



Coconut Research at CPCRI - Programmes, Achievements and Perspectives

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and V. Niral**

Coconut research in India has a glorious history of more than nine and half decades. It had a humble beginning with the establishment Central Coconut Research Station (CCRS) at Kasaragod under the erstwhile Madras Presidency in 1916. The Central Plantation Crops Research Institute (CPCRI) was established in 1970 as one of the agricultural research institutes in the National Agricultural Research System (NARS) under the Indian Council of Agricultural Research (ICAR) by merging the erstwhile 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 grown up as a premier research institute with the major objective to conduct research on small holders plantation crops viz., coconut, arecanut and

cocoa. With the headquarters at Kasaragod (Kerala), the institute has two regional stations (Kayamkulam-Kerala and Vittal-Karnataka), three research centres (Kidu-Karnataka, Mohitnagar-West Bengal, Kahikuchi-Assam) and a Production cum Demonstration Centre at Minicoy in the Lakshadweep islands. The research programmes are being undertaken under five divisions: Crop Improvement, Crop Production, Crop Protection, Physiology, Biochemistry and Post harvest technology and Social Sciences. The Government of India hosts the International Coconut Gene Bank for South Asia (ICG-SA) at the CPCRI Research Centre, Kidu, under the umbrella of Coconut Genetic Resources Network (COGENT), of the Bioversity International (formerly International Plant Genetic Resources Institute).

Networking of national research programmes on coconut

The institute also serves as the headquarters of the All India Co-ordinated Research Project on Palms to co-ordinate research within the country on palm species viz.

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coconut, palmyrah and oilpalm. At present, the Project is implemented in 21 Centres including its headquarters at Kasaragod and Pilicode (Kerala); Aliyarnagar, Aduthurai, Killikulam, Veppankulam (Tamil Nadu); Arsikere, Gangavathi (Karnataka); Ambajipeta, Pandirimamidi, Vijayarai (Andhra Pradesh); Bhubaneswar (Orissa); Navsari (Gujarat); Madhopur, Sabour (Bihar); Pasighat (Arunachal Pradesh); Kahikuchi (Assam); Mondouri (West Bengal); Jagadapur (Chhattisgarh); Ratnagiri and Mulde (Maharashtra). CPCRI is also involved in National Networking Programme on mega seed project, global warming and climate resilient agriculture, Phytofura, application of agriculturally important micro-organisms, harnessing arbuscular mycorrhizae and AICRP on Post harvest technology.

Partnership in International Collaborative Research

The institute has implemented several international projects of Bioversity International, COGENT, APCC and IFAD. The institute has been an important partner in the international collaborative efforts through the establishment of International Coconut Genebank for South Asia (ICG-SA) at Research Centre, Kidu; standardization of embryo culture protocol and its application for exotic germplasm collection; molecular studies on DNA finger printing; overcoming poverty in coconut growing communities; coconut genetic resources for sustainable livelihoods and the collaborative efforts on Weligama leaf wilt disease of Sri Lanka and the coconut root (wilt) disease in India.

Research highlights

Research efforts in the National Agricultural Research System under the aegis of Indian Council of Agricultural Research have yielded fruitful results in terms of increasing the production and productivity of coconut farming systems through high yielding varieties, development of cropping and farming systems for increased profitability, technologies for management of major pests and diseases, development of processing technologies for value addition, and farm mechanization. The research programmes

undertaken at CPCRI and salient achievements made are summarized below.

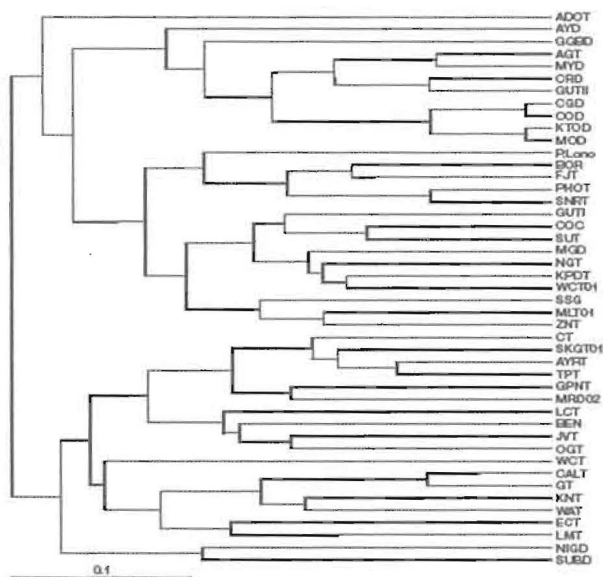
The world's largest repository of coconut genetic resources

