food and nutritional security. The institute has successfully demonstrated organic fruits and vegetable production at the centre with optimum utilization of available resources through organic methods under coconut gardens and made available fruits and vegetables to the islanders throughout the year.

In the recent studies on the evaluation of different varieties of banana under organic cultivation, 'Saba' recorded higher bunch weight ranging from 18 kg to 23 kg followed by 'Udayam' and 'Robusta' varieties with average bunch weight of 16 kg and 18 kg, respectively. The suckers of these varieties have also been distributed to the islanders for growing under coconut gardens.

Two papaya varieties *viz.*, Arka Prabhath and Arka Surya were introduced during 2012 and are being successfully

Brinjal cultivationin Minicoy Island

grown under Island conditions. The varieties Co2, Co3 and Co5 were also performing well under Island conditions. Sapota is one of the important fruit crops that have been performing well under Island conditions. Among the sapota varieties grown as mixed crop in coconut gardens, PKM 2 performed better with higher fruit yield of over 35 kg per tree per year with medium sized canopy making it suitable for growing under coconut gardens. Watermelon was also grown and yielded fairly well in Islands.

### 2.13.3. Protected cultivation of vegetables

As chemicals are not advocated for plant protection in the Islands, there was increased infestation of insect pests. Hence, a demonstration of protected cultivation of vegetables such as brinjal, chilli, bhindi and amaranth using insect proof cage was taken up at the Research Centre, Minicoy. Initial attempts showed the success of crops under screen houses owing to the lesser incidence of pests. The seeds of various vegetables were sourced from TNAU, Coimbatore, IIHR, Bengaluru and KAU, Vellayani. Protected cultivation of vegetables such as tomato, chilli and brinjal were initiated at the centre. Besides, protected cultivation using low cost poly house for cultivation of tomato, brinjal and amaranth were also established in the homestead farms of two farmers of Minicoy Island for demonstration.

Protected cultivation of Chillies in Minicoy

### 2.13.4. Bio-suppression of papaya mealy bug (*Paracoccus marginatus* Williams and Granarade Willink)

Papaya mealy bug, an invasive pest, was found to severely infest papaya leaves and fruits in the Minicoy Island bringing down the production quite significantly. Affected plants fail to flower and bear fruits and get dried up in severe infestation.

Introduction and releases of the exotic parasitoid, *Acerophagus papaya* Noyes and Schauff (Encyrtidae: Hymenoptera) obtained from NBAII, Bengaluru during December 2011 and April 2012 has reduced the population and resulted in successful establishment of the parasitoid and brought down incidence of mealy bug to $<5\%$, thereby resulting in rejuvenation of papaya plants in the Island.

The lepidopteran predator, *Spalgius epius* was also observed from the mealy bug infested papaya plants. The caterpillar of *S. epius* was found feeding on the mealy bug colonies. The population of *Acerophagus papaya* was so high that the parasitoids could be collected and released in other areas.

### 2.13.5. Training programmes for Island systems

Various training programmes were organized at Minicoy centre as well as at different islands on need basis for the benefit of islanders. Following thematic areas are covered in the training programmes.

1) Organic vegetable and fruit production under island conditions
2) Coconut based cropping and farming systems
3) Mixed farming in coconut gardens under Lakshadweep Ecosystem
4) Azolla production under island conditions
5) Biological control and treatment of stem bleeding disease of coconut using *Trichoderma*.
6) Biological control of rhinoceros beetle

Training at Minicoy

7) Popularization of vermicompost under island condition
8) Coconut climbing using paddle type coconut climbing machine
9) Management of rat menace in coconut garden
10) Production of coconut vinegar
11) Preparation of snow ball tender coconut, coconut chips
12) Coconut inflorescence sap tapping using CPCRI technology

## 2.14. Development of location-specific technologies /services for the North East Region

The Institute has a Research Centre at Kahikuchi, Assam serving to the farming community in North Eastern region. The major advancements made during the decade are given below.

**Release of arecanut variety "Kahikuchi":** The arecanut variety "Kahikuchi" was released during 2009 for commercial cultivation in rainfed and irrigated areas of Assam and NE region of the country. This is a tall cultivar with medium thick stem possessing comparatively shorter internodes; bunches are well-placed with uniform development of nuts. The average yield is 3.70 kg dry kernel/palm/year, with a potential to yield up to 6.28 kg dry kernel/ palm/ year.

HDMSCS of arecanut at Kahikuchi

**Development of arecanut based High Density Multispecies Cropping System Models:** The model with arecanut, black pepper (Panniyur-1 / Karimunda), banana (Malbhog/ Chennichampa) and lemon (Assam lemon/ Gandharaj) provided a net return of Rs 2.07 lakhs with a B:C ratio of 4.70. Application of 2/3rd dose of fertilizer helps in obtaining maximum yield per unit area except for banana which responded well to full recommended dose of fertilizer. The total biomass available from the system for vermicomposting was approximately 12.1 t/ha. An additional 200 mandays can be generated by adopting the system.

**Standardization of irrigation system to arecanut:** Drip irrigation at 66% pan evaporation ($E_0$) under 2/3rd dose of recommended fertilizer resulted in maximum yield (4.11 kg dry kernel/palm/ year) of "Kahikuchi" arecanut variety.

***In situ* water conservation measures suitable for water-shed of NE region:** Hilly terrain and sloppy areas constitute nearly two-third of the region's geographical area. *In-situ* soil and moisture conservation practices help in conservation of soil and moisture. Catch pit filled with coconut husks was found to be the best measure for achieving maximum yield (3.22 kg chali/palm/year) in arecanut. An yield increase of 26% was obtained by following this practice.

**Intercropping of seasonal vegetables in arecanut garden:** Long gestation period and the need to effectively use the natural resources are addressed by growing intercrops in the interspaces of arecanut garden. Ridge gourd, okra and amaranth were found to be the best intercrops during summer season with a B:C ratio of 2.86-2.91. Spinach and cauliflower were the best intercrops during winter with B:C ratio of 2.52-2.95.

**Vermicomposting of biowaste from arecanut based cropping systems:** To utilize the biomass obtained from growing of arecanut / arecanut based cropping systems, vermicomposting with suitable earthworm species was undertaken. July-September was found to be the best time for vermicomposting under Assam conditions. Recovery was the highest in the tank method (71.7 to 72.8%). A net profit of Rs. 3118 and Rs. 1068 could be realized from biomass of 300 kgs in cement tank and ground heap method, respectively.

**Standardization of soil mixtures for raising arecanut seedlings in secondary nursery:** Soil mixtures containing soil, sand and vermicompost in 1:1:2 ratio was the best for growth of arecanut seedlings in secondary nursery.

**Intercropping of vegetable and flowering crops in pre-bearing arecanut gardens under Assam condition:** Among the vegetables, brinjal and cabbage were found to be the best two intercrops in pre-bearing arecanut gardens with B:C ratios of 5.05 and 4.68, respectively. Among the flowers, growing gladiolus in pre-bearing arecanut garden recorded maximum B:C ratio of 2.43.

**Development of INM practices for high-yielding varieties of arecanut:** Application of vermicompost (2/3$^{rd}$)+ fertilizers (1/3$^{rd}$) recorded maximum yield (3.71 kg chali/palm/year) in variety "Kahikuchi". Variety Mohitnagar and Sumanagala produced maximum yield (3.1, 2.94 kg chali/palm, respectively) under the combination of vermicompost (2/3rd)+ fertilizers (1/3rd). Mangala and Sreemangala performed better under application of 200% vermicompost (3.6kg, 3.1 kg chali/palm/year, respectively).

**Management of bud rot of arecanut**

Spraying Dithane-M-45 @0.3% along with placing of 10 g of Phorate 10G was found effective against bud rot of arecanut.

**Management of basal stem rot of arecanut**

Soil drenching with Calixin (0.3 %) @ 10 l/ palm and application of neem cake 2 kg/ palm fortified with *Trichoderma viride* showed best control measure against basal stem rot of arecanut caused by *Ganoderma*.

**Control measure of stem weevil of arecanut in Assam condition**

The pest affects all the varieties but with less infestation in variety Kahikuchi. The infestation was found to be severe during July to October. Application of mud slurry Lindane 10 G @ 1% was found to be the best in controlling the pest menace.

**Rooting media for quality rooted cuttings of black pepper:** Rooted cuttings grown in Sand + Soil + FYM (1:1:1 ratio) amended with 1 g of *Trichoderma viride* per Kg of rooting mixture showed better result in terms of morphological growth parameters such as girth, height and number of leaves per rooted cutting.