CPCRI, being the premier national institute undertaking coconut research, maintains the world's largest repository of coconut germplasm with 400 collections (consisting of 268 indigenous and 132 exotic types) from 28 countries covering South Asia, South-East Asia, Caribbean Islands, Indonesian Islands, Pacific Ocean Islands, African countries, Bangladesh and Sri Lanka. The germplasm repository also contains unique accessions including Mohacho Narel, Thairu thengai, soft endosperm coconut, horned coconut etc; CPCRI is designated as National Active Germplasm Site for coconut by National Bureau of Plant Genetic Resource (NBPGR) New Delhi. Conservation and utilization of coconut biodiversity have resulted in development of 32 improved varieties, including 15 coconut hybrid varieties and contributed to enhanced coconut productivity. The International Coconut gene bank for South Asia established at Kidu (Karnataka) is conserving 90 designated accessions. The germplasm is characterized through morphological and molecular markers and used in the coconut improvement programme. DNA profiles of coconut germplasm accessions have been utilized to study genetic relationship between accessions. Based on microsatellite (SSR) analysis, the coconut accessions have been separated into two major groups, i.e. Dwarf group and Tall group, with a few anomalies. Further, among the



Thairu thengai - soft endosperm coconut

Talls, two sub-clusters could be identified, namely South-East Asian Talls and Indian Ocean Talls, with some exceptions.



Dendrogram indicating relationship of major indigenous and exotic coconut germplasm conserved at CPCRI, based on SSR data

Varietal improvement and release of high yielding varieties

The germplasm base has been utilized in the coconut improvement programme both at the institute and various State Agricultural Universities under the All India Coordinated Research Project on Palms. A total of 32 improved varieties have been developed through selection and hybridization. These hybrids and varieties are capable of yielding 1.62 to 4.07 tonnes of oil/ha/year.



Chowghat Orange Dwarf - a tender nut variety

Selection and evaluation of promising accessions conserved at the institute and the various coordinating centres under the All India Coordinated Research Project on Palms as well as State Agricultural Universities have resulted in the development and release of 18 high yielding varieties of coconut viz. Chandra Kalpa, Pratap, Chowghat Orange Dwarf, Kera Chandra, VPM 3, Kamrupa, ALR 1, Kera Sagara, Kalpa Pratibha, Kalpa Dhenu, Kalpa Mitra, Kalparaksha, Kalpatharu, Kalpasree, Kera Keralam, Kera Bastar, Kalyani Coconut and Gautami Ganga. The following table indicates the varieties suitable for cultivation in the different states of the country.

Improved varieties of coconut released by CPCRI/AICRPP Centres/SAUs

Coconut	Nut yield (palm/year)	Area for which recommended
Chandra Kalpa [#]	97	Kerala, Karnataka, Tamil Nadu, Andhra Pradesh, Maharashtra
Kera Chandra [#]	110	Kerala, Karnataka, Konkan region, Andhra Pradesh, West Bengal
Chowghat Orange Dwarf [#]	63	All coconut growing areas
Kalpa Pratibha [#]	91	West Coast region, Peninsular India
Kalpa Dhenu [#]	86	West Coast region, Tamil Nadu & Andaman & Nicobar Islands
Kalpa Mitra [#]	80	West Coast region & West Bengal
Kalparaksha	65 [#] (87) [*]	Kerala & Root (wilt) disease prevalent tracts
Kalpatharu [#]	117	Kerala, Karnataka, Tamil Nadu
Kalpasree	90	Root (wilt) disease prevalent tracts
Pratap	151	Konkan region of Maharashtra
Assam Green Tall (Kamrupa)	101	Assam
Aliyarnagar Tall - ALR(CN)1	126	Tamil Nadu
Gauthami Ganga	65	Tamil Nadu, Andhra Pradesh
Kera Bastar	110	Chhattisgarh, Tamil Nadu, Andhra Pradesh, Maharashtra
Kalyani coconut 1	80	West Bengal
Kerakeralam	147	Tamil Nadu, Andhra Pradesh, Maharashtra, Kerala
Aliyarnagar Tall - ALR(CN)2	120	Tamil Nadu
VPM-3 (Double century)	84	Tamil Nadu

[#]Yield under rainfed conditions, ^{*}Yield under disease-free & rainfed conditions

Exploitation of heterosis and development of superior hybrids

In coconut, heterosis has been tapped through hybridization between Talls and Dwarfs. India was the first country in the world to report on heterosis/hybrid vigour in coconut when Patel (1937) observed early germination, increased seedling collar girth, higher leaf number, early bearing habit and high yield in a cross between the local tall and the local dwarf. In India, more than 100 cross combinations have been developed for evaluation of yield potential at CPCRI, SAUs and the centres under the AICRPP. So far 15 hybrids have been released for cultivation in different states of the country.



Kalpa Samrudhi - high yielding drought tolerant DXT hybrid

The coconut hybrids and varieties released so far in the country are popular with the farmers and the demand for quality planting material far outstrips the present supply. CPCRI provides seeds/seedlings of commercial varieties and hybrids to farmers, NGOs, developmental agencies and research organizations. In addition, the institute produces planting material of germplasm and experimental hybrids for distribution to research institutes for carrying out multi-location trials.

Release of varieties for root (wilt) diseased tract

Breeding for disease resistance, especially root (wilt) disease of coconut has resulted in identification of



Kalpa Sankara - DXT hybrid for root (wilt) affected tracts

Improved hybrid varieties of coconut released by CPCRI

Hybrid	Parentage	Nut yield	Area for which recommended (palm/yr)
Chandra Sankara [#]	COD x WCT	110	Kerala, Karnataka, Tamil Nadu
Kera Sankara [#]	LCT x GBGD	106	Kerala, Karnataka, Maharashtra, Andhra Pradesh
Chandra Laksha [#]	LCT x COD	109	Kerala, Karnataka
Kalpa Samrudhi [#]	MYD x WCT	117	Kerala, Assam
Kalpa Sankara	WCT x CGD	84	Root (wilt) disease prevalent tracts
Laksha Ganga	LCT x GBGD	108	Kerala
Ananda Ganga	ADOT x GBGD	95	Kerala
Kera Ganga	WCT x GBGD	100	Kerala
Kera Sree	WCT x MYD	112	Kerala
Kera Sowbagya	WCT x SSAT	130	Kerala
VHC-1	ECT x MGD	98	Tamil Nadu
VHC-2	ECT x MYD	107	Tamil Nadu
VHC-3	ECT x MOD	156	Tamil Nadu
Godhavari Ganga	ECT x GBGD	140	Andhra Pradesh
Konkan Bhatye coconut hybrid - 1	GBGD x ECT	116	Maharashtra

[#]Yield under rainfed conditions

Chowghat Green Dwarf and Malayan Green Dwarf as resistant varieties. Superior selections of these have been released by the institute for cultivation in the root (wilt) affected tracts under the name Kalpasree and Kalparaksha, respectively. A high yielding root (wilt) disease tolerant hybrid variety with CGD as the female parent and WCT as the male parent has been evaluated and released for the root (wilt) tracts under the name Kalpa Sankara.