***In-vitro* studies on the effect of *Trichoderma* spp on growth of *Ganoderma lucidum*, causal organism of basal stem rot of arecanut:** Trichoderma viride (67% inhibition after 96h) inhibited the pathogen to a maximum extend followed by *T. harzinaum and T. virens.*

***In vitro* studies on the efficacy of locally available botanicals on the management of basal stem rot of arecanut caused by *Ganoderma lucidum* :** *Azadirachta indica, Allium sativum, Clerodendron infortunatum* and *Centella asiatica* were found to be effective botanicals (100% inhibition after 96h) in inhibiting the mycelial growth of the fungus.

***In vitro* studies on the efficacy of locally available botanicals on the management of bud rot of arecanut caused by *Phytophthora meadii*:** *Allium sativum, Cleome viscosa, Melastoma malabathricum* and *Oxalis corniculata* showed 100 per cent inhibition over control after 48 h, 72 h and 96 h of incubation compared to other botanicals.

**Comparative toxicity of fungicides on the growth of the *Phytophthora meadii* under *in vitro* condition**: Akomin and contaf @ 0.3% showed 100 per cent inhibition over control. The other fungicides *viz*., Dithane M-45 and Antracol @ 0.3% recorded 82.22 and 76.22 % inhibition, respectively, over control after 96 h of incubation.

***In-vitro* studies on the effect of different bio-agents and locally available botanicals on the growth of *Thielaviopsis paradoxa*, the causal organism of stem bleeding of coconut**: *Trichoderma viride* was most effective in inhibiting (61.6% inhibition over control) mycelial growth of the fungus followed by *T. harzianum* and *T. virens*. Among the botanicals, the aqueous extract (10%) of *Allium sativum*, exerted 100 per cent inhibition of the pathogen over control.

***In vitro* study of botanicals against white grub (*Leucopholis burmeisteri*) of arecanut**: *Lippia geminata, Ocimum basilicum* and *Calotropis procera* showed 80, 70 and 70% grub mortality after 96 h of application.

**Report of red palm weevil infestation in arecanut** was first described in Assam. The infestation ranged from 1 to 2% in different gardens of the research field.

**Control measure of white grub of arecanut**: Soil application of Phorate 10G (Thimet) @ 15g/palm found effective in controlling white grub population in arecanut.

**Production of quality planting materials of major plantation crops-** The centre produces and distributes quality planting materials of various crops like arecanut (variety-Kahikuchi, Mohitnagar, Mangala, Sumangala, Sreemangala); Coconut ( Var-Kamrupa); Cinnamon (Var-Nithyasree, Navasree); Lemon (Cv-Assam Lemon and Gandharaj); Black pepper (Var-Panniyur-1, Karimunda and other released varieties).

# 3. Important conferences and meetings organized

## 3.1. International Conference on "Coconut Biodiversity for Prosperity"

An International conference on "Coconut Biodiversity For Prosperity" was organized at the Institute from 25-28 October 2010, with the participation of over 250 delegates from 12 countries *viz.*, India, United Kingdom, USA, Australia, France, Mexico, Brazil, Indonesia, Philippines, Sri Lanka, Cote de Ivoire and Nigeria in association with Indian Society for Plantation Crops, *Bioversity International* and active support and partnership from Coconut Development Board, National Horticultural Board, India, NABARD, Asia and Pacific Coconut Community, Jakarta and State Departments of Agriculture.

Prof. K. V. Thomas, then Hon'ble Minister of state for Agriculture and co-operation, lighting the lamp during the inaugural function

Dr. S. Ayyappan, Hon'ble Director General, ICAR New Delhi delivering keynote address

The conference had effective interactions during the technical sessions, workshops and offered a good platform for flow of knowledge on global coconut research and development. Apart from researchers, development personnel and officials from Coconut Development Board, NABARD, NGOs, KVKs, Farmers' Self Help Groups and number of farmers have shared their experiences and views. Considering the challenges faced by the coconut community and the global and national scenario of coconut farmers, the conference had adopted a declaration, unanimously accepted by the global researchers present at the conference. The resolution named as Kasaragod Declaration, stressed that coconut is to be promoted as food for nutrition, health care and environmental services to support the farming community and also the consumers. The conference also declared that there should be global initiatives for sustainability of coconut through understanding of structural and functional genomics, long term conservation through cryopreservation of genetic resources, unfolding more nutritional and health benefits and also understanding of coconut wilt and its management.