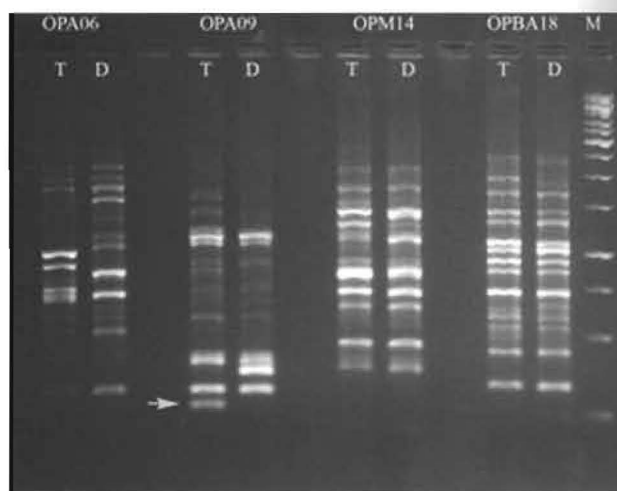
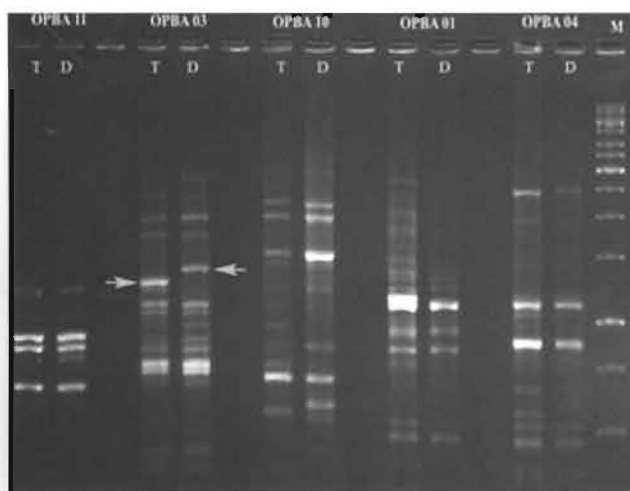
Application of Biotechnology and Bioinformatics Tools

The major achievements in biotechnology include standardization of coconut plumule culture technique and embryo culture protocol for germplasm exchange. Cryopreservation techniques have been standardized for mature coconut zygotic embryos and coconut pollen. DNA finger printing using molecular markers viz., RAPD, AFLP, DAF and microsatellite analysis have been carried out in coconut accessions to document the genetic integrity and diversity. These techniques are also being exploited to identify different biotic and abiotic stress tolerant genes in coconut particularly for root (wilt) disease and drought tolerance. About 139 accessions have been characterized using SSR markers. WRKY sequences and Resistant Gene Analogues (RGAs) were cloned and characterised from coconut using degenerate primers. Work on identification of molecular markers linked to plant habit is in progress.

Primer screening of bulked DNA samples of tall and dwarf accessions with 200 primers revealed two primers which could distinguish the two bulks. Under the Bioinformatics initiative, several comprehensive databases for the mandate crops have been developed. The germplasm characterization and evaluation data is entered in a global database developed under the COGENT initiative in collaboration with CIRAD, viz. Coconut Genetic Resources Database (CGRD). In addition, the institute has developed various databases both on coconut as well as other mandated activities of the institute.

List of databases developed at CPCRI on coconut

Sl. No.	Name of Database
1.	Palm Database
2.	Coconut Microsatellite Database
3.	Phytoplasma Database
4.	Vegetable Oil Database
5.	Microbial Information Systems on Plantation Crops (MIFSPC)
6.	Coconut Disease Database
7.	Coconut Cultivar Identification
8.	Pest control Management Systems
9.	Coconut Oil Palm Rice Protein Kinase (CORPK) Database
10.	Coconut Germplasm Database Production System Management



RAPD banding pattern of tall and dwarf bulks with different primers of OPBA and OPA series. Arrow heads indicate polymorphic bands

Production System Management

CPCRI has developed production technologies for coconut and coconut based cropping/farming systems. Coconut based inter/mixed, multi storied multi-species cropping systems developed at CPCRI are being widely adopted by the farmers. The high density multi-species cropping system and coconut based mixed farming system, involving annuals/biennials/perennials grown in different tiers by exploiting soil and air space more efficiently and integrating with poultry and animal husbandry, help to maximize profits and can even buffer the price crash of the main crop. For maximizing economic returns, high value medicinal and aromatic crops, vanilla and flower crops have been recommended in the palm based cropping system. Coconut based High Density Multispecies cropping system (HDMSCS) involving black pepper, banana, pineapple, clove was found to be the best model to provide net profit of over Rs 1.50 lakhs annually.

Water requirement for coconut and coconut palm based cropping systems and drip fertigation requirements have been standardized. In coastal sandy soil, intercropping in coconut garden with pineapple, banana, elephant foot yam and vegetable crops like brinjal has been profitably demonstrated by adopting adequate soil moisture conservation methods. The Institute has developed various bio-engineering measures to sustain crop production in rainfed areas of west coast region. The low cost water harvesting structures developed by the Institute has helped in augmenting ground water recharge to a great extent. The Institute has made rapid strides in developing organic farming technologies. The Vermicomposting of coconut farm wastes by using indigenous earthworm, *Eudrilus* sp. has received national recognition. Information on diversity of plant beneficial microbes and their beneficial traits has been further strengthened through the introduction of BIOLOG identification system and molecular approaches.



Coconut based mixed farming system (CBMFS)



*Vermicomposting of coconut wastes using indigenous earthworm *Eudrilus sp.**

Organic cultivation strategy for coconut involving vermicomposting in coconut basins, green manuring in basins and application of biofertilisers of *Azospirillum* and *Phosphobacteria* has been standardized, to achieve an annual coconut yield of over 100 coconuts per palm .

Remote sensing and Geographical Information System applications

Spectral mixture modelling method was applied to produce land cover maps of coconut and spectral mixture analysis (SMA) results were compared with ground truth data. The subpixel accuracy achieved for the coconut land cover was 82% using SMA of DN Values, while it was 93% for SMA of radiance values. The technique has also been successfully used for identification of root (wilt) diseased palms with accuracy of 98% based on ground traits data analysis.

Global warming and carbon sequestration

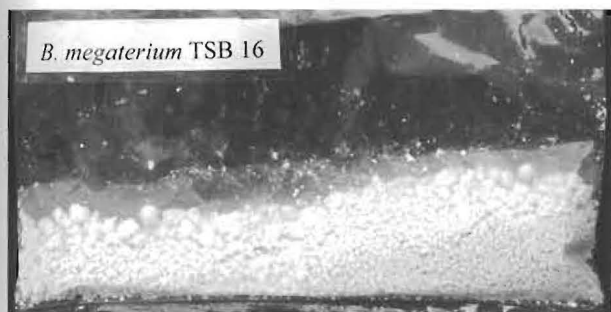
Genotypes relatively tolerant to drought have been identified in coconut by screening the vast array of germplasm accessions. Physiological and biochemical processes underlying drought tolerance mechanism in coconut has been delineated. Quantitative assay of total proteins/HSPFs in five cultivars has shown significant differences among the treatments and cultivars. The carbon sequestration potential of coconut, arecanut and cocoa plantations was assessed to be very high, opening up new opportunities for claiming higher carbon credit under Clean Development Mechanism (CDM) along with natural vegetations. Under climate change studies, field

response of coconut to increased temperatures and CO₂ is being evaluated.

Analysis of past weather data indicated general warming trends in most of the coconut growing areas in the country, with increase in average maximum temperature ranging from 0.01-0.13°C/year coupled with declining trend in minimum temperatures. Impact of climate change parameters, such as increased temperature and elevated CO₂ on coconut has been studied by Open Top Chamber facility and by development of simulation models. Simulation studies to analyse the influence of increased atmospheric CO₂ at 550 ppm along with increase in temperature by 1°C indicated increase in coconut yields by around 5-12% depending upon the agroclimatic zone and management. Mitigation measures and carbon sequestration potential and stock in coconut have also been studied. Annual carbon sequestration in coconut above ground biomass varied from 15-35 t CO₂ ha⁻¹ yr⁻¹ depending on cultivar, agroclimatic zone, soil type and management.

Integrated Disease Management

Root (wilt) disease continues to be a major problem affecting the productivity of palms in the major coconut producing state of Kerala. The etiology of the disease has been proved to be Phytoplasma based on electron microscopic observations, insect transmission studies, dodder transmission studies and molecular detection technique. Breeding for resistance to root (wilt) disease has resulted in development of three varieties, viz. Kalpasree and Kalparaksha and the hybrid Kalpa Sankara