## 3.2. National Conference on Organic Farming

A "National Conference on Organic Farming in Horticultural crops with Special Reference to Plantation Crops" was held at Central Plantation Crops Research Institute, Kasaragod from 15-18th October 2008 under the auspices of Indian Society for Plantation Crops, Central Plantation Crops Research Institute, Kasaragod and the Association for the Improvement in Production and Utilization of Banana, NRC Banana, Trichi. About 200 delegates from different parts of the country including scientists from ICAR Institutes, SAUs, officers of commodity boards, certification agencies, NGOs and successful organic farmers attended the conference and deliberated the organic farming issues.

Dr. S. Nagarajan, Chairperson, PPV & FR Authority, New Delhi addressing the gathering

## 3.3. National debate on DUS test Guidelines for Tropical and Sub Tropical Plantation Crops

The institute organized on behalf of the PPV&FR Authority a National debate on DUS test Guidelines for Tropical and Sub Tropical Plantation Crops on the 9th July 2009 and a Group Meeting on DUS test procedures for coconut on 10th July 2009, under the Chairmanship of Dr. S. Nagarajan, Chairperson, PPV & FR Authority, New Delhi. The participants deliberated on the development of DUS guidelines on the respective crops.

## 3.4. South zone symposium- Indian Phytopathological Society

Indian Phytopathological Society – Southern Zone Symposium was organized at CPCRI, Kasaragod on 27th and 28th November, 2006. A total of 40 delegates from ICAR Institutes, Universities and other research organizations have participated in the symposium and 29 research papers were presented.

## 3.5. Impact of Climate Change in Indian Agriculture

National Workshop on Impact of Climate Change in Indian Agriculture was held during 22-24 September 2005. Dr. J.S. Samra, DDG (NRM) was the chief guest. Dr. Y.S. Ramakrishna, Director, CRIDA, Hyderabad, Dr. A.K. Sikka, Director, ICAR Research Complex for Eastern Region and Dr. P.K. Aggarwal, National Coordinator of the Network Programme was the dignitaries present. During the workshop the progress of work under climate change project, the methodologies to be adopted and targets for next year were discussed. 15 participating institutions and universities were represented by 75 delegates.

## 3.6. Swadeshi Science Congress

22nd (All Kerala) Swadeshi Science Congress was held at CPCRI Kasaragod from 6th to 8th November 2012 in which a total of 110 research papers were presented under mathematics, ocean technology and fisheries sciences, life sciences (biotechnology, microbiology, botany and zoology), environmental sciences, agriculture, animal and aquatic sciences, health sciences, physical sciences (IT, engineering, physics and chemistry) and traditional sciences.

## 3.7. National Seminar on Strategies for Enhancing Productivity of Cocoa

Seminar on 'Strategies for enhancing productivity of cocoa' sponsored by the Directorate of Cashew and Cocoa Development (DCCD), Cochin was held during 28-29th January 2011 at CPCRI Regional Station, Vittal, Karnataka in which 65 delegates from Karnataka, Kerala, Tamil Nadu and Andhra Pradesh have participated. Scientists from CPCRI, KAU, TNAU and APAU have presented the research accomplishments in cocoa.

## 3.8. The 16th International Coconut Genetic Resources Network Steering Committee Meeting organized at Kochi

The 16th Steering Committee Meeting SCM) of International Coconut Genetic Resources Network (COGENT) was held at Kochi, India, from 8 to 10th July, 2012 under the aegis of Bioversity International and the Indian Council of Agricultural Research (ICAR). India, represented by the Central Plantation Crops Research Institute (CPCRI), has been one of the active members of the COGENT Steering Committee since its inception in 1992, owing to its contribution to coconut genetic resources conservation. The 16th COGENT SC meeting included COGENT participants from 14 coconut growing countries: China, India, Indonesia, Ivory Coast, Kenya, Madagascar, Malaysia, Mexico, Oman, Papua New Guinea, Philippines, Sri Lanka, Tanzania, Vietnam, Brazil and also representatives from the Asian Pacific Coconut Community, Coconut Development Board, the Global Crop Diversity Trust, the Secretariat of the Pacific Community, Bioversity International as well as the private sector from India and Brazil. As an outcome of the meeting, focused recommendations were finalized for shaping research on coconut conservation and utilization in the 39 COGENT member countries. The COGENT Steering Committee (COGENT SC) meeting concluded with the unanimous election of Dr. George V. Thomas, Director, CPCRI as the Chairman of the COGENT Steering Committee.