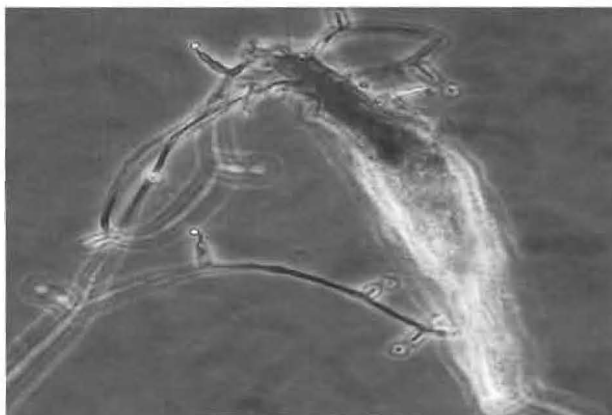
Talc based formulation of PGPRs

for the root (wilt) affected tracts. Hot spot survey and identification of disease escapes has been utilized in the breeding programme for production of quality planting material in the disease affected areas. For management of root (wilt) affected gardens, an integrated management strategy involving nutrient management through application of organic manures along with chemical fertilizers, cover cropping in the basin etc., and adopting mixed cropping and mixed farming enterprises is recommended. Application of *B. subtilis* and *P. fluorescens* in combination, after removal of rotten portion of spindle leaf was found to be very effective in managing leaf rot disease of root (wilt) affected coconut palms. ELISA for the detection of root (wilt) disease using polyclonal antibodies has been refined further to a simple and very rapid test.

Integrated Management strategies for other diseases such as bud rot caused by *Phytophthora palmivora*, stem bleeding caused by *Thielaviopsis paradoxa* and basal stem rot caused by *Ganoderma* species have also been developed.

Integrated Pest Management

The major pests of coconut palm in India are rhinoceros (*Oryctes rhinoceros* L.), red palm weevil (*Rhynchophorus ferrugineus* Oliv.), leaf eating caterpillar (*Opsina arenosella* Walk.), eriophyid mite (*Aceria guerreronis* Keifer) and white grub (*Leucopholis coneophora*). Pests like coreid bug, scale insects, mealy bugs, slug caterpillars and rodents also cause considerable damage in certain locations. Integrated Pest Management strategies comprising compatible integration of various pest

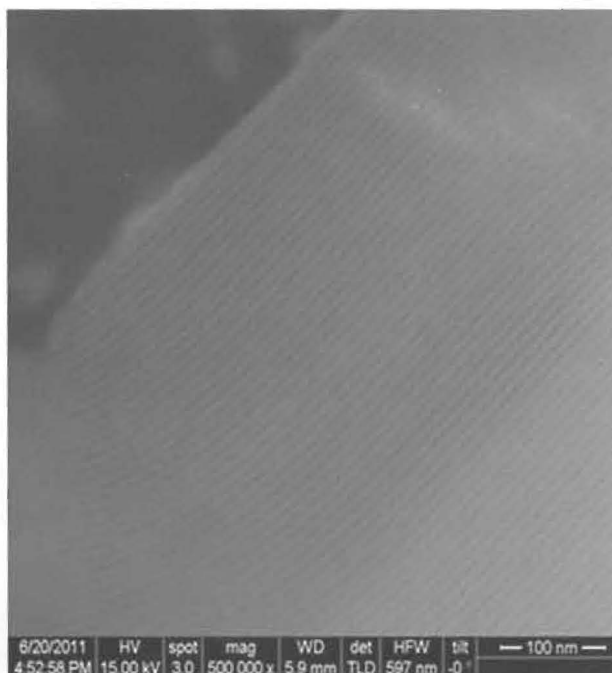


Hirsutella sp. biocontrol agent for Eriophyid mite

suppression techniques including cultural, chemical and biological methods have been standardized. Biological control using entomopathogens and entomophaga is found effective for management of rhinoceros beetle and leaf eating caterpillar. Evaluation of new molecules against common pests is also under progress in addition to biopesticides.

Nanomatrix for loading Pheromone synergists

A novel nanomatrix with ordered pore channels was developed for loading pheromone and kairomone. Pheromone of red palm weevil when loaded in nanomatrix



FSEM image of ordered pores in the nanomatrix

showed delayed dissipation as compared to pheromone alone when assayed by thermal gravity analysis.

Post harvest processing and mechanization

Agricultural implements/gadgets such as copra dryers using different energy sources and capacities, coconut splitting device, copra moisture meter, manual/power operated coconut sprayer, coconut grating machine, coconut chips slicing machine, a simple coconut palm climbing device etc. have been developed by the Institute.