# 4. Consultancy services

Consultancy services were rendered to farmers and clients from private sectors on the following aspects:

1. Management of field problems in coconut
2. Soil sample analyses and recommendations
3. Design and development of crop profile databae consisting of information on varieties, produce and products, cultivation practices in MS SQL
4. Management of coconut diseases
5. Analyzing organic manures for NPK, organic carbon and testing quality
6. Evaluation of Mak Agri Spray Oil against coconut scale insect
7. Transfer of technology and installation of modern copra dryer and coconut chips unit
8. Design and drawing of copra dryer
9. Soil and water conservation
10. Coconut processing/Value addition of coconut
11. Gas Chromatography of vegetable oils
12. Consultancy project on climate change
13. Coconut climbing using mechanical device

# 5. Technology commercialization

Various technologies developed at the Institute were commercialized and the technical knowhow was transferred successfully to entrepreneurs under ITMU.

| Sl.No. | Technology | Name/ Agency |
|---|---|---|
| 1 | Virgin coconut oil by hot process | 1. M/s Malabar Ayurveda Ashram, Kanhangad, Kerala<br>2. Mr. Mahesh Bhat, Kumbla, Kerala<br>3. Shanthi Sivashanmugam, Tamil Nadu<br>4. The President, Meenja Berika Nalikera Utpadaka Sangham, Meeyapadav, Kasaragod district, Kerala<br>5. Shri Balakrishnan, Manya, Kasaragod, Kerala<br>6. M/s Vadakara Taluk Primary Cooperative Society, Vadakara |

| | | |
|---|---|---|
| 2 | Production of virgin coconut oil (VCO) by fermentation process. | 1. M/s Dinesh Foods, Kannur, Kerala<br>2. M/s Kaayi Kompany, Karnataka<br>3. M/s Coconess, Bangalore, Karnataka |
| 3 | Technologies for collection of fresh and hygienic coconut sap and production of natural coconut sugar | 1. Mr. Augustine Joseph, Karkala, Karnataka<br>2. Mr. Raam Mohan, Tirupur, Tamil Nadu<br>3. Shri M. Dhanabal, Coimbatore, Tamil Nadu<br>4. Chairman, Palakkad Coconut Producers Company Limited (PCPCL), Idukkippara, Govindapuram, Palakkad district, Kerala<br>5. President, Nemom Block Federation of Coconut Producers Societies, Oottyyarathal, Thiruvananthapuram, Kerala<br>6. Shri Mohandas, Bantwala, Karnataka<br>7. M/s Thejaswini Coconut Farmers Producer Co., Kannur, Kerala |
| 4 | Safety device for *Chemberi* Joseph model of paddle type coconut climbing machine | St. Mary's Industry, Kannur, Kerala |
| 5 | Coconut leaf vermicomposting | 1. Mr. V. K. Abraham, Rajapuram, Kerala<br>2. M/s DeeJay Consultancy Services, Bangalore, Karnataka |
| 6 | Mass mulitplication technique of *Goniozus nephantidis* (parasitoid of coconut black headed caterpillar) | Shri Arvindh Sabhapathy, Pollachi, Tamil Nadu |
| 7 | Know-how on utilization of *Metarhizium anisopliae* culture | M/s DeeJay Consultancy Services, Bangalore, Karnataka |
| 8 | Coconut Chips | M/s Evergreen Enterprises, Tamil Nadu |
| 9 | Arecanut tissue culture protocol | M/s Sunglow Biotech, Perur, Coimbatore, Tamil Nadu |
| 10 | Coconut embryo culture protocol | M/s DeeJay Consultancy Services, Bangalore, Karnataka |

# 6. Patents and trademarks

| Title | Inventors | Patent Application Filing No. | Year | Date of grant | Remarks | Patent No. |
|---|---|---|---|---|---|---|
| Design and development of shell fired copra dryer | T. Vidhan Singh | 1127/DEL /2005 | 2005 | NA | Application is under Examination | NA |
| Surge irrigator | K. Madhavan, A.C. Mathew, S. Senthillvel, G S Hareesh | 666/CHE /2006 | 2006 | NA | Application Awaiting Examination | NA |
| Ferro cement check dam | A.C. Mathew, K.S. Shajatnam, | 667/CHE /2006 | 2006 | NA | Application Not Yet Published | NA |
| Ferro cement sub surface dam | A.C. Mathew, K.S. Shajatnam, | 668/CHE /2006 | 2006 | NA | Application Not Yet Published | NA |
| Development of telescopic sprayer | T. Vidhan Singh | 669/CHE /2006 | 2006 | 15.03. 2011 | Granted | 246751 |
| Development of a manually operated tender coconut punch and cutter | T. Vidhan Singh, K.G. Narayanaswamy, M.V. Krishnan | 670/CHE /2006 | 2006 | 2.04. 2009 | Granted | 233744 |
| Development of a manually operated coconut splitting device | T. Vidhan Singh | 671/CHE /2006 | 2006 | NA | Application Awaiting Examination | NA |
| Design and development of coconut deshelling machine | T. Vidhan Singh | 672/CHE /2006 | 2006 | 02.04. 2009 | Granted | 233742 |

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|---|---|---|---|---|---|---|
| Portable snowball tender nut machine | K. Madhavan<br>S.J.D. Bosco<br>A.C. Mathew<br>T. Vidhan Singh | 2956/CHE /2007 | 2007 | NA | Application Awaiting Examination | NA |
| Automatic pumping system for skimming wells | A.C. Mathew<br>K. Madhavan<br>G.S. Hareesh | 2957/CHE /2007 | 2007 | NA | Application` Awaiting Examination | NA |
| Coconut chips slicing machine | Abraham Chira purathutharayil Mathew, Madhavan Kadavakkat | 2475/ CHE / 2008 | 2008 | NA | Application Awaiting Examination | NA |
| Coconut testa removing machine | A.C. Mathew, K. Madhavan | 1363/CHE /2008 | 2008 | NA | Application Awaiting Examination | NA |
| Manually operated coconut kernel slicing machine | A.C. Mathew & K. Madhvan | 983/CHE /2009 | 2009 | NA | Application Awaiting Examination | NA |
| Coconut and arecanut palm climbing device | A.C. Mathew & K. Madhvan | 2294/CHE /2009 | 2009 | NA | Application Awaiting Examination | NA |
| *Trichoderma* coir pith cake | R. ChandraMohan | 4310/CHE /2011 | 2011 | NA | Application Awaiting Examination | NA |
| A simple device to collect fresh and hygienic neera | K.B. Hebbar | 2425/CHE /2013 | 2013 | NA | Application Awaiting Examination | NA |
| A composition, device or a trap and methods thereof | K. Subaharan | 5126/CHE /2013 | 2013 | NA | Application Not Yet Published | NA |

### Trademark applications filed

| S. No. | Trademark | Application number | Date of application | Publication date |
|---|---|---|---|---|
| 1 | KALPA | 2320116 | 23/4/2012 | 3/8/2013 |
| 2 | CPCRI logo | 2574582 | 2/8/2013 | N A |

# 7. Advanced training of scientists abroad

About one third of scientists belong to different disciplines at the Institute were trained at various leading laboratories under International organizations during the period on various frontier areas of science and cutting edge technologies. The foreign trainings were funded by National Agricultural Innovation Project of ICAR and also by Department of Biotechnology, Government of India. The brief details of the international trainings are as follows.

| Sl. No. | Scientist | Programme | Place | Period |
|---|---|---|---|---|
| 1 | Dr. V. Selvamani | Sensor Based applications including Bio-indicators | Centre for Landscape and Climate Research, University of Leicester, UK | 29-01-2014 to 29-03-2014 |
| 2 | Dr. K. Devakumar | Marker-Assisted Selection | Boyce Thompson Institute for Plant Research, Cornell University, Ithaca, USA. | 1-10-2013 to 31-12-2013 |
| 3 | Dr. M.R. Manikantan | Smart Packaging | Kansas State University, Manhattan, Kansas State, USA | 16-09-2013 to 14-12-2013 |
| 4 | Dr. B. Augustine Jerard | Marker Assisted Selection | University of Guelph, Vineland Research Station, Ontario, Canada | 8-7-2011 to 5-10-2011 |
| 5 | Dr. V. Niral | Marker Assisted Selection | Iowa State University, Ames, USA | 22-3-2011 to 21-6-2011 |
| 6 | Dr. M.K. Rajesh | Marker Assisted Selection | Iowa State University, Ames, USA | 22-3-2011 to 21-6-2011 |