Shell fired copra dryer

Tender nut punching machine

Two other machineries, viz. tender nut punch and cutter and coconut deshelling machine developed by the institute have been awarded national patents. Technologies for making value added products like snowball tender nut (SBTN) and coconut chips of various flavours have been developed and are being promoted vigorously among prospective entrepreneurs.

Technology/know-how for production of virgin coconut oil by fermentation and by hot processing has been



Coconut chips production

standardized and the technology is being transferred to entrepreneurs, self help groups and NGOs. Modification/evaluation of processing gadgets like manual coconut slicing machine, biofuel dryer and biofuel virgin coconut oil cooker



Value added products from coconut

are underway and these equipments are expected to considerably reduce the cost of production of the value added products. Recently, a safety device for the coconut climbing has been developed at the institute.



Safety device for coconut climbing

Value Chain in Coconut

A project on 'Value chain in coconut' under National Agriculture Innovation Project of ICAR (NAIP) is being implemented in eight Panchayaths of Kasaragod District of Kerala, with over 500 farmers under 10 coconut clusters as direct beneficiaries. For improving the coconut production and productivity and profitability of farming, various agro-production techniques are demonstrated in farmers' fields for wider acceptance and better adoption of technologies.

Planting material production

The institute supplies seeds/seedlings of commercial varieties and parental lines and seedlings of released

hybrids to farmers, NGO's, developmental agencies and research organizations. Annually, over 1.5 lakh seed nuts/seedlings are produced at the institute for meeting the requirements of different end users. Seed nuts are supplied all around the year, depending on the availability, while seedling sales are initiated during June and continue during the rest of the year, depending on availability. The institute also looks forward to liaison with nursery men/seed companies and has developed modalities to commercialize the varieties developed at the institute through licensing in order to boost quality planting material production of the improved varieties and facilitate area expansion under these varieties.

Quality Assurance

National Horticulture Board (NHB) has accredited the CPCRI coconut nurseries at Kasaragod and Kidu and awarded four star rating taking into consideration the availability of mother palm gardens, hybrid production programme and quality of planting material produced.

Technology Transfer

Over the years, strenuous efforts have been made to promote the mandate crops of the Institute through effective extension activities including trainings, farmer participatory approaches in technology development and dissemination, participation in exhibitions and conduct of Kisan melas, and production and distribution of planting materials. The demand forecasting of coconut has also been carried out. Under NABARD project, demonstration of integrated model coconut clusters has been organised. Under farmer participatory action research programme sponsored by Ministry of Water Resources and Technologies for soil and water conservation were demonstrated in farmers' plots.

The two Krishi Vigyan Kendras under the Institute (at Kasaragod and Kayamkulam) have been on the forefront of helping the farming community in the respective districts.

Besides, Agricultural Technology Information Centre (ATIC) operational at CPCRI, Kasaragod serves as single window access for the farmers. In the present digital age, cyber extension through videoconferencing and other IT enabled services has been increasingly resorted to as an efficient delivery tool for reaching out to the clientele.

Future Thrust

In the changing scenario, coconut farming needs special attention from the perspective of small farmers and also taking into consideration the changing climate. In addition to cropping system research with focus on organics and microbial techniques and integrated nutrient management through precision farming techniques, there is an urgent need to focus on post harvest technologies and farm mechanization. Further, diagnostics and integrated pest/disease management with focus on cleaner and safer environment is essential to combat and manage new/emerging pests. Utilization of available biodiversity in the crop through gene/allele mining and genomic resources is envisaged to overcome the challenges faced by the crop from biotic/abiotic stresses and also to further enhance the crop productivity. In addition to *ex situ* conservation in gene banks, alternative conservation strategies such as cryopreservation and *in situ* conservation of genetic resources are also being undertaken to help preserve the valuable biodiversity for posterity. Coconut genome sequencing is envisaged to obtain greater insight into the crop and in depth studies on identification of genes and regulatory mechanisms and understanding of gene function are expected to provide leads to solve complex problems affecting coconut productivity, including challenges from biotic and abiotic stress. Further, keeping in focus the 'FARMER FIRST' approach of the Indian Council of Agricultural research, effective technology dissemination mechanism and greater interaction with producers and users are envisaged to address and develop technologies appropriate to the requirements of the coconut community.