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|---|---|---|---|---|
| 7 | Dr. K.B. Hebbar | Norman E. Borlaug International Agricultural Science and Technology Fellowship Program | Throckmorton Plant Science Center, Kansas State University, Manhattan, KS, USA | 1-02-2011 to 19-4-2011 |
| 8 | Dr. H.P. Maheswarappa | Carbon sequestration and climate change | Ohio State University, USA | 15-7-2010 to 14-10-2010 |
| 9 | Dr. Alka Gupta | Molecular Microbial Taxonomy | Dept. of Microbiology, Univ. of Georgia, Athens, Georgia, USA | 20-08-2010 to 19-11-2010 |
| 10 | Dr. Murali Gopal | Molecular Microbial Taxonomy | Dept. of Microbiology, Univ. of Georgia, Athens, Georgia, USA | 20-08-2010 to 19-11-2010 |
| 11 | Dr. R. Manimekalai | Bioinformatics | Department of Disease and Stress Biology at The John Innes Centre, Norwich Research Park, UK | 2-6-2010 to 31-8-2010 |
| 12 | Dr. B. Augustine Jerard | Plant Variety Protection and DUS Testing | National Institute of Agricultural Botany, Cambridge, United Kingdom | 28-06-2010 to 09-07-2010 |
| 13 | Dr. Elain Apshara | Gene expression during fruit development stages of cucumber | Michigan University, USA | 15-12-2009 to 15-3-2010 |
| 14 | Dr. K. Subaharan | Biotechnology Overseas Associateship at Max Planck Institute of Chemical Ecology on Olfactory basis of host selection in tobacco hornworm, *Manduca sexta* | Dept. Evolutionary Neuroethology, Max Plank Institute for Chemical Ecology, Jena, Germany | March 2008 to March, 2009 |
| 15 | Dr. Murali Gopal | Post Doctoral Rothamsted International Fellowship programme | Agriculture and Environment Division, Rothamsted Research, UK | April 2007 to March 2008 |
| 16 | Dr. R. Manimekalai | DBT sponsored overseas fellowship for young | National Institute of Agrobiological Sciences, | March 2007 to December 2007 |

| | | | | |
|---|---|---|---|---|
| | | scientists in Niche areas of Biotechnology | Tsukuba, Japan | |
| 17 | Shri M. Gunasekaran | Training on coconut root (wilt) disease (Pathogen detection and categorization) | CIRAD, France | 25-09-2006 to 18-11-2006 |
| 18 | Dr. C. Thamban | Training course on socio-economic and participatory approaches to reduce poverty in coconut growing communities | Bogor, Indonesia | 15-06-2006 to 21-06-2006 |

# 8. Monitoring targets and achievements

The Institute has prepared a Results Framework Document in line with ICAR, New Delhi under the Ministry of Agriculture, Government of India for effective monitoring and implementation of programmes and achieving targets from 2010-11. The Institute has been categorized under Outstanding or Very Good grades till date, indicating the achievements under success indicators in prescribed time schedule.

The Institute has devised the Citizens' charter outlining the services offered and the definitive time frame for delivery of services to the public/user community and quality policy for self evaluation and refinement and increasing responsiveness in achieving the targets.

The management system of CPCRI has been certified with ISO9001:2000 for its mission on harnessing science and technology to enhance competitiveness in coconut, arecanut and cocoa through generation of appropriate technologies.

Institute Project Approval Committee and PMEC have been constituted to scrutinize the research proposals, effective evaluation of research projects at the Institute and to help the Prioritization, Monitoring and Evaluation Cell at the Institute in setting priorities.

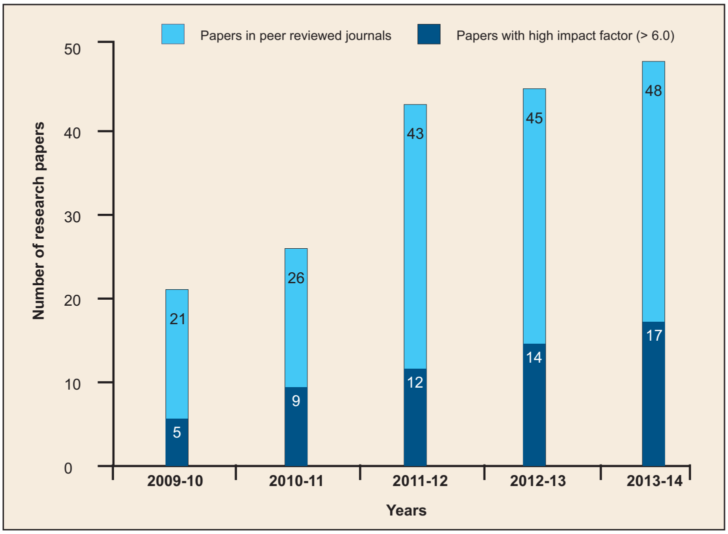
Institute Technology Management Unit (ITMU) has started functioning during this period to implement the decisions taken in Institute Technology Management Committee (ITMC) for commercialization and popularization of the technologies generated from the Institute.

# 9. Publications during 2005-2014

During the period from 2005 to 2014, the Institute has published a large number of publications including research articles, technical papers, popular articles, reviews, books, book chapters and other publications emanating from ongoing research projects. Out of 388 research articles those were published in NAAS rated peer reviewed journals, 114 papers appeared in the NAAS rated journals having impact factor of more than 6.00. The number of research papers appeared in the high rated journals has

| Sl No | Type of publication | Number of publication |
|---|---|---|
| 1 | Research articles | 388 |
| 2 | Technical papers | 373 |
| 3 | Popular articles | 326 |
| 4 | Review articles | 16 |
| 5 | Book chapters | 153 |
| 6 | Books | 52 |
| 7 | Technical bulletins | 30 |
| 8 | Training manuals, phamplets, DVD etc. | 48 |

increased over the years implying the improvement in quality of research at the Institute over the period.




Research publications from CPCRI during the last five years

# 10. Budget Allocation

Fund allocation and utilization (Rs. in lakhs)

| Category | X Plan (2002-03 to 2006-07) | | XI Plan (2007-08 to 2011-12) | | XII Plan (2012-13 to 2016-17) |
|---|---|---|---|---|---|
| | Allocation | Expenditure | Allocation | Expenditure | Allocation |
| Plan | 1430.00 | 1270.00 | 2318.00 | 2261.30 | 4604.21 |
| Non-Plan | 5869.50 | 5868.24 | 7000.00 | 13587.70 | 26832.77 |
| Total | 7299.50 | 7138.24 | 9318.00 | 15849.00 | 31436.98 |

# 11. Way forward

Considering the challenges faced by the sector, following thrust areas are identified for attention of the scientific community working on coconut, arecanut and cocoa for strengthening the ongoing works as well as formulating new initiatives to make the sector competitive and to take the Institute to the position of world leader in research on these crops.

- Multi dimensional approaches to tackle root (wilt) disease of coconut and yellow leaf disease of arecanut
- Adaptation strategies for drought and temperature stress management in coconut, arecanut and cocoa
- Development robust tissue culture techniques in coconut
- Utilization, augmentation and conservation of genetic resources in coconut, arecanut and cocoa for improved productivity, resilient agriculture and diversified products
- Unravelling genomic sequences, transcriptomic approaches and molecular technology applications for crop improvement and stress management
- Development of efficient production systems for high resource use efficiency, enhanced sustainable productivity and profitability and bioresource utilization
- Management of plant health through biointensive approaches, diagnostics and forecasting models
- Development of technologies for value addition and product diversification and labour saving and drudgery reducing machineries
- Refining technology delivery systems, entrepreneurship development and business promotion
- Demonstration of improved technologies for cultivation of coconut and arecanut and high density multi species cropping system, post harvest processing and value addition and development of diagnostic facility in North East Hilly region
- Demonstration and popularization of production technology for fruits/ vegetables among the island community, capacity building of entrepreneurs/ farmers on coconut value addition and product diversification under Tribal Sub Plan (TSP).

भाकृअनुप
ICAR

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